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December 4, 2019
E-55203

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Subject: Response to Request for Supplemental Information for the Technical Review of the Application for Certificate of Compliance No. 1029 (Docket No. 72-1029, CAC/EPID Nos. 001028/L-2019-RNW-0014)

Reference: Letter from Christopher Markley (NRC) to Prakash Narayanan (TN Americas LLC), Request for Supplemental Information for the Technical Review of the Application for Certificate of Compliance No. 1029 (Docket No. 72-1029, CAC/EPID Nos. 001028/L-2019-RNW-0014), dated November 4, 2019

TN Americas LLC (TN) hereby submits responses to the Request for Supplemental Information (RSI) forwarded by the letter referenced above. Enclosure 2, herein, provides a proprietary version of the responses to the RSI and Observation (OBS) items. Each RSI and OBS response has an impact section that describes any changes made to the enclosed Certificate of Compliance (CoC) No. 1029 Renewal Application for the Standardized Advanced NUHOMS® System as a result of the RSI or OBS. Enclosure 3 provides a public version of the responses to the RSI and OBS items. Enclosure 4 provides a proprietary version of the entire CoC renewal application, updated to Revision 1. Enclosure 5 provides a public version of the entire CoC renewal application updated to Revision 1. Enclosures 6 and 7 provide proprietary calculations in support of the response to RSI A-2. Enclosures 8 and 9 provide public supplemental inspection reports in support of the response to RSI A-1. Changes in the Revision 1 CoC renewal application are tracked and indicated by revision bars. Changes based on the RSI and OBS responses are annotated accordingly with the RSI or OBS number, whereas an updated reference to NUREG-2214 in Attachment A is delineated by revision bar only.

Portions of this submittal include proprietary information which may not be used for any purpose other than to support NRC staff review of the application. In accordance with 10 CFR 2.390, I am providing an affidavit (Enclosure 1) specifically requesting that you withhold this proprietary information from public disclosure.

Should you have any questions regarding this submittal, please do not hesitate to contact Mr. Douglas Yates at 434-832-3101, or by email at Douglas.Yates@orano.group.

A-Prakash

Prakash Narayanan
Chief Technical Officer

cc: Christopher Markley, NRC DFM
Doug Yates, Licensing Engineer, TN

Enclosures:

1. Affidavit Pursuant to 10 CFR 2.390
2. RSIs, Observations and Responses (Proprietary Version)
3. RSIs, Observations and Responses (Public Version)
4. Certificate of Compliance Renewal Application for the Standardized Advanced NUHOMS® System, Certificate of Compliance No. 1029 (Docket No. 72-1029), Revision 1 (Proprietary Version)
5. Certificate of Compliance Renewal Application for the Standardized Advanced NUHOMS® System, Certificate of Compliance No. 1029 (Docket No. 72-1029), Revision 1 (Public Version)
6. Calculation 503821-TLAA03, Revision 0, Time-Limited Aging Analysis for Boron Depletion and Radiation Fluence for CoC 1029 License Renewal, Associated with the Response to RSI A-2 (Proprietary)
7. Calculation 503821-TLAA02, Revision 0, Fatigue Evaluation of 24PT1 and 24PT4 Dry Shielded Canisters for CoC 1029, Associated with the Response to RSI A-2 (Proprietary)
8. AREVA Final Report 1001060 R000, "Calvert Cliffs Nuclear Power Plant Horizontal Storage Module (HSM) and Dry Shielded Canister (DSC) Examination" Revision 0, September 29, 2017, Associated with the Response to RSI A-1 (Public)
9. Exelon Generation Report R000, "Aging Management Program Inspections for Spent Fuel Horizontal Storage Modules" dated July 2017, Associated with the Response to RSI A-1 (Public)

Electronic Information Exchange (EIE) Document Components:

001 Public E-55203 TN Letter, Affidavit, Public Encl.pdf
002 SUNSI E-55203 Encl 2 RSIs, Observations and Responses-Proprietary.pdf
003 SUNSI E-55203 Encl 4 CoC 1029 Renewal Application R1-Proprietary.pdf
004 SUNSI E-55203 Encl 6 Calc 503821-TLAA03 R0-Proprietary.pdf
005 SUNSI E-55203 Encl 7 Calc 503821-TLAA02 R0-Proprietary.pdf

AFFIDAVIT PURSUANT
TO 10 CFR 2.390

TN Americas LLC)
State of Maryland) SS.
County of Howard)

I, Prakash Narayanan, depose and say that I am the Chief Technical Officer of TN Americas LLC, duly authorized to execute this affidavit, and have reviewed or caused to have reviewed the information which is identified as proprietary and referenced in the paragraph immediately below. I am submitting this affidavit in conformance with the provisions of 10 CFR 2.390 of the Commission's regulations for withholding this information.

The information for which proprietary treatment is sought is contained in Enclosures 2, 4, 6 and 7 and are listed below:

- Enclosure 2, Portions of the Request for Supplemental Information, Observations and Responses
- Enclosure 4, Portions of various chapters and appendices of the Certificate of Compliance No. 1029 Renewal Application, Revision 1
- Enclosures 6 and 7, Time-Limited Aging Analysis Calculations

This document has been appropriately designated as proprietary.

I have personal knowledge of the criteria and procedures utilized by TN Americas LLC in designating information as a trade secret, privileged or as confidential commercial or financial information.

Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure, included in the above referenced document, should be withheld.

1) The information sought to be withheld from public disclosure involves operating experience with spent fuel storage system aging and details of spent fuel storage system aging management studies, associated with the renewal application for the Standardized Advanced NUHOMS® System, which are owned and have been held in confidence by TN Americas LLC.

2) The information is of a type customarily held in confidence by TN Americas LLC, and not customarily disclosed to the public. TN Americas LLC has a rational basis for determining the types of information customarily held in confidence by it.

3) Public disclosure of the information is likely to cause substantial harm to the competitive position of TN Americas LLC, because the information consists of operating experience with the aging degradation of Standardized Advanced NUHOMS® System loaded casks, and details of spent fuel storage system aging management studies and planned aging management strategies associated with the renewal application for the Standardized Advanced NUHOMS® System, the application of which provide a competitive economic advantage. The availability of such information to competitors would enable them to modify their product to better compete with TN Americas LLC, take marketing or other actions to improve their product's position or impair the position of TN Americas LLC's product, and avoid developing similar data and analyses in support of their processes, methods or apparatus.

Further the deponent sayeth not.

A. Prakash
Prakash Narayanan
Chief Technical Officer, TN Americas LLC

Subscribed and sworn before me this 4th day of December, 2019.

[signature]
Notary Public

My Commission Expires 10/16/23

RONDA JONES
NOTARY PUBLIC
MONTGOMERY COUNTY
MARYLAND
MY COMMISSION EXPIRES OCT. 16, 2023

Enclosure 2 to E-55203

RSIs, Observations and Responses

(Proprietary Version)

Withheld Pursuant to 10 CFR 2.390

Enclosure 3 to E-55203

RSIs, Observations and Responses

(Public Version)

RSI 2-1:

Provide supplemental information to complete the scoping evaluation for the optional lightning plates included in CoC No. 1029 renewal application Table 2-6 for the Advanced Horizontal Storage Module (AHSM)-HS. The renewal application does not indicate the assessment for Criterion 1 or Criterion 2.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO RSI 2-1:

As stated in CoC No. 1029 Renewal Application Table 2-6, the optional lightning plates (UFSAR Drawing NUH-03-4012, Item 10A) have a safety classification of not-important-to-safety (NITS) and do not have an impact on any intended safety functions. Therefore, the optional lightning plates do not satisfy scoping criterion No. 1 or 2. Table 2-6 has been revised to reflect this assessment.

Application Impact:

CoC Renewal Application Table 2-6 has been revised as described in the response.

RSI 2-2 (Refers to Proprietary):

Provide supplemental information to complete the scoping evaluation for the Control Components included in CoC No. 1029 renewal application Table 2-7 for the spent fuel assemblies. The renewal application does not indicate the assessment for Criterion 2.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO RSI 2-2:

CoC No. 1029 Renewal Application Table 2-7 had inadvertently indicated that Criterion 2 was not applicable even though Criterion 1 was "NO." Failure of a control component would not affect any intended safety functions of a spent fuel assembly. Therefore, the control components do not satisfy scoping Criterion 2. Table 2-7 has been revised to reflect this assessment.

Application Impact:

CoC Renewal Application Table 2-7 has been revised as described in the response.

RSI 3-1:

Provide supplemental information on the assessment of thermal aging of steel material to justify that this aging mechanism is not credible. The CoC No. 1029 renewal application Section 3.5.3.1.8 states that the effects of elevated storage temperatures on material properties were evaluated during the initial license application. The analysis in CoC renewal application Section 3.5.3.1.8 relies on the analysis in the MAPS report (NUREG-2214) Section 3.2.1.8 and concludes that thermal aging of the steel is a credible aging mechanism for the steel materials. The staff notes that while the MAPS report indicates that thermal aging of generally is not expected to produce degradation of the mechanical properties of steels in the period of extended operation, the MAPS report also states that this conclusion should be verified on a case-by-case basis. The staff reviewed the steel materials used in the DSCs used in the CoC No. 1029 and verified that all of the materials have a maximum continuous operating temperature of 700 °F [371 °C] (ASME code Section II Part D). Provide supplemental information on the maximum steel component temperatures to support the assessment that thermal aging is not credible for the steel components.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System Certificate of Compliance (CoC) renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO RSI 3-1:

CoC No. 1029 renewal application Section 3.5.3.1.8 was revised to state that the maximum steel component temperatures occur in the spacer discs of the 24PT1 and 24PT4 DSCs. The maximum temperature for these subcomponents at the beginning of the initial storage period with design basis contents is 617 °F and 653 °F, respectively, which is lower than the 700 °F limit cited in the RSI (see CoC No. 1029 Renewal Application Tables 4.1.3 and A.4.1-1.

These subcomponents are constructed out of SA-537 CL 2 or SA-533 GR B CL 1. Per the American Society of Mechanical Engineers (ASME) Code Section II materials specifications, SA-537 CL 2 and SA-533 GR B CL 1 materials are tempered to at least 1,100 °F. Following the tempering, the expected mechanisms are fully completed, consisting of the conversion of the martensitic into ferrite and cementite (Fe_3C) accompanied by the precipitation of carbides with some alloying elements. After a high-temperature temper such as this, the steel grades at stake are expected to be softened compared to the quench state or other lower-temperature tempers. The final microstructure is composed of equiaxed ferrite grains decorated with coarse and spheroidized cementite and carbides. From that microstructure state, further tempering or thermal treatment would lead to very slight changes, since it will only contribute to slowly pursue the grain coarsening/ripening and the dislocations annealing, with a kinetic driven by self-diffusion. The expected effect of the thermal exposure during the period of extended operation (PEO) is negligible compared to the minimum tempering required by ASME. Therefore, the tempering during fabrication will dominate any effects of thermal aging at the lower temperatures seen during the PEO.

Therefore, thermal aging of steel material is not a concern.

Application Impact:

CoC Renewal Application Section 3.5.3.1.8 has been revised as described in the response.

RSI 4-1:

Provide supplemental information to describe the inspection ring tool that is under development (72-1029 CoC renewal application section 4.3.4.2) including the following information:

- methods of inspection that will be included on the inspection ring tool
- types of aging mechanisms and other flaws and/or defects that may by detected
- ability of the inspection ring tool to characterize and size aging effects and other flaws and/or defects
- status of development and testing
- expected availability

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO RSI 4-1:

The discussion in CoC No. 1029 Renewal Application section of the inspection ring tool under development was intended to provide information to the NRC staff to show that TN Americas LLC (TN) is working on tooling that could be used by the general licensees to perform aging management program (AMP) inspections. It was not intended to be a requirement that the general licensee use this inspection ring or that the NRC staff review and approve its use. However, since the NRC staff has indicated that they need the supplemental information concerning the inspection ring in order to determine if regulatory requirements will be met, TN has elected to remove the discussion of the optional dry shielded canister (DSC) inspection equipment from Section 4.3.4.2 of the CoC Renewal Application.

Application Impact:

CoC Renewal Application Section 4.3.4.2 has been revised as described in the response.

RSI A-1 (Refers to Proprietary):

Provide supplemental information to support the results of the 2017 inspection at the Calvert Cliffs ISFSI including the actual inspection report for the 2017 inspection and supporting analyses. The document referenced in 72-1029 CoC renewal application section 3C.5.2 (2017 Calvert Cliffs Inspection) is a presentation that has limited information with respect to the inspection results.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO RSI A-1:

To support the results of the 2017 inspection performed at Calvert Cliffs independent spent fuel storage installation (ISFSI), TN Americas LLC (TN) has submitted AREVA Final Report 1001060, "Calvert Cliffs Nuclear Power Plant Horizontal Storage Module (HSM) and Dry Shielded Canister (DSC) Examination" Revision 0, September 29, 2017, which provides the details of the June 2017 inspection of the Calvert Cliffs ISFSI, including the internal surfaces of select HSMs and the external surfaces of select DSCs.

In addition, TN has also submitted Exelon Generation Report, "Aging Management Program Inspections for Spent Fuel Horizontal Storage Modules" dated July 2017, which provides details of inspections performed in June 2017 on the external surfaces of select HSMs.

The AREVA and Exelon documents have been provided in Enclosures 8 and 9, respectively, as supplemental information in response to this RSI. Note that the subject supporting documents were taken from the Institute of Nuclear Power Operations (INPO) Aging Management Information Database (AMID) "as is," including missing or redacted pages from the documents.

Application Impact:

No change as a result of this RSI.

RSI A-2:

Provide supplemental information to support the UFSAR changes associated with the CoC No. 1029 renewal listed in Table A-1 including the following calculations:

- Time-Limited Aging Analysis for Boron Depletion and Radiation Fluence for CoC No. 1029 License Renewal, Calculation Number 503821-TLAA03, Revision 0.
- Fatigue Evaluation of Dry Shielded Canisters for CoC No. 1029, Calculation Number 503821-TLAA02, Revision 0.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO RSI A-2:

In response to this request for additional information, Calculation 503821-TLAA03, Revision 0, "Time-Limited Aging Analysis for Boron Depletion and Radiation Fluence for CoC 1029 License Renewal" and Calculation 503821-TLAA02, Revision 0, "Fatigue Evaluation of 24PT1 and 24PT4 Dry Shielded Canisters for CoC 1029" have been provided in this submittal as Enclosures 6 and 7, respectively. These calculations are proprietary in their entirety.

Application Impact:

No change as a result of this RSI.

RSI A-3:

Provide supplemental information pertinent to the time-limited aging analyses (TLAAs) for irradiation effects on 24PT1 DSC, 24PT4 DSC, and AHSM:

- The spectrum for the neutron source used in the TLAAs with justification that the spectrum used in the TLAAs are appropriate for capturing the radiation damage; or
- The TLAAs with the design basis neutron spectrum.

The applicant provides neutron and gamma sources that are used in TLAAs for irradiation effects on 24PT1 DSC, 24PT4 DSC, and AHSM. However, the applicant provided only the magnitude of the neutron source in Table 3A-2 of the CoC No. 1029 Renewal Application. It is not clear what neutron spectrum was used in the TLAAs. Because the energy of the incident neutrons is critical for calculating the neutron irradiation effects on materials, it is imperative to use the right neutron energy to evaluate the irradiation damages on different materials.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.124(a) and 10 CFR 72.240(c).

RESPONSE TO RSI A-3:

A Cm-244 spontaneous fission spectrum is utilized in neutron fluence Calculation 503821-TLAA03. Use of a Cm-244 spontaneous fission spectrum is consistent with the original design basis horizontal storage module (HSM) calculations, as the neutron source is typically ~95% due to Cm-244. In addition, the total fluence (all energies) and not simply the fast fluence (E > 1 MeV) is conservatively computed and compared against the fluence limits. Therefore, the methodology is conservative.

Application Impact:

No change as a result of this RSI.

Observations

OBS 2-1:

Clarify the design basis of the 1029 system with respect to retrievability. Section 2.2 of the CoC No. 1029 renewal application references ISG-2 Revision 2 approved in 2016 which was after this CoC was approved.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c)(1).

RESPONSE TO OBS 2-1:

Interim Staff Guidance (ISG)-2 is not explicitly mentioned in the updated final safety analysis report (UFSAR) or NRC safety evaluation reports (SERs) associated with Certificate of Compliance (CoC) No. 1029. Therefore, the licensing basis does not contain an explicit commitment to a particular revision of ISG-2.

Though the body of internal TN Americas LLC (TN) design criteria documents for the 24PT1 and 24PT4 dry shielded canisters (DSCs) do not refer to any specific requirements from ISG-2, the design criteria documents do list ISG-2 Revision 0 in the reference section. The design criteria document for the 32PTH2 DSC does not reference ISG-2, but was approved subsequent to the issuance of Revision 1 of ISG-2. Therefore, it is reasonable to conclude that the original design basis of the CoC 1029 system, with respect to retrievability, would be Revisions 0 and 1 of ISG-2.

However, the applicability of ISG-2 Revision 2 explicitly says:

> "The staff will apply ISG-2, Rev. 2 in reviewing ISFSI applications conducted in accordance with NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems" (Reference 6), NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (Ref. 7), or NUREG-1927, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel" (References 8 and 9).
>
> This revision of ISG-2 redefines retrievability and supersedes the definition of retrievability in NUREG-1536, NUREG-1567, and NUREG-1927 and applicable storage ISGs. The previous revision of ISG-2, Rev. 1 (Ref. 10) is superseded in its entirety by ISG-2, Rev. 2."

Since the NRC staff uses ISG-2 Revision 2 to review CoC 1029, it has been used in the CoC renewal application to perform the scoping evaluation (relative to retrievability).

Application Impact:

No change as a result of this OBS.

OBS 2-2:

Justify why the spent fuel assemblies are not screened in category 2 for the shielding analysis for the system.

Table 2-1, “Scoping Evaluation of Standardized Advanced NUHOMS® System SSCs” identified the spent fuel assemblies as not providing a shielding function. However, a review of the USFAR Section 5.4.1.1 reveals that the materials and geometric shape of the fuel assemblies (except failed fuel) are considered in the shielding analyses. As such, the geometry of the fuel assemblies in the cask is important in the shielding analysis. Although the fuel assemblies are not credited for providing a shielding function, degradation of the fuel assemblies and rearrangement of the source term could prevent fulfillment of the shielding function for the 1029 system. If the fuel assembly fails during storage, the shielding analyses for the system will become invalid because of source relocation and changes in material density of the fuel. Therefore, it appears that the geometry of the fuel assemblies should be screened in the shielding analysis under category 2 as described in NUREG-1927 Revision 1 Section 2.4.2 (ML16179A148). The staff notes that the spent assemblies are scoped in in the AMR for other reasons, but it is not clear why the effect of fuel assembly geometry on the shielding function is not identified in the AMR.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.236(d) and 10 CFR 72.240(c).

RESPONSE TO OBS 2-2:

Observation 2-2 correctly points out that “the fuel assemblies are not credited for providing a shielding function…”, but that degradation of the fuel assemblies and rearrangement of the source term would impact the shielding analysis. However, it is the structural intended safety function and not the shielding intended safety function that maintains the fuel assembly geometry and prevents rearrangement of the source term. In addition, a review of previously approved renewal submittals (e.g., Certificate of Compliance No. 1004) determined that the shielding intended safety function was not assigned to the spent fuel assemblies. Additionally, the MAPS report (NUREG-2214) only credits the fuel rod cladding with a shielding function.

Therefore, the submittal assigned a structural intended safety function to the spent fuel assemblies and not a shielding intended safety function.

Application Impact:

No change as a result of this OBS.

OBS 2-3 (Refer to Proprietary):

Provide additional information on the transfer casks (TC) included in the 1004 system and used in the 1029 storage system to address the period of extended operation (PEO) applied for in the 1029 renewal which, if approved, would extend past the PEO for the 1004 system. Provide a scoping evaluation, aging management review, and any necessary TLAAs and aging management programs (AMPs) for the transfer casks approved for use in the 1029 system. The CoC No. 1029 renewal application Section 2.3.3 states that the TCs approved for use with the Standardized Advanced NUHOMS® System are the OS197, OS197H, and the OS200FC (Section 1.1 of CoC No. 1029 Technical Specifications). The TCs are certified under CoC No. 1004, renewed until 2055, and are not considered part of the Standardized Advanced NUHOMS® System subject to renewal. However, the TC is identified as an important to safety component in the CoC No. 1029 renewal application, which is requesting renewal through 2063. Therefore, the TCs authorized for use for the CoC No. 1029 should be considered in scope and included in the renewal application.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c).

RESPONSE TO OBS 2-3:

Although it is believed that the Department of Energy will have contractually taken possession of the spent fuel stored within the Certificate of Compliance (CoC) No. 1029 system before the CoC No. 1004 system PEO ends in 2055, TN Americas LLC proposes a new condition for the renewed CoC that prohibits use of the OS197, OS197H, and the OS200FC TCs aged 20 years or more to perform the TC functions described in the Standardized Advanced NUHOMS® System Updated Final Safety Analysis Report after the PEO for CoC 1004 ends. This proposed new CoC Condition, Condition 13 for Amendments 0 and 1 and Condition 14 for Amendments 3 and 4, has been added to CoC No. 1029 Renewal Application Attachment B, Section B.1.

Application Impact:

CoC Renewal Application Attachment B, Section B.1 has been revised as described in the response.

OBS 3-1 (Refers to Proprietary):

Provide additional information to support the determination that an assessment of fatigue of aluminum basket transition rails and basket assembly shims used in the 32PTH2 dry shielded canister (DSC) is not necessary for the period of extended operation. The CoC No. 1029 renewal application Section 3.5.3.3.6 Fatigue of Aluminum Material provides a general description of cyclic loading of aluminum components in the DSC. Section 3.5.3.3.6 of the renewal application states that the only cyclic loading experienced by the DSC aluminum material is associated with thermal cycling, but the DSC does not experience the full amplitude of ambient temperature cycles and the seasonal and daily variations in ambient conditions are ameliorated by the thermal mass of the HSM. In addition, Section 3.5.3.3.6 of the renewal application cites Section 3.2.3.6 of NUREG-2214 which calls for a review of all fatigue analyses contained in the design basis documents but also states that if no fatigue analysis was performed in support of the component design, no action is required.

The staff notes that renewal application Table 2-4 for the 32PTH2 DSC Drawing ANUH-01-4005 lists basket transition rails (items 1A, 1B and 2) and DSC Drawing ANUH-01-4004 lists the basket assembly shims (item 27) as having structural functions. It is not clear whether the design basis used to determine that a fatigue analysis was not necessary in the CoC amendment for the 32PTH2 DSC is applicable for the period of extended operation. Provide additional information on the cyclic loading of the basket transition rails which considers DSC loading and fuel drying operations, diurnal and seasonal temperature variations, and anticipated operational occurrences that may result in cyclic loading of the basket transition rails to support the determination that a fatigue analysis is not needed.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO OBS 3-1:

In response to OBS 3-1, the following information is provided. The thermal cycle associated with loading and fuel drying operations would occur once for the design life of the dry shielded canister (DSC). The thermal evaluations of the loading conditions are discussed in Updated Final Safety Analysis Report (UFSAR) Sections 4.7, A.4.7 and B.4.8. The only sources of potential thermal fatigue of the DSC are ambient seasonal and daily temperature fluctuation; however, because of the large mass of the loaded DSC, the DSC does not experience the full amplitude of ambient temperature cycles, and a gradual, long-term temperature decrease occurs during the course of storage. To be consistent with the assumptions used for the fatigue evaluation of the DSC shell assembly described in Section 3A.6.1 of the CoC Renewal Application, it is reasonable to assume that there were five ambient temperature cycles per year with a temperature fluctuation that bounds the maximum difference in the off-normal temperatures of -40 °F to 117 °F.

NUREG-1927, Section 2.3 “Regulatory Requirements,” states that certificate of compliance (CoC) renewal is based on “…the continuation of the approved design bases throughout the period of extended operation.” Section 2.3 also states that “The renewal process cannot be used to facilitate approval of design changes.” Application of these regulatory requirements is illustrated in NUREG-2214, Section 3.2.3.6, which generally states: 1) the NRC reviewer should review the applicant’s original design basis to determine if any fatigue analyses that were performed address the implications of extending the operating period to 60 years, and 2) if no fatigue analysis was performed in support of the component design, no action is required of the applicant. The regulatory requirements do not call for a redetermination that the design basis is applicable for the period of extended operation.

As stated in CoC No. 1029 Renewal Application Section 3.5.3.3.6, a review of the design basis for CoC No. 1029 was conducted looking for fatigue evaluations. The review (documented in CoC License Application Appendix 3A of the renewal application) determined that the design basis documents do not contain any fatigue evaluations for the aluminum basket transition rails or basket assembly shims. Any fatigue evaluation or analysis of the aluminum components provided with the renewal application would become part of the design basis and would therefore constitute a design change. Since the renewal process is not used to facilitate approval of design changes, no new fatigue evaluation or analysis of the aluminum components are provided. Therefore, per the regulatory requirements discussion in NUREG-1927 and the guidance in NUREG-2214, no further action is required.

Application Impact:

No change as a result of this OBS.

OBS 3-2:

Clarify the text in CoC No. 1029 Renewal Application Section 3.5.3.6.6 Corrosion of Reinforcing Steel of Concrete Material which states:

> *Although no cases of corrosion-induced damage have been reported, the results of a durability model show that corrosion of the reinforcing steel in concrete can potentially initiate and propagate within the 60-year timeframe for concretes of moderate to low quality. Therefore, corrosion of reinforcing steel in concrete exposed to outdoor and groundwater or soil (below-grade) environments is considered credible.*

As stated, this may be interpreted to imply that the HSM concrete is of moderate to low quality. A clarification that the HSM concrete is designed and constructed in accordance with ACI standards and that this is included to be conservative may be appropriate.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO OBS 3-2:

As stated in Section 1.2.2.2, the horizontal storage modules (HSMs) are designed and constructed in accordance with American Concrete Institute (ACI) standards and, therefore, are not considered to be constructed of moderate- to low-quality concrete. However, the aging management review (AMR) evaluation conservatively assumes that corrosion of reinforcing steel is possible in the HSMs, and is, therefore, considered credible for concrete exposed to an air-outdoor or groundwater/soil environment. CoC No. 1029 Renewal Application Section 3.5.3.6.6 has been revised to clarify the HSM design and construction standards and clarify that corrosion of the reinforcing steel is conservatively assumed to be possible.

Application Impact:

CoC Renewal Application Section 3.5.3.6.6 has been revised as described in the response.

OBS 3-3:

Clarify the information provided in CoC No. 1029 renewal application Section 3.5.3.8.1, Creep of Spent Fuel Assembly Hardware Materials. The text at the end of Section 3.5.3.8.1 appears to be out of place. The text states:

> *Section 3.5.3.2.6 evaluated the creep aging mechanism for stainless steel with the DSC and concluded it was not credible.*
>
> *Therefore, creep is not credible for the SFA hardware materials.*

It is unclear how the evaluation in Section 3.5.3.2.6 is related to the evaluation in Section 3.5.3.8.1.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO OBS 3-3:

The reference to CoC No. 1029 Renewal Application Section 3.5.3.2.6 within CoC Renewal Application Section 3.5.3.8.1 was intended to use the evaluation for creep of stainless steel material in addressing creep of stainless steel spent fuel assembly hardware material.

As discussed in Section 3.5.3.2.6, the highest temperature within the dry shielded canister (DSC) is the spent fuel cladding (i.e., 727 °F). This temperature is below the minimum temperature needed for creep to occur in stainless steel (i.e., 763 °F). Therefore, creep of stainless steel spent fuel assembly hardware material is not credible during the period of extended operation.

Section 3.5.3.8.1 of the CoC Renewal Application has been revised to include the evaluation of creep of stainless steel spent fuel assembly hardware rather than referring to Section 3.5.3.2.6.

Application Impact:

CoC Renewal Application Section 3.5.3.8.1 has been revised as described in the response.

OBS 3-4:

Table 3-6 page 4 (CoC No. 1029 renewal application page 3-72) appears to be in need of a format correction. The first 7 entries in Table 3-6 on page 3-72 appear to be in the “Spent Fuel Cladding” Material Grouping although the format of the table on this page suggests that only Mechanical Overload is included in that material grouping and the following 6 entries are associated with an unnamed material grouping.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO OBS 3-4:

The first seven entries in CoC No. 1029 Renewal Application Table 3-6 on page 3-72 are potential aging mechanisms associated with the spent fuel assembly cladding material group. The format of Table 3-6 has been revised to reflect the proper material grouping for the aging mechanisms.

Application Impact:

CoC Renewal Application Table 3-6 has been revised as described in the response.

OBS 3-5:

Clarify the applicable ISFSI Basemat AMP for the credible aging mechanism Leaching of Calcium Hydroxide for Concrete in an Air-Outdoor environment. Table 3-9 of the CoC No. 1029 renewal application indicates the aging management activity is the HSM AMP. However, Table 3-16 (pages 3-136 and 3-137) indicates the aging management activity for this aging mechanism is covered by the Basemat AMP.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO OBS 3-5:

The leaching of calcium hydroxide aging mechanism of the basemat pad will be managed via the Basemat AMP and not the Horizontal Storage Module (HSM) AMP. CoC No. 1029 Renewal Application Table 3-9 has been revised to show the correct aging management activity for leaching of calcium hydroxide.

Application Impact:

CoC Renewal Application Table 3-9 has been revised as described in the response.

OBS 3-6:

Provide information on how to detect loss of the shielding function of the concrete components.

Table 3-6 of the LRA provides a summary of potential aging mechanisms for the structures and components of the NUHOMS® dry storage system. The data in the table indicate that several aging mechanisms could result in cracking and loss of materials of concrete components. Because one of the important safety functions of the concrete components is shielding the radiation from the contents, it important to detect aging effects in a timely matter. However, it was not clear how the cracks, particularly cracks not visible from the surfaces, will be managed to ensure the impairment of the shielding function of these components are detected in a timely manner before unexpected radiation streaming may occur.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.236(d) and 10 CFR 72.240(c).

RESPONSE TO OBS 3-6:

When preparing the Horizontal Storage Module (HSM) Aging Management Program (AMP) for Certificate of Compliance (CoC) No. 1029, TN Americas LLC (TN) considered information pertaining to previously approved NUHOMS® HSM AMPs, namely the renewal of Calvert Cliffs independent spent fuel storage installation (ISFSI)-specific license SNM-2505 [1] and Standardized NUHOMS® CoC No. 1004 [2].

The Calvert Cliffs (SNM-2505) HSM AMP includes annual gamma and neutron radiation surveys on each HSM door and semiannual readings of thermoluminescent dosimeters (TLDs) on the ISFSI perimeter fence. In order for these surveyed locations to detect a reduction in shielding effectiveness in non-accessible areas (e.g., cracks not visible from the surface) of an HSM, the degradation would have to be so severe that it is reasonable to expect that the aging mechanism causing the degradation would manifest itself in an external area that is periodically inspected. Therefore, TN determined that the radiation surveys outlined in the SNM-2505 HSM AMP would not provide any more assurance that the HSM is able to perform its intended radiation shielding safety function than would be obtained from visual inspections.

The CoC 1004 HSM AMP relies on visual inspections to detect degradation before there is a loss of the shielding intended safety function, i.e., it does not include radiation surveys. Therefore, the TN-proposed HSM AMP is consistent with the precedent in the renewed CoC for the Standardized NUHOMS® System. While Section 6.6 and Table 6-3 of NUREG-2214 report do mention radiation surveys, it also allows for excluding such surveys from the AMP on a case-by-case basis.

To detect a reduction in radiation shielding effectiveness in non-accessible areas of HSMs that are not periodically inspected, a detailed radiation survey of the entire surface of all HSMs would be necessary. As previously stated, in order for radiation surveys to detect a reduction in shielding effectiveness in non-accessible areas of an HSM, the degradation would have to be so severe that it is reasonable to expect that the aging mechanism causing the degradation would manifest itself in an external area that is periodically inspected. Therefore, the increase in worker dose (and personal safety issues) to perform these surveys would not result in a corresponding increase in safety considering the degree of assurance that the visual inspections will provide in ensuring that the intended radiation shielding safety function will not be lost.

CoC 1029 Technical Specification (TS) 5.2.3 requires a radiological environmental monitoring program. Specifically, TS 5.2.3(a) requires a radiological environmental monitoring program to ensure the annual dose equivalent to an individual located outside the independent spent fuel storage installation (ISFSI) controlled area does not exceed the annual dose limits specified in 10 CFR 72.104(a). While not included in the proposed HSM AMP, the procedures used to comply with the TS would detect any significant decrease in HSM shielding effectiveness or an increasing trend over time in a manner that the cause could be determined and appropriate corrective actions could be implemented, if required.

TN has, therefore, determined that additional periodic radiation surveys as part of the HSM AMP are not necessary to ensure that an aging-related degradation of the intended radiation shielding safety function would be detected.

References:

1. Letter from G H Gellrich (CCNPP) to Document Control Desk (NRC), “Response to Fourth Request for Additional Information for Renewal Application to Special Nuclear Materials License No. 2505 for the Calvert Cliffs Site Specific Independent Spent Fuel Storage Installation (TAC No. L24475),” September 18, 2014, (ADAMS Accession No. ML14267A065).

2. Letter E-46190 from Jayant Bondre (AREVA Inc.) to Document Control Desk (NRC), “Response to Re-Issue of Second Request for Additional Information – AREVA Inc. Renewal application for Standardized NUHOMS® System – CoC 1004 (Docket No. 72-1004, CAC No. L24964),” September 29, 2016, (ADAMS Accession Number ML16279A367).

Application Impact:

No change as a result of this OBS.

OBS 4-1:

Provide additional information to clarify the potential use of surrogate inspections. The CoC No. 1029 renewal application Section 4.3.1 identifies the potential for utilizing surrogate inspection results in lieu of an inspection of the DSC. It is not clear what information is considered in the "operational history" as described in Section 4.3.1. The NRC response to Nuclear Energy Institute (NEI) 14-03 Revision 2 (https://www.nrc.gov/docs/ML1832/ML18325A207.pdf) states that the NRC does not believe there is substantial operating experience for canister examinations for the various susceptibility rankings to understand how the susceptibility assessments may be applied, and surrogates used, across the independent spent fuel storage installation fleet. In addition, the NRC response to NEI 14-03 Revision 2 indicates that an approach of using surrogates would need to be justified on a case-by-case basis by an applicant, considering canister examination results for the susceptibility rankings.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.240(c) and (d).

RESPONSE TO OBS 4-1:

After reconsidering the geographical location of the general licensee that currently stores spent fuel using Certificate of Compliance (CoC) No. 1029 (i.e., San Onofre Nuclear Generating Station), and the likelihood of future users, TN Americas LLC (TN) has determined that it is unlikely that a general licensee will use a surrogate inspection. Therefore, TN has revised the Dry Shielded Canister (DSC) Aging Management Program (AMP) to remove the option for a general licensee to use the inspection results from other general licensee inspections from CoC No. 1029 Renewal Application Section 4.3.1.

Application Impact:

CoC Renewal Application Section 4.3.1 has been revised as described in the response.

OBS A-1:

Justify why the conservatism can be reduced or revise the TLAAs for the irradiation effects on 24PT1 DSC, 24PT4 DSC, and AHSM.

On page 3A-16 of the LRA, the applicant states: [

] The staff does not understand why it is acceptable to reduce the conservatism in the design basis analyses.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.236(d) and 10 CFR 72.240(c).

RESPONSE TO OBS A-1:

As stated in Section 3A.5 of the CoC No. 1029 Renewal Application, the time-limited aging analyses (TLAAs) for the irradiation embrittlement of metals in the 24PT1 and 24PT4 DSC, and the irradiation effects on the concrete in the advanced horizontal storage module (AHSM) must be revised or updated. Rather than revising the original TLAA, TN Americas LLC chose to update the information in a new TLAA. Therefore, the reductions of conservatisms discussed in CoC Renewal Application Section 3A.7.3 are to a reference analysis, and not to the original design basis analysis.

CoC Renewal Application Section 3A.7 summarizes the evaluation contained in Calculation 503821-TLAA03, a copy of which has been submitted to the NRC as part of the response to RSI A-2. As shown in 503821-TLAA03, the evaluation is based on adjustments to an analysis in Calculation 502917-0500, which was performed to support the renewal of the Rancho Seco Independent Spent Fuel Storage Installation (ISFSI)-specific license SNM-2510 (Note that a copy of Calculation 502917-0500 was provided to the NRC as Enclosure 9 in Reference 1). Calculation 502917-0500 used several overly conservative assumptions.

The first two columns of CoC Renewal Application Table 3A-2 of the submittal summarize the bounding neutron sources for the 24PT1 and 24PT4 systems, respectively, [

] CoC Renewal Application Section 3A.7.3 proposes an approach to scale down the overly conservative results obtained in the reference analysis, while ensuring appropriate levels of conservatism for the 24PT1 and 24PT4 systems.

Since the evaluation in Calculation 503821-TLAA03 is used to update and replace the TLAA, it is acceptable to reduce the overly conservative assumptions used in a reference analysis.

Reference:

1. Letter DPG 18-114, from Dan Tallman (SMUD) to Director Division of Spent Fuel Management (NRC), “Response to Request for Supplemental Information for Acceptance Review of the Application for the Renewal of 10 CFR Part 72 Special Nuclear Materials License No. SNM-2510 for the Rancho Seco Independent Spent Fuel Storage Installation (CAC/EPID Nos. 001028/L- 2018-RNW-0005;000993/L-2018-LNE-0004),” June 25, 2018.

Application Impact:

No change as a result of this OBS.

OBS A-2:

Address apparent inconsistency between Section 4.3.4.3 and Section 3B.6 regarding DSC thickness needed to ensure confinement boundary.

Section 3B.6 states "… that a DSC shell thickness of [ ] was adequate to maintain confinement …". Furthermore, Section 4.3.4.3 states that "Subsequent inspections are to be conducted every 5 years ± 1 year or when an engineering evaluation predicts an identified crack will reach [ ] through-wall, whichever is less [emphasis added], following the baseline inspection." Based on the first statement, a thickness of [ ] represents approximately a [ ] reduction of the DSC overall shell thickness. This is less than the [ ] through-wall crack depth inspection requirement in the second statement. It is not clear to the staff how confinement is maintained when both these statements seem to provide conflicting requirements. Address or justify this apparent inconsistency.

The staff needs this information to proceed with its review to determine if the Standardized Advanced NUHOMS® System CoC renewal application meets the regulatory requirements of 10 CFR 72.236(d) and 10 CFR 72.240(c).

RESPONSE TO OBS A-2:

The wording in CoC No. 1029 Renewal Application Section 3B.6 (relative to maintaining confinement) is based on Appendix 3N of the Certificate of Compliance (CoC) No. 1004 renewal application in Reference [1]. Section 3N.1 of Reference [1] states that "The confinement function is considered to be met if the DSC confinement boundary stresses due to normal and off-normal loads meet the American Society of Mechanical Engineers (ASME) code stress limits for Level A and B conditions [3N.5.4]." The analysis described in Appendix 3N of Reference [1] showed that the ASME code limits were met when the dry shielded canister (DSC) total thickness (i.e., the uniform thickness) was reduced to [ ] inches. Therefore, Appendix 3N of Reference [1] concluded that a DSC shell thickness of [ ] inches was adequate to maintain confinement.

The CoC 1029 renewal application provides a [ ] through-wall criteria for cracks, i.e., a localized indication. The localized [ ] through-wall criteria requirement is not comparable to the uniform DSC shell thickness evaluated in Section 3B.6.

Section 3B.6 has been revised to clarify that the evaluation was performed to demonstrate that ASME code limits were met with a uniform DSC shell thickness of only [ ] inches.

References:

1. Letter E-46190 from Jayant Bondre (AREVA Inc.) to U.S. NRC Document Control Desk (NRC), "Response to Re-Issue of Second Request for Additional Information – AREVA Inc. Renewal application for Standardized NUHOMS® System – CoC 1004 (Docket No. 72-1004, CAC No. L24964)," September 29, 2016, (Adams Accession Number ML16279A367).

Application Impact:

CoC Renewal Application Section 3B.6 has been revised as described in the response.

Enclosure 4 to E-55203

Certificate of Compliance Renewal Application for the Standardized Advanced NUHOMS® System, Certificate of Compliance No. 1029 (Docket No. 72-1029), Revision 1

(Proprietary Version)

Withheld Pursuant to 10 CFR 2.390

Enclosure 5 to E-55203

Certificate of Compliance Renewal Application for the Standardized Advanced NUHOMS® System, Certificate of Compliance No. 1029 (Docket No. 72-1029), Revision 1

(Public Version)

PUBLIC

Certificate of Compliance Renewal Application for the Standardized Advanced NUHOMS® System

Certificate of Compliance No. 1029
(Docket No. 72-1029)

Prepared by:
TN Americas LLC
Columbia, Maryland

Revision 1
December 2019

Table of Contents

CHAPTER 3 AGING MANAGEMENT REVIEW

APPENDIX 3A TLAA IDENTIFICATION AND DISPOSITION

Acronyms and Abbreviations

ACI	American Concrete Institute
AHSM	Advanced Horizontal Storage Module
AMA	Aging Management Activity
AMID	Aging Management INPO Database
AMP	Aging Management Program
AMR	Aging Management Review
ANSI/ASCE	American National Standards Institute / American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASR	Alkali-Silica Reaction
ASTM	American Society of Testing Materials
B4C	Boron Carbide
B&PV	Boiler and Pressure Vessel
CAR	Corrective Action Report
CFR	Code of Federal Regulations
CGR	Crack growth rate
CISCC	Chloride Induced Stress Corrosion Cracking
CO	Confinement intended function
CoC	Certificate of Compliance
CR	Sub-Criticality Control intended function
DEF	Delayed Ettringite Formation
DHC	Delayed Hydride Cracking
DOE	Department Of Energy
DSC	Dry Shielded Canister
DSS	Dry Storage System
EPRI	Electric Power Research Institute
GALL	Generic Aging Lessons Learned
HAZ	Heat Affected Zone
HBU	High Burnup
HDRP	High Burnup Fuel Dry Storage Cask Research and Development Project
HSM	Horizontal Storage Module
INPO	Institute of Nuclear Power Operations
ISFSI	Independent Spent Fuel Storage Installation
ISG	Interim Staff Guidance
ITS	Important-To-Safety
LRA	License Renewal Application

MAPS	Managing Aging Processes in Storage
MCNP	Monte Carlo N-Particle code
MIC	Microbiologically Influenced Corrosion
MMC	Metal Matrix Composite
MOX	Mixed Oxide fuel
NEI	Nuclear Energy Institute
NITS	Not Important-to-Safety
NPP	Nuclear Power Plant
OE	Operating experience
ODSCC	Outer Diameter Stress Corrosion Cracking
PCMI	Pellet-to-Cladding Mechanical Interaction
PEO	Period of Extended Operation
PWR	Pressurized Water Reactor
QA	Quality Assurance
RH	Relative Humidity
RT	Retrievability intended function
SAR	Safety Analysis Report
SCC	Stress Corrosion Cracking
SER	Safety Evaluation Report
SFA	Spent Fuel Assembly
SH	Radiation Shielding intended function
SONGS	San Onofre Nuclear Generating Station
SIF	Stress Intensity Factor
SMUD	Sacramento Municipal Utility District
SR	Structural Integrity intended function
SS	Stainless steel
SSCs	Structures, Systems and Components
TC	Transfer Cask
TH	Heat Removal Capability intended function
TLAA	Time-Limited Aging Analysis
TNUG	TN User’s Group
TS	Technical Specifications
UFSAR	Updated Final Safety Analysis Report

CHAPTER 1
GENERAL INFORMATION

CONTENTS

LIST OF TABLES

1.1 Introduction

The Standardized Advanced NUHOMS® Horizontal Modular Storage System (herein referred to as the Standardized Advanced NUHOMS® System) Certificate of Compliance (CoC) No. 1029, Revision 0 [1-3] was approved by the U.S. Nuclear Regulatory Commission (NRC) effective February 5, 2003, for storage of spent nuclear fuel by general licensees. The expiration date for CoC 1029 is February 5, 2023. As the certificate holder of CoC 1029, TN Americas LLC (TN)[1] is applying for renewal of CoC 1029 for a term of 40 years, in accordance with the 10 CFR 72.240(a) [1-1].

This application for CoC 1029 renewal includes the Safety Analysis Report (SAR) information required by 10 CFR 72.240(c). The SAR content of this application is based on the guidance provided in NUREG-1927 [1-2].

In accordance with NUREG-1927 [1-2], this renewal application is based "on the continuation of the approved design basis throughout the period of extended operation."

The identification and management of potential aging degradation mechanisms for different material/environment combinations was based on the guidance of NUREG-2214 [1-13] in support of this renewal application.

[1] TN Americas LLC, formerly AREVA TN, and Transnuclear, Inc.

1.2 Standardized Advanced NUHOMS® System Description

1.2.1 General System Description

The Standardized Advanced NUHOMS® System is a modular canister-based system for the dry storage of irradiated spent fuel assemblies (SFAs) consisting of a dry shielded canister (DSC) and a reinforced concrete horizontal storage module (HSM). Additional structures, systems, and components (SSCs) include an onsite transfer cask (TC) and other fuel transfer and auxiliary equipment used to support DSC loading and transfer operations.

Unless otherwise noted, the term DSC applies to the 24PT1, 24PT4, and 32PTH2 DSC types. Similarly, unless otherwise noted, the term HSM applies to the Advanced Horizontal Storage Module (AHSM) and AHSM-HS designs.

The following paragraphs provide an overview of the Standardized Advanced NUHOMS® System. A more complete system description, including supporting design basis, is contained in the UFSAR, Revision 9 [1-6].

1.2.2 Principal Components of the Standardized Advanced NUHOMS® System

1.2.2.1 Dry Shielded Canister

The DSC consists of the shell assembly and the internal basket assembly. The shell assembly is a high integrity stainless steel welded pressure vessel that provides confinement of radioactive materials, encapsulates the fuel in an inert atmosphere (the canister is back-filled with helium before being seal-welded closed), and provides radiological shielding. The shell assembly consists of a cylindrical shell and the top and bottom end assemblies, which form the pressure-retaining confinement boundary for the spent fuel.

The DSC has double, redundant seal welds that join the shell and the top end assembly to form the confinement boundary. The bottom end assembly confinement boundary welds are made during fabrication of the DSC. The top end assembly confinement boundary welds are made after fuel loading. Both top plug penetrations (siphon and vent ports) are redundantly sealed after DSC drying operations are complete. The DSC shell assembly also includes a shield plug at both top and bottom ends to minimize occupational doses during drying, sealing, and handling operations.

The internal basket assembly contains a storage position for each fuel assembly. The basket assembly may consist of an assemblage of spacer discs supported on vertical rods (spacer disc design), or an assemblage of individual tubes or a grid of plates (tube or plate grid design).

The 24PT1 and 24PT4 DSCs use the spacer disc basket design. In this design, circular spacer disc plates provide the structural support for the fuel assemblies in the lateral direction. Support rods and spacer sleeves maintain the spacing between the discs and provide the axial support of the basket assembly. The geometric separation of the fuel assemblies by the basket assembly and the neutron absorbing capability of the DSC materials of construction ensure subcriticality of the DSC.

The 32PTH2 DSC uses the tube basket design. The basket structures for this DSC consist of assemblies of stainless steel fuel compartments made up of individual tubes welded to form a grid-like structure. Fixed neutron absorber material provides the necessary criticality control. Aluminum sheets/plates provide the heat conduction paths from the fuel assemblies to the canister shell. Transition rails, which consist of aluminum parts, form the transition between the box-like fuel compartment structure and the cylindrical DSC shell.

The DSC shell assemblies are designed and fabricated in accordance with the provisions of the ASME B&PV Code, Section III, Division 1, [1-9 for the 24PT1 and 24PT4, and 1-10 for the 32PTH2], Subsection NB, with certain code alternatives as described in the UFSAR [1-6]. The basket assemblies are designed and fabricated in accordance with the provisions of ASME B&PV Code, Section III, Division 1, [1-9 for the 24PT1 and 24PT4, and 1-10 for the 32PTH2], Subsections NF and/or NG (depending on the specific basket design), with certain code alternatives as described in the UFSAR [1-6].

1.2.2.2 Horizontal Storage Module

The HSM is a low-profile, modular, reinforced concrete structure whose primary functions are to provide a means for passively removing spent fuel decay heat, provide structural support and environmental protection to the loaded DSC, and provide radiation shielding protection. Heat removal is achieved by a combination of radiation, conduction, and convection. Ambient air enters the HSM through ventilation inlet openings located in the lower region of the front or side walls and circulates around the DSC. Air exits through outlet openings in the top regions of the HSM walls. Thermal monitoring or visual inspections are used to provide indication of HSM performance or a blocked vent condition. Structural support of the loaded DSC is provided by a structural steel frame/rail structure anchored to the HSM. Environmental protection and radiation shielding are provided by massive, thick side walls and roof of the HSM, supplemented by thick wall units attached at the ends of the array and at the rear walls of the HSM if the array is of single row configuration.

The HSMs are designed in accordance with the rules of ACI-349 [1-11 for the AHSM, and 1-12 for the AHSM-HS] and constructed in accordance with ACI-318 [1-7 for the AHSM, and 1-8 for the AHSM-HS].

1.2.2.3 Onsite Transfer Cask

The onsite TC is a non-pressure retaining cylindrical vessel with a welded bottom assembly and a bolted lid. The TC is designed for onsite transfer of the DSC to and from the plant's spent fuel pool and the independent spent fuel storage installation (ISFSI). The TC provides the shielding and heat rejection mechanism for the DSC and SFAs during handling in the fuel or reactor building, DSC closure operations, transfer to the ISFSI, and insertion into the HSM. The TC also provides primary protection for the loaded DSC during off-normal and drop accident events postulated to occur during the transfer operations.

The TCs approved for use with the Standardized Advanced NUHOMS® System are the OS197, OS197H, and the OS200FC. These TCs are certified under CoC 1004 and are not considered part of the Standardized Advanced NUHOMS® System subject to renewal.

1.2.2.4 Other Structures, Systems, and Components

1.2.2.4.1 Spent Fuel Assemblies

The Standardized Advanced NUHOMS® System is designed to store pressurized water reactor (PWR) spent fuel assembly types as authorized contents per the associated Technical Specifications (TS) and applicable amendments.

1.2.2.4.2 Fuel Transfer and Auxiliary Equipment

The Standardized Advanced NUHOMS® System is provided with the following auxiliary equipment for fuel handling and transfer inside the reactor/fuel building and at the ISFSI:

- TC lifting yoke
- DSC automatic welding machine to enable sealing the DSC top end
- Vacuum drying system to drain and vacuum dry the DSC cavity following loading of SFAs into the DSC
- Transfer trailer equipped with a TC skid to support the TC during transfer and a skid positioning system
- Hydraulic ram system for insertion and withdrawal of a loaded DSC into and from an HSM

1.2.2.4.3 ISFSI Basemat and Approach Slab

The HSM is installed on a load-bearing foundation, which consists of a reinforced concrete pad on a subgrade suitable to support the loads. There are no structural connections or means to transfer shear between the HSM base unit module and the concrete basemat. The approach slab is a reinforced concrete slab that provides access and support to the DSC transfer system.

1.3 Background

The Standardized Advanced NUHOMS® System, originally approved in February 2003, has evolved with time via approval of amendments to the original CoC 1029. Each of these amendments has been designed to accommodate the evolving needs of the industry to store spent PWR fuel that is intact, damaged, or in a failed condition while having characteristics such as high decay heat loads, high U-235 enrichments, and high burnup levels.

A listing of the currently approved CoC 1029 Amendments is provided in Table 1-1. This table provides: (a) the effective date of the amendment, (b) a brief description of the scope of each amendment, and (c) a listing of the UFSAR appendix or chapter where the licensing basis of a specific amendment is located.

1.4 Application Format and Content

This application includes SAR information required by 10 CFR 72.240 (c) [1-1]. The format and content of this SAR information is consistent with the guidance contained in NUREG-1927 [1-2].

Chapter 1, General Information: Chapter 1 provides (1) a general description of the Standardized Advanced NUHOMS® System, (2) a discussion of CoC 1029 Amendments, and (3) information on the format and content of this application.

Chapter 2, Scoping Evaluation: Chapter 2 provides a description of the methodology used to identify the SSCs of the Standardized Advanced NUHOMS® System that are within the scope of the renewal. This methodology is based on the process described in NUREG-1927 [1-2]. Chapter 2 also provides a summary of the results of the scoping evaluation based on Revision 9 of the UFSAR [1-6].

Chapter 3, Aging Management Review: Chapter 3 provides the methodology used for the aging management review (AMR) of the Standardized Advanced NUHOMS® System, based on the guidance provided in NUREG-1927 [1-2]. The AMR documented in Chapter 3 identifies the materials and environment for those SSCs and associated subcomponents determined to be within the renewal scope in Chapter 2. This is accomplished by reviewing the drawings and the design basis included in the current UFSAR [1-6], CoC Amendment 4 [1-4], and associated TS [1-5]. Once the component material/environment combinations are determined, a review is performed to identify credible aging degradation mechanisms for the different material/environment combinations. NUREG-2214 Rev. 0 (based on technical literature, related research, industry information, and existing operating experience) is used as a guide for the review. After the credible aging mechanisms and effects are identified, it is determined whether the effects can be managed via a time-limited aging analysis (TLAA) or will require an aging management program (AMP).

Appendix 3A, Time-Limited Aging Analyses: Appendix 3A identifies the calculations or analyses used to demonstrate that in-scope SSCs will maintain their intended safety function throughout an explicitly stated period of operation, i.e., TLAAs. For those TLAAs that would not remain valid through the period of extended operation, Appendix 3A provides a summary of the revised or updated analysis.

Appendix 3B, Supplemental Evaluations: Appendix 3B provides a summary of supplemental evaluations and calculations performed to support the AMR and/or an element in an AMP.

Appendix 3C, Operating Experience Review: Appendix 3C provides a summary of the operating experience review performed to support the AMR and AMPs.

Chapter 4, Aging Management Programs: Chapter 4 provides the AMPs credited for managing each of the identified aging effects for the in-scope SSCs of the Standardized Advanced NUHOMS® Horizontal Modular Storage System. The purpose of an AMP is to ensure that no aging effects result in a loss of intended safety function of the SSCs that are within the scope of renewal, for the term of the renewal. Each of the AMPs consists of the ten elements called for in NUREG-1927 [1-2].

Attachment A: This attachment provides the recommended changes to the UFSAR for CoC 1029 renewal.

Attachment B: This attachment provides the recommended changes to the TS for CoC 1029 renewal.

1.5 References (Chapter 1, General Information)

1-1 Title 10 Code of Federal Regulations Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

1-2 NUREG-1927, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel," Revision 1, U.S. Nuclear Regulatory Commission, June 2016.

1-3 U.S. Nuclear Regulatory Commission, "Certificate of Compliance for Spent Fuel Storage Casks," Certificate No. 1029, Revision 0, February 05, 2003, Docket No. 72-1029.

1-4 U.S. Nuclear Regulatory Commission, "Certificate of Compliance for Spent Fuel Storage Casks," Certificate No. 1029, Amendment No. 4, Effective March 12, 2019, Docket No. 72-1029.

1-5 CoC 1029 Appendix A, "Technical Specifications for the Standardized Advanced NUHOMS System Operation Controls and Limits," Amendment 4, March 12, 2019, Docket No. 72-1029.

1-6 TN Americas LLC, ANUH-01.0150, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 9, March, 2019.

1-7 ACI-318, "Building Code Requirement for Reinforced Concrete," American Concrete Institute, 1989 (92) Edition.

1-8 ACI-318, "Building Code Requirement for Reinforced Concrete," American Concrete Institute, 2008 Edition.

1-9 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section III, Division 1, 1992 Edition, with 1994 Addenda.

1-10 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section III, Division 1, 2010 Edition.

1-11 ACI-349, "Code Requirements for Nuclear Safety Related Concrete Structures and Commentary," American Concrete Institute, 1997 Edition.

1-12 ACI-349, "Code Requirements for Nuclear Safety Related Concrete Structures and Commentary," American Concrete Institute, 2006 Edition.

1-13 NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report" (draft report for comment), U.S. Nuclear Regulatory Commission, October 2017 (ADAMS Accession Number ML17289A237).

1-14 Safety Evaluation Report for the Standardized NUHOMS® System Certificate of Compliance No. 1004 Renewal, Docket No. 72-1004, May 2017 (ADAMS Accession Number ML17338A121).

Table 1-1
Listing of CoC 1029 Amendments

Amendment No.	Amendment Effective Date	Description	Location of Supporting Licensing Basis within the FSAR
0	02/05/03	Initial approval to store spent fuel in the Standardized Advanced NUHOMS® System; i.e., 24PT1 DSC and AHSM.	Main FSAR Body
1	05/16/05	Approved the use of the 24PT4 DSC as part of the Standardized Advanced NUHOMS® System.	Appendix A
2	N/A	The Amendment was submitted, but was subsequently withdrawn.	N/A
3	02/23/15	Approved the use of the 32PTH2 DSC and AHSM-HS as part of the Standardized Advanced NUHOMS® System.	Appendix B
4	3/12/19	Revised UFSAR and Technical Specifications to 1) remove any implied statements related to maintenance of a spent fuel pool, 2) change the thermal monitoring program, 3) add AHSM dose rate limits on the front of the birdscreen and doors, and 4) update the temperature increase for the 24PT4 DSC stored in an AHSM.	Various

CHAPTER 2
SCOPING EVALUATION

CONTENTS

LIST OF TABLES

2.1 Introduction

Chapter 2 describes the evaluation process and methodology used to identify the structures, systems, and components (SSCs) of the Standardized Advanced NUHOMS® Horizontal Modular Storage System (herein referred to as the Standardized Advanced NUHOMS® System) that are within the scope of renewal.

In accordance with the guidance contained in NUREG-1927, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance" [2-2], the first step of the renewal process is the performance of a scoping evaluation. The objective of the scoping evaluation is to identify the SSCs of the Standardized Advanced NUHOMS® System that are within the scope of renewal.

A description of the scoping process and methodology is provided in Section 2.2. The results of the scoping evaluation are provided in Section 2.3.

2.2 Scoping Evaluation Process and Methodology

The scoping evaluation of the Certificate of Compliance (CoC) No. 1029 storage system is performed based on the process described in NUREG-1927 [2-2]. SSCs (and associated subcomponents) are considered to be within the scope of the renewal if they satisfy either of the following criteria:

Criterion 1:

The SSC (and associated subcomponents) is classified as important-to-safety (ITS) as it is relied on to perform one of the following functions (10 CFR 72.3):

a) Maintain the conditions required by the regulations or the CoC to store spent fuel safely.
b) Prevent damage to the spent fuel during handling and storage.
c) Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

These SSCs ensure that important to safety functions are met for (1) sub-criticality control, (2) radiation shielding, (3) confinement, (4) heat-removal capability, (5) structural integrity, and (6) retrievability.

Criterion 2:

The SSC (and associated subcomponents) 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 retrievability safety function is based on the ability to remove a canister loaded with spent fuel assemblies from the storage overpack; i.e., option B in Revision 2 of Interim Staff Guidance (ISG) – 2 [2-11].

In accordance with NUREG-1927 [2-2], the renewal is based "on the continuation of the approved design bases throughout the period of extended operation." Accordingly, the sources of information reviewed for this scoping evaluation that describe the approved design basis and the intended safety functions of the SSCs (and associated subcomponents) are the following:

a) Standardized Advanced NUHOMS® Horizontal Modular Storage System Updated Final Safety Analysis Report (UFSAR) (Reference [2-1]).
b) CoC 1029 Certificate and Technical Specifications (TS) for each amendment.
c) Safety Evaluation Reports (SERs) for each amendment [2-5, 2-7, 2-9, 2-13].

These documents were reviewed to determine those SSCs (and associated subcomponents) with safety functions that meet either Scoping Criterion 1 or Criterion 2, as defined above. Based on this review, those subcomponents that perform or support any of the identified intended safety functions are determined to be in-scope and require an aging management review (AMR). Those subcomponents that do not perform or support a safety function are excluded from further evaluation in the AMR.

The scope of the CoC 1029 renewal encompasses the initial approved application (Amendment 0) and three subsequently approved amendments; i.e., Amendments 1, 3, and 4. Amendment 2 was docketed for review but was subsequently withdrawn [2-3].

Amendment 0 of CoC 1029 [2-4] approved the design of the 24PT1 dry shielded canister (DSC) stored in an Advanced Horizontal Storage Module (AHSM). Section 1.2 of the associated U.S. Nuclear Regulatory Commission (NRC) SER [2-5] states that the drawings contained in Section 1 of the Safety Analysis Report (SAR) contained sufficient detail to allow for a thorough evaluation. These drawings and the intended safety functions of the 24PT1 DSC and AHSM were not affected by subsequent amendments. Therefore, the drawings in Section 1 (along with the design information in Sections 2 through 14) of Revision 9 of the UFSAR [2-1] represent the approved design bases for the 24PT1 DSC and AHSM. The drawings in Section 1 of the UFSAR were used as the source of the 24PT1 DSC and AHSM subcomponents (along with their material specifications and quality classification) for the scoping evaluation.

Amendment 1 of CoC 1029 [2-6] approved the design of the 24PT4 DSC stored in the previously approved AHSM design. Section 1.2 of the associated NRC SER [2-7] states that the drawings contained in Section A.1 of the SAR contained sufficient detail to allow for a thorough evaluation of the 24PT4 DSC. These drawings and the intended safety functions of the 24PT4 DSC were not affected by subsequent amendments. Therefore, the drawings in Section A1 (along with the design information in Sections A.2 through A.14) of Revision 9 of the UFSAR [2-1] represent the approved design bases for the 24PT4 DSC. The drawings in Section A.1 of the UFSAR were used as the source of the 24PT4 DSC subcomponents (along with their material specifications) for the scoping evaluation.

Amendment 3 of CoC 1029 [2-8] approved the design of the 32PTH2 DSC stored in an AHSM-HS. Section 1.2 of the associated NRC SER [2-1] states that the drawings contained in Section B.1.5.2 of the SAR contained sufficient detail to allow for a thorough evaluation. These drawings and the intended safety functions of the 32PTH2 DSC and AHSM-HS were not affected by Amendment 4. Therefore, the drawings in Section B.1.5.2 (along with the design information in Sections B.2 through B.14) of Revision 9 of the UFSAR [2-1] represent the approved design bases for the 32PTH2 DSC and AHSM-HS. The drawings in Section B.1.5.2 of the UFSAR were used as the source of the 32PTH2 DSC and AHSM subcomponents (along with their material specifications and Quality Category) for the scoping evaluation.

Amendment 4 was submitted for NRC approval in Reference [2-12] and approved by the NRC in Reference [2-15]. The scope of Amendment 4 is limited to:

1. Revising the Technical Specifications and the UFSAR to remove any implied statements related to maintenance of a spent fuel pool after all spent fuel has been removed from the pool and loaded into the AHSM or AHSM-HS at the independent spent fuel storage system installation (ISFSI).
2. Revising the thermal monitoring program for the AHSM air vents in TS 5.2.5(c) for the 24PT1 DSC to credit the use of the installed temperature monitoring system specified in TS 5.2.5(b) in lieu of performing daily visual vent inspections (as done for the 24PT4 and 32PTH2 DSCs).
3. Adding AHSM dose rate limits for the 24PT1 and 24PT4 DSCs to TS 5.4 to provide peak dose rates on the front inlet birdscreen and the door of the concrete storage module for the AHSM.
4. For the 24PT4 DSC stored in an AHSM, updating the limit in TS 5.2.5(b) for temperature increase associated with a blocked vent accident condition based on dual thermocouple locations.

In summary, the drawings and design information in UFSAR Revision 9 [2-1] represent the approved design bases of the SSCs used for the scoping evaluation.

2.3 Results of Scoping Evaluation

The results of the scoping evaluation are summarized in Table 2-1. The following subsections provide a discussion of the scoping evaluation performed for each SSC.

2.3.1 Dry Shielded Canister

The DSC includes (but is not limited to) the DSC shell confinement boundary assembly and the internal basket assembly, shield plugs, and grapple ring. The DSCs approved for use under CoC 1029 are the 24PT1, 24PT4, and the 32PTH2 [2-14]. These DSCs are classified as ITS in Tables 2.5-1, A.2.5-1, and B.2.5-1 of the UFSAR [2-1]. Therefore, they satisfy Criterion 1 and are in-scope. The scoping evaluations of the subcomponents of the DSCs are summarized in Table 2-2 for the 24PT1, Table 2-3 for the 24PT4, and Table 2-4 for the 32PTH2.

2.3.2 Horizontal Storage Modules

The horizontal storage module (HSM) includes (but is not limited to) the HSM reinforced concrete walls, roof, and end/rear shield walls; DSC steel structure support assembly, heat shield panels, shielded door assemblies and door supports, and associated attachment/installation hardware. The HSM approved for use under CoC 1029 are the AHSM and the AHSM-HS [2-14]. These HSMs are classified as ITS in Tables 2.5-1, A.2.5-1, and B.2.5-1 of the UFSAR [2-1]. Therefore, they satisfy Criterion 1 and are in-scope. The scoping evaluations of the subcomponents of the HSMs are summarized in Table 2-5 for the AHSM and Table 2-6 for the AHSM-HS.

2.3.3 Transfer Cask

The transfer casks (TCs) approved for use with the Standardized Advanced NUHOMS® System are the OS197, OS197H, and the OS200FC (Section 1.1 of CoC 1029 TS, [2-16]. The TCs are certified under CoC 1004 and are not considered part of the Standardized Advanced NUHOMS® System subject to renewal. Therefore, these TCs are within the scope of the license renewal for CoC 1004 [2-10], as approved by the NRC in the SER [2-13] for CoC 1004 renewal. The AMR of the TCs in Reference [2-10] encompassed the materials and environments applicable to or bounding those associated with the Standardized Advanced NUHOMS® System. Therefore, the TCs are not within the scope of the renewal of CoC 1029.

2.3.4 Transfer Cask Lifting Yoke

The lifting yoke used for handling the TC within the fuel/reactor building is designed and procured as a “safety-related” component (Tables 2.5-1, A.2.5-1, and B.2.5-1 of the UFSAR [2-1]) as it is used by the general licensee under their 10 CFR Part 50 program. Due to site unique requirements, rigid or sling lifting members may be used to augment the lifting yoke. These members shall be designed, fabricated, and tested in accordance with the same requirements as those for the cask lifting yoke.

Part 1(b) of CoC 1029 [2-14] states; "With the exception of the TC, fuel transfer and auxiliary equipment necessary for ISFSI operations are not included as part of the Standardized Advanced NUHOMS® System referenced in this certificate of compliance (CoC). Such site-specific equipment may include, but is not limited to, special lifting devices, the transfer trailer, and the skid positioning system." Therefore, the TC Lifting Yoke is not within the scope of the CoC 1029 license renewal.

2.3.5 Spent Fuel Assemblies

The subcomponents of the spent fuel assemblies have intended safety functions required to maintain the conditions required by regulations to store the spent fuel safely. Therefore, the spent fuel assemblies satisfy Criterion 1 and are in-scope. The scoping evaluations of the subcomponents of the spent fuel assemblies are summarized in Table 2-7.

2.3.6 ISFSI Basemat

The basemat (also referred to as storage pad) is classified as a NITS structure (Tables 2.5-1, A.2.5-1, and B.2.5-1 of the UFSAR [2-1]) designed and constructed to plant-specific site conditions, and is not part of CoC 1029 certification. However, failure of the basemat could prevent fulfillment of a function that is ITS (e.g., retrievability). Therefore, the basemat is within the scope of the CoC 1029 license renewal.

2.3.7 ISFSI Approach Slab

The approach slab is a NITS, reinforced concrete structure, designed and constructed to plant-specific site conditions. The approach slab provides access to the HSM and supports the DSC transfer system. It does not provide a safety function, and its failure would not prevent fulfillment of a safety function of the HSM loaded with a DSC. Therefore, the approach slabs are not within the scope of the CoC 1029 license renewal.

2.3.8 Other Transfer Equipment

Other fuel transfer equipment necessary for ISFSI operations include the transfer trailer, skid positioning system, hydraulic ram system, ram support assembly, and the cask support skid.

Part 1(b) of CoC 1029 [2-14] states; "With the exception of the TC, fuel transfer and auxiliary equipment necessary for ISFSI operations are not included as part of the Standardized Advanced NUHOMS® System referenced in this certificate of compliance (CoC). Such site-specific equipment may include, but is not limited to, special lifting devices, the transfer trailer, and the skid positioning system." This equipment is classified as NITS (Tables 2.5-1, A.2.5-1, and B.2.5-1 of the UFSAR [2-1] and its failure would not prevent the fulfillment of a function that is ITS. Therefore, this equipment is not within the scope of the CoC 1029 license renewal.

2.3.9 Auxiliary Equipment

Auxiliary equipment used to facilitate canister loading, draining, drying, inerting, and sealing operations include, but are not limited to, the vacuum drying system, automatic welding equipment, cask/canister annulus seal.

Part 1(b) of CoC 1029 [2-14] states; “With the exception of the TC, fuel transfer and auxiliary equipment necessary for ISFSI operations are not included as part of the Standardized Advanced NUHOMS® System referenced in this CoC. Such site-specific equipment may include, but is not limited to, special lifting devices, the transfer trailer, and the skid positioning system.” This equipment is classified as NITS (Tables 2.5-1, A.2.5-1, and B.2.5-1 of the UFSAR [2-1]), and its failure would not prevent the fulfillment of a function that is ITS. Therefore, this equipment is not within the scope of the CoC 1029 license renewal.

2.3.10 Miscellaneous Equipment

Miscellaneous ISFSI equipment (e.g., ISFSI security fences and gates, lighting, lightning protection, communications, and monitoring equipment) are not part of the CoC 1029 storage system approved in accordance with 10 CFR Part 72, Subpart L. They are not classified as ITS, nor would their failure prevent the fulfillment of a function that is ITS. Therefore, they are not within the scope of the CoC 1029 license renewal.

2.4 References

2-1 TN Americas LLC, ANUH-01.0150, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal ModularStorage System for Irradiated Nuclear Fuel," Revision 9, March 2019.

2-2 NUREG-1927, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance," Revision 1, U.S. Nuclear Regulatory Commission, June 2016.

2-3 Letter from Eric Benner (NRC) to Donis Shaw (Transnuclear), "Receipt of Withdrawal Request for Amendment 2 to the Standardized Advanced NUHOMS® System (TAC No. L24056)," dated June 26, 2008 (ADAMS Accession Number ML081790672).

2-4 U.S. Nuclear Regulatory Commission, "Certificate of Compliance for Spent Fuel Storage Casks, Certificate No. 1029," Amendment 0, Effective Date February 5, 2003, Docket No. 72-1029 (ADAMS Accession Number ML030100440).

2-5 U.S. Nuclear Regulatory Commission, Safety Evaluation Report for Transnuclear Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Amendment 0 (ADAMS Accession Number ML030100459).

2-6 U.S. Nuclear Regulatory Commission, Certificate of Compliance for Spent Fuel Storage Casks, Certificate No. 1029, Amendment 1, Effective Date May 16, 2005, Docket No. 72-1029 (ADAMS Accession Number ML051520118).

2-7 U.S. Nuclear Regulatory Commission, SER for Amendment 1, Safety Evaluation Report, Docket No. 72-1029, Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Certificate of Compliance No. 1029, Amendment No. 1, (ADAMS Accession Number ML051520145).

2-8 U.S. Nuclear Regulatory Commission, "Certificate of Compliance for Spent Fuel Storage Casks, Certificate No. 1029," Amendment 3, Effective Date February 23, 2015, Docket No. 72-1029 (ADAMS Accession Number ML15054A469).

2-9 Final Safety Evaluation Report, Transnuclear, Inc. Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Docket No. 72-1029, Amendment 3 (ADAMS Accession Number ML15054A499).

2-10 Letter E-46190 from Jayant Bondre (AREVA Inc.) to Document Control Desk (NRC), "Response to Re-Issue of Second Request for Additional Information – AREVA Inc. Renewal application for Standardized NUHOMS® System – CoC 1004 (Docket No. 72-1004, CAC No. L24964)," September 29, 2016 (ADAMS Accession Number ML16279A367).

2-11 NRC, Division of Spent Fuel Management, Interim Staff Guidance 2, "Fuel Retrievability in Spent Fuel Storage Applications," Revision 2, April 26, 2016.

2-12 Letter from Jayant Bondre (TN Americas) to Document Controk Desk (NRC), E-49353, "Application for Amendment 4 to Standardized Advanced NUHOMS® Certificate of Compliance No. 1029 for Spent Fuel Storage Casks, Revision 0 (Docket No. 72-1029)," dated November 15, 2017 (ADAMS Accession Number ML17326A130).

2-13 Safety Evaluation Report for the Standardized NUHOMS® System Certificate of Compliance No. 1004 Renewal, Docket No. 72-1004, May 2017 (ADAMS Accession Number ML17338A121).

2-14 U.S. Nuclear Regulatory Commission, "Certificate of Compliance for Spent Fuel Storage Casks, Certificate No. 1029," Amendment 4, Effective Date March 12, 2019, Docket No. 72-1029 (ADAMS Accession Number ML19036A559).

2-15 Letter from John McKirgan (U.S. Nuclear Regulatory Commission) to Prakash Narayanan (TN), "Amendment No. 4 to Certificate of Compliance No. 1029 for the Standardized Advanced NUHOMS® System," dated February 5, 2019 (ADAMS Accession Number ML19036A560).

2-16 CoC 1029, Appendix A, "Technical Specifications for the Standardized Advanced NUHOMS System Operation Controls and Limits," Amendment 4, March 12, 2019, Docket No. 72-1029.

Table 2-1
Scoping Evaluation of Standardized Advanced NUHOMS® System SSCs

SSC	Intended Safety Function						Criterion		In-Scope
	Confinement	Radiation Shielding	Sub-Criticality Control	Structural Integrity	Heat-Removal Capability	Retrievability	No. 1	No. 2	
Dry Shielded Canister (DSC)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	Yes
HSM	No	Yes	No	Yes	Yes	Yes	Yes	N/A	Yes
TC (2)	No	Yes	No	Yes	Yes	Yes	—	—	No
TC Lifting Yoke	No	No	No	No	No	No	No	No	No
Spent Fuel Assemblies	Yes	No	Yes	Yes	Yes	No	Yes	N/A	Yes
ISFSI Basemat	No	No	No	Note 1	No	Note 1	No	Yes	Yes
ISFSI Approach Slab	No	No	No	No	No	No	No	No	No
Other Transfer Equipment	No	No	No	No	No	No	No	No	No
Auxiliary Equipment	No	No	No	No	No	No	No	No	No
Miscellaneous Equipment	No	No	No	No	No	No	No	No	No

Notes:

1. Failure of this SSC item could prevent fulfillment of this intended safety function.
2. TC license renewed under CoC 1004.

Proprietary Information on Pages 2-11 through 2-28
Withheld Pursuant to 10 CFR 2.390

Table 2-7
Scoping Evaluation For Spent Fuel Assemblies
(2 Pages)

Subcomponent	Material of Construction	Intended Safety Function: Confinement	Radiation Shielding	Sub-Criticality Control	Structural Integrity	Heat-Removal Capability	Retrievability	Criterion No. 1	Criterion No. 2
Fuel Pellets	Uranium oxide	No	No	No	No	No	No	No	No
	Uranium oxide and Plutonium oxide								
Fuel Cladding and End Plugs [(1) (2)]	Type 304 Stainless Steel	Yes	No	Yes	Yes	Yes	No	Yes	N/A
	Zirconium-Based Alloy [(1)]								
Spacer Grid Assemblies	Inconel 718	No	No	Yes	Yes	No	No	Yes	N/A
	Zirconium-Based Alloy [(1)]								
	Inconel 625								
Upper End Fitting/Nozzle (and related subcomponents)	Type 304 SS	No	No	No	Yes	No	No	Yes	N/A
	Inconel 718								
Lower End Fitting/Nozzle (and related subcomponents)	Type 304 SS	No	No	No	Yes	No	No	Yes	N/A
Guide Tubes	Zirconium-Based Alloy [(1)]	No	No	No	Yes	No	No	Yes	N/A
Reconstituted Fuel Rods	Stainless Steel	No	No	Yes	No	No	No	Yes	N/A
Hold-Down Spring	Inconel X-750	No	No	No	No	No	No	No	No

Table 2-7
Scoping Evaluation For Spent Fuel Assemblies
(2 Pages)

Subcomponent	Material of Construction	Intended Safety Function						Criterion	
		Confinement	Radiation Shielding	Sub-Criticality Control	Structural Integrity	Heat-Removal Capability	Retrievability	No. 1	No. 2
Control Components [3]	Type 304 SS Inconel X-750 Ag-In-Cd	No	No	No	No	No	No	No	*No*
Poison Rod Assemblies (24PT4 DSC Only)	B_4C Stainless Steel	No	No	Yes	No	No	No	Yes	N/A

Notes:

1. Zirconium alloy claddings including, Zircaloy-4, OPTIN™, M5™, or Zirlo™.
2. The cladding of failed fuel assemblies is not able to provide any intended safety function and is, therefore, not considered in scope for renewal.
3. Authorized control components include burnable poison rod assemblies (BPRAs), control rod assemblies (CRAs), thimble plug assemblies (TPAs), axial power shaping Rod assemblies (APSRAs), control element assemblies (CEAs), vibration suppression inserts (VSIs), orifice rod assemblies (ORAs), neutron source assemblies (NSAs), and neutron sources.

All changes on this page are as a result of RSI 2-2

CHAPTER 3
AGING MANAGEMENT REVIEW

CONTENTS

LIST OF TABLES

3.1 Introduction

This chapter describes the aging management review (AMR) of the Certificate of Compliance (CoC) No. 1029 Standardized Advanced NUHOMS® dry storage system (i.e., the Dry Shielded Canisters (DSCs) 24PT1, 24PT4, and the 32PTH2 designs, along with the Advanced Horizontal Storage Modules (AHSM) and the high seismic version of these modules (AHSM-HS). Unless otherwise noted, the term DSC applies to the 24PT1, 24PT4, and 32PTH2 DSC types. Similarly, unless otherwise noted, the term HSM applies to the AHSM and AHSM-HS designs. The purpose of the AMR is to assess the need for aging management activities (AMA) for the structures, systems, and components (SSCs) determined to be within the scope of the CoC 1029 renewal. The AMR addresses aging mechanisms and effects that could adversely affect the ability of the SSCs to perform their intended safety functions during the period of extended operation (PEO).

Section 3.2 describes the AMR methodology, which follows the guidance and the processes of NUREG-1927 [3-1]. This section addresses each of the major steps of the AMR: Section 3.2.1 – Identification of Materials and Environments; Section 3.2.2 – Identification of Aging Mechanisms and Aging Effects, and Section 3.2.3 – Identification of the Activities Required to Manage the Effects of Aging.

Section 3.3 – Description of Standardized Advanced NUHOMS® System, provides a brief description of the in-scope CoC 1029 SSCs.

Section 3.4 – Design and Fabrication Considerations, briefly discusses the fabrication aspects of the in-scope SSCs that are most relevant to the AMR.

Section 3.5 – Aging Management Review of Material/Environment, lists the materials of construction and the environments for the in-scope SSCs. The section goes on to evaluate the known aging degradation mechanisms/effects based on the material/environment combination. For each mechanism, a determination is made of whether the mechanism is considered “credible” in each environment that the material is exposed to during the PEO.

Sections 3.6, 3.7, 3.8, and 3.9 provide the AMR results of the DSC, HSM, Basemat, and spent fuel assemblies (SFAs), respectively.

Section 3.10 provides a summary of the conclusions of the operating experience (OE) review contained in Appendix 3C.

Appendix 3A, Time-Limited Aging Analyses, identifies the calculations or analyses used to demonstrate that in-scope SSCs will maintain their intended safety function throughout an explicitly stated period of operation, i.e., TLAAs.

Appendix 3B, Supplemental Evaluations, provides a summary of supplemental evaluations and calculations performed to support the AMR and/or an element in an AMP.

Appendix 3C, Operating Experience Review, provides a summary of the operating experience review performed to support the AMR and AMPs.

3.2 Aging Management Review Methodology

The AMR follows the methodology recommended in NUREG-1927 [3-1]. The AMR provides an assessment of the aging effects that could adversely affect the ability of the SSCs to perform their intended safety functions during the PEO.

The AMR process involves the following major steps:

- Identification of materials and environments
- Identification of aging effects and mechanisms requiring management
- Determination of the activities required to manage the effects and mechanisms of aging; this involves the identification of time-limited aging analyses (TLAAs) or aging management programs (AMPs) for managing the effects of aging.

The scoping and screening evaluation in Chapter 2 identifies the in-scope SSCs for which potential aging effects must be identified and evaluated. For each SSC, the material of construction and the environment to which each SSC is exposed are determined. The component environments are determined based on the location of the component within the storage system. The draft report for comment, NUREG-2214 [3-2] (NUREG-2214 Rev. 0 is based on technical literature, related research and industry information, and existing OE), was reviewed to identify potential aging degradation mechanisms for different material/environment combinations. After the potential aging mechanisms and effects are identified, it is determined whether the effects can be managed via a TLAA or will require an AMP.

3.2.1 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 SSCs and the environments to which those materials are exposed during normal storage conditions. The combinations of materials and environments are used to identify the potential aging effects that require management during the PEO.

Materials

The Standardized Advanced NUHOMS® System SSCs and associated subcomponent materials of construction are summarized in:

- Table 3-11 – Aging Management Review for 24PT1 DSC
- Table 3-12 – Aging Management Review for 24PT4 DSC
- Table 3-13 – Aging Management Review for 32PTH2 DSC
- Table 3-14 – Aging Management Review for AHSM
- Table 3-15 – Aging Management Review for AHSM-HS
- Table 3-16 – Aging Management Review for Basemat

- Table 3-17 – Aging Management Review for Spent Fuel Assemblies

The materials of construction were identified through a review of the drawings provided in the UFSAR, along with other pertinent design information.

Environments

The environments to which SSCs and associated subcomponents are exposed play a critical role in the determination of potential aging mechanisms and effects. A review of the information presented in Chapter 2 of the Updated Final Safety Analysis Report (UFSAR) [3-3] was performed to assess the environmental conditions to which the SSCs are normally exposed. The configuration of a Standardized Advanced NUHOMS® System at an independent spent fuel storage installation (ISFSI) consisting of an array of individual HSM storage modules provides an effective means of protection against extreme seasonal weather conditions as described in Reference [3-3].

The Standardized Advanced NUHOMS® System has been designed and qualified for a wide range of environmental conditions. The Standardized Advanced NUHOMS® System components have been evaluated for a bounding seasonal normal ambient operating temperature range of 0 °F to 104 °F, and an off-normal range of -40 °F to 117 °F with concurrent extreme insolation.

The environments to which the Standardized Advanced NUHOMS® System is exposed are affected by the characteristics of the ISFSI site environment, as well as by the component location within the storage system. Seven basic environments apply for the Standardized Advanced NUHOMS® System SSCs and subcomponents:

- Air-Outdoor – In this environment, components are directly exposed to weather, including precipitation and wind (possibly salt laden). During storage, the exterior surfaces of the HSMs are exposed to all outdoor weather conditions including insolation, wind, rain, snow, and plant-specific ambient air conditions including moist, possibly salt-laden atmospheric air, ambient temperatures, and humidity.
- Embedded-in-Concrete – In this environment, one or more surfaces of a component are in contact with concrete. This may prevent ingress of water and contaminants to the embedded surface, depending on the permeability of the embedding environment. These include rebar and anchorage embedded in the HSM concrete.
- Embedded-in-Metal – In this environment, one or more surfaces of a component are in contact with another component or material. This may prevent ingress of water and contaminants to the embedded surface, depending on the permeability of the embedding environment. However, for the purposes of this AMR, the materials in this environment are treated as though they are exposed to the surrounding environment. For example, the surfaces of the BORAL® poison plate

are in contact with the guide sleeves and the oversleeves, but are treated as though they are exposed to the helium environment.

- Fully Encased – In this environment, the component is fully enclosed inside another component, or the surface between two components is sealed or fully lined by another material (e.g., steel), which prevents ingress of water and contaminants. An example is the DSC bottom shield plug encased between the inner and outer cover plates.
- Helium – In this environment, the component surface is exposed to the helium fill gas inside the canister and trace quantities of other gases, such as nitrogen, oxygen, argon, and fission product gases. This environment applies to the fuel assemblies and other components inside the DSC.
- Groundwater/Soil – In this environment, the component surface is exposed to a soil environment; i.e., below-grade. Groundwater is subsurface water found in wells, tunnels, or drainage galleries, or water that flows naturally to the earth's surface via seeps or springs. Soil is a mixture of organic and inorganic materials produced by the weathering of rock and clay minerals or the decomposition of vegetation. Below-grade concrete structures are assumed to be partially exposed to a groundwater or soil environment.
- Sheltered – In this environment, the surfaces are within the confines of a shielding structure. The sheltered environment may be open to outdoor air, but it is shielded from direct exposure to precipitation. This environment may contain moisture, salts, and other contaminants from the outdoor air. Examples include the external surface of the DSC and support structures within the HSM.

The environments considered in the AMR are the environments that the Standardized Advanced NUHOMS® System SSCs and associated subcomponents normally experience. Environmental stressors that are conditions not normally experienced (such as extreme cold), or that may be caused by a design or fabrication condition, are considered event-driven and are not aging-related. Such event-driven situations are evaluated and corrective actions, if any, implemented at the time of the event.

3.2.2 Identification of Aging Mechanisms and Aging Effects

After the component material/environment combinations are identified, potential aging mechanisms are determined. NUREG-2214 [3-2] is reviewed to identify potential aging degradation mechanisms for different materials and environments.

Aging effects are the manifestation of aging mechanisms. In order to effectively manage an aging effect, it is necessary to determine the aging mechanisms that are potentially at work for a given material and environment combination. Therefore, the AMR process identifies both the aging effects and the associated aging mechanisms that cause them. Some aging mechanisms are only applicable at certain conditions such as high temperature or moisture. Each identified aging mechanism is characterized by a set of applicable conditions that must be met for the mechanism to occur. Given this evaluation process, each subcomponent that is subjected to AMR is evaluated to determine if the potential aging mechanisms and effects are credible considering the various material/environment combinations.

3.2.3 Identification of the Activities Required to Manage the Effects of Aging

For each subcomponent with a credible aging mechanism and effect, a determination is made to ascertain whether the effect can be managed via a TLAA or if an AMP is necessary.

TLAAs are calculations or analyses used to demonstrate that an in-scope SSC will maintain its intended safety function throughout the PEO. TLAAs have a time-dependent operating life such as fatigue life (cycles), change in a mechanical property such as fracture toughness or strength of materials due to irradiation. The TLAAs associated with CoC 1029 are identified in Appendix 3A.

AMPs are developed for managing the effects of aging. As appropriate, an AMP is created to summarize the activities to monitor and manage the aging effects. The AMPs credited for managing the effects of aging degradation are presented in Chapter 4.

3.3 Description of Standardized Advanced NUHOMS® System

Chapter 2 lists the following in-scope SSCs for the Standardized Advanced NUHOMS® System.

- Dry Shielded Canisters
- Horizontal Storage Module
- Spent Fuel Assemblies
- ISFSI Basemat

3.3.1 Description of DSC Subcomponents

All the DSC types consist of two main subcomponents: (1) the DSC shell assembly, and (2) the internal basket assembly. DSC descriptions are generic and apply to all DSC types, except when specifically noted.

DSC Shell Assembly

The DSC shell assembly is a high-integrity, welded pressure vessel that consists of a cylindrical shell and the top and bottom end assemblies. The cylindrical shell is made of stainless steel (SA-240 Type 316). The top and bottom end assemblies include a shield plug and inner and outer cover plates. The shield plugs are made of steel or cast lead encased between steel plates.

The main component of construction of each DSC is a stainless steel cylindrical shell. The DSC cylindrical shell serves as a portion of the confinement boundary and consists of a rolled and welded plate. The DSC cylindrical shell is constructed using two pieces of rolled plate, with either two full-length longitudinal seams, or two half-length longitudinal welds and a circumferential weld. These welds are full penetration, American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code Subsection NB compliant welds.

The top end assembly consists of the top shield plug and the inner and outer cover plates.

The top shield plug for the 24PT1 and 32PTH2 DSCs is a stand-alone steel component made of A36 carbon steel plate. The top shield plug for the 24PT4 DSC is cast lead encased by stainless steel. The top shield plug is placed into the DSC after the SFAs are loaded and before the DSC is removed from the spent fuel pool. It is supported by a support ring, which is welded to the interior circumference of the DSC shell. The inner top cover plate is placed over the top shield plug and is welded to the shell to form the inner seal. In the 24PT4 design, the top shield plug and inner cover plate are integrated as a stainless steel shell encasing lead and welded to the DSC shell to form the confinement boundary. In these DSCs, there is no separate inner top cover plate.

The outer top cover plate is placed on top of the inner top cover plate, or the integrated top shield plug and inner top cover assembly, after the drying and helium backfill operations are complete. The outer top cover plate is then welded to the DSC shell to form the redundant seal required by Code of Federal Regulations (CFR) 10 CFR 72.236(e). The top cover plate is a stainless steel plate.

The top end assembly includes a stainless steel siphon and vent block with two penetrations into the canister cavity. Swagelok® quick-connect fittings are installed in recesses at the top of the block. The vent penetration opens to the DSC interior just below the top shield plug. The siphon penetration incorporates a tube that continues to the bottom of the DSC interior cavity. Stainless steel plates are welded over the siphon and vent port recesses prior to installation of the outer top cover plate.

The bottom end assembly consists of the inner bottom cover plate, the bottom shield plug, and the outer bottom cover plate. The design of the bottom end assembly allows for different configurations: in one configuration, the inner bottom cover plate is completely inside the shell, while in other configurations, a portion of the inner bottom cover plate is part of the DSC external surface.

The bottom shield plug is placed into the bottom end of the DSC during fabrication. It can be steel or cast lead encased between steel plates.

The bottom end assembly includes a stainless steel grapple ring that is used for extraction of the DSC from the HSM.

<u>DSC Basket Assembly</u>

The 24PT1 and 24PT4 DSCs use the spacer disc basket design. In this design, structural support for the SFAs in the lateral direction is provided by guide sleeves supported by circular spacer disc plates. Axial support of the basket assembly is provided by support rods, which are preloaded to maintain each spacer disc in place using spacer sleeves between the spacer discs. The support rods extend over the full length of the DSC cavity with allowance provided for thermal growth of the support rods in the axial direction. Subcriticality is maintained through the geometric separation of the SFAs and the fixed borated neutron absorbing material, BORAL®.

The 32PTH2 DSC basket structure consists of stainless steel fuel compartments with aluminum and neutron absorber plates sandwiched in the space between adjacent compartments. The metal matrix composite (MMC) absorber plates provide the necessary criticality control along with the geometric separation of the SFAs. The aluminum plates, together with the neutron absorber plates, provide a heat conduction path from the fuel assemblies to the DSC shell. The fuel compartments are welded together at selected elevations along the axial length of the basket through stainless steel support plates, which separate the aluminum and poison plates arranged in an egg crate configuration. The transition rails, made from aluminum Type 6061, provide the transition between the “rectangular” basket structure and the cylindrical DSC shell. The transition rails support the fuel compartments and transfer mechanical loads to the DSC shell. They also provide the thermal conduction path from the basket assembly to the canister shell wall.

3.3.2 Description of HSM Subcomponents

CoC 1029 includes two HSM models (types), the AHSM and the AHSM-HS. The AHSM is licensed for storage of a loaded 24PT1 DSC or 24PT4 DSC. The AHSM-HS is licensed for storage of a loaded 32PTH2 DSC.

The HSM is a prefabricated, modular, freestanding reinforced concrete structure whose primary functions are to provide a means for spent fuel decay heat removal, structural support and environmental protection for the loaded DSC, and radiation shielding protection.

At the ISFSI, the HSMs may be installed in a single row array of side-by-side modules, with additional shield walls at the ends of the array and rear shield walls at the back of each HSM. They may also be installed in a double row array (i.e., back-to-back array), which eliminates the need for the rear shield walls.

The HSM consists of two separate units: a base storage unit, where the DSC is stored, and a top shield block that serves to provide environmental protection and radiation shielding. The top shield block is attached to the base unit by vertical ties and by interlocking concrete keys in the horizontal directions. Similarly, adjacent HSMs are connected to each other with module-to-module ties located at the top and bottom of the HSMs.

The DSC is supported inside the HSM base storage unit on two stainless steel rails. The rail assembly spans between the front block and the rear wall of the base storage unit and acts as a sliding surface during DSC insertion and retrieval.

For thermal protection of the HSM concrete, a thin stainless steel heat shield is installed on the inside of the storage unit. The heat shield guides cooling airflow through the HSM. The HSM shield door is a combination rectangular/circular concrete block located in the front face circular opening of the base unit.

In an AHSM, the air inlet vent extends through the front block of the base unit. The base unit also provides the air inlet shielding. The air outlet vent is formed in the rear of the top shield block.

In an AHSM-HS, the air inlet vents are located in the front face at the bottom of the side walls of the base unit. The air outlet vents are formed along the sides of the roof. A roof vent shield cap above the outlet vent provides additional shielding.

A general description of the HSM subcomponents follows. These descriptions are generic (except when noted) and applicable to both HSM types:

Concrete Walls and Roof

The HSM is a reinforced concrete structure consisting of a base unit and a roof unit. The base unit, which resists loads by frame and shear wall action, and the roof, which is keyed to and connected to the base unit, form the load-resisting structural system. The roofs of the AHSMs are attached to the base by threaded rods through holes in the roof. The AHSM-HS roof is attached to the base by internal bracket assemblies.

DSC Support Structure Assembly

Structural support of the loaded DSC is provided by a DSC support structure assembly composed of two longitudinal support beams that extend approximately the full length of the HSM module supported on the front and rear walls.

Stainless steel rail faces (Nitronic® 60) are welded to the longitudinal support beams to provide a sliding surface for the DSC. The sliding surface of the DSC support rails is coated with a dry film graphite lubricant.

Heat Shields

Stainless steel sheets are provided between the DSC and the HSM concrete to mitigate high concrete temperatures and prevent concrete degradation due to design basis thermal conditions. The heat shields are anchored to the HSM ceiling and interior walls. The heat shields are mounted to the ceiling and interior walls with stand-off embedment anchors.

HSM Door

Each HSM has an access opening in the front wall to accommodate transfer of DSCs from and into a transfer cask. A thick shielded access door covers the access opening.

DSC Axial Retainer

Axial retainers restrict axial sliding of the DSC during seismic events. After insertion of the DSC into the HSM, the retainer is adjusted by a setscrew to minimize the gap between the retainer and the DSC.

Anchorage and Embedments

Anchorages/embedments are the steel members, studs, etc., that are embedded-in-concrete. These anchors also have an exposed surface above the concrete.

3.3.3 Description of Basemat Subcomponents

The basemat is a 3-foot thick (minimum) reinforced concrete structure designed and constructed in accordance with codes and standards set by the general licensee. It is subject to site-specific foundation analyses and design considerations, including licensee-specific HSM loading configurations.

3.3.4 Description of Spent Fuel Assemblies Subcomponents

The Standardized Advanced NUHOMS® System is designed to store Westinghouse 14x14 (WE 14x14) (including Mixed Oxide (MOX) fuel) and Westinghouse-CENP, AREVA 16x16 (CE 16x16) Pressurized Water Reactor (PWR) fuel assemblies. A general description of SFA subcomponents is as follows:

Fuel Cladding and End Plugs

The fuel rods consist of enriched UO_2 or MOX pellets inserted into the cladding tubes. End plugs are seal welded to each end. The cladding and end plugs confine the fuel pellets and fission gases. Each rod is pressurized with helium during fabrication.

Guide Tubes

The guide tubes of PWR fuel assemblies are mechanically attached and secured to the top and bottom nozzles. They provide the structural support for the fuel assembly.

Spacer Grid Assemblies

The grid assemblies provide support for the fuel rods, positioning them in a square array and maintaining the designed rod pitch.

Lower Nozzle (and related subcomponents)

The lower nozzle functions as the bottom structural element of a fuel assembly.

Upper Nozzle (and related subcomponents)

The upper nozzle functions as the top structural element of a fuel assembly. It also interfaces with the fuel assembly grapple as the lifting point for the fuel assembly.

3.4 Design and Fabrication Considerations

3.4.1 DSC Design and Fabrication Considerations

This section focuses on the fabrication aspects of the DSC that are most relevant to the AMR of the DSCs, more specifically, the DSC shell assembly.

The DSC shell assembly is designed and fabricated in accordance with the provisions of the ASME B&PV Code, Section III, Division 1, Subsection NB, with certain code alternatives for each DSC type as described in the UFSAR [3-3].

The DSC shell assembly is a high-integrity welded pressure vessel that consists of a cylindrical shell and the top and bottom end assemblies. The DSC cylindrical shell and the top and bottom inner cover plate assemblies form the pressure-retaining confinement boundary for the spent fuel. The redundant confinement boundary weld is provided by the outer top cover plate welded to the shell. The bottom end assembly confinement boundary welds are made during fabrication of the DSC. The top end assembly confinement boundary welds are made after fuel loading.

The DSC cylindrical shell consists of a rolled and welded plate. The DSC cylindrical shell is constructed from two pieces of rolled plate with either two full-length longitudinal seams or two half-length longitudinal welds and a circumferential weld. These welds are full penetration, ASME B&PV Code Subsection NB compliant welds. The design of the bottom end assembly allows for different configurations: in one configuration, the inner bottom cover plate is completely inside the shell, while in other configurations, a portion of the inner bottom cover plate is part of the DSC external surface.

3.4.2 HSM Design and Fabrication Considerations

This section focuses on those fabrication aspects relevant to the AMR of the HSM. Unless otherwise noted, the discussion applies to the AHSM and AHSM-HS types in this application.

The AHSMs are designed in accordance with the rules of the American Concrete Institute (ACI) ACI-349-97 Code [3-5] and constructed in accordance with the ACI-318-89 Code [3-6]. The AHSM-HSs are designed in accordance with the rules of the ACI-349-06 Code [3-7] and constructed in accordance with the ACI-318-08 Code [3-8].

The HSM is a reinforced concrete structure consisting of two separate units: a base storage unit, where the DSC is stored, and a roof that serves to provide environmental protection and radiation shielding. Three-foot thick shield walls are installed behind each HSM (single-row array only) and at the ends of each row to provide additional shielding. The HSMs are tied together and placed next to, and in contact with, adjacent module(s) to form continuous single or double-row arrays. The roof is tied to the base storage unit in the vertical direction and by interlocking concrete keys in the horizontal directions. Similarly, adjacent AHSMs are connected to each other with module-to-module ties located at the top and bottom of the AHSMs. The top ties are integrated into the roof unit and consist of reinforced concrete tie "beams" with the rebar between adjacent modules mechanically connected. The bottom ties consist of steel rods connecting adjacent base storage units. The top and bottom ties are designed to carry tensile loads to prevent module-to-module separation. A system of horizontal and vertical keys, located between adjacent modules, restrains relative horizontal (front-to-back) and vertical (rocking) movement between AHSMs.

The HSMs are installed on a load-bearing foundation, which consists of a cast-in-place 3-foot thick (minimum) reinforced concrete pad (also referred to as the basemat) on a subgrade suitably engineered to support the loads. There are no structural connections or means to transfer shear between the HSM base unit module and the basemat. The concrete pad is classified as not important-to-safety (NITS). However, the licensee must evaluate the foundation in accordance with 10 CFR 72.212(b)(5)(ii). The concrete basemat is designed and constructed in accordance with codes and standards set by the general licensee as it is subject to site-specific design considerations and licensee-specific HSM loading configurations.

3.4.3 Temporary Attachment Evaluation

DSC fabrication is in accordance with ASME B&PV Code, Section III, Division I, Subsection NB. Welding of any temporary attachments and their removal is per NB-4435, which requires examination of the base metal by liquid penetrant or magnetic particle method in accordance with NB-5110 after the temporary attachment is removed. The acceptance criteria of NB-5340 or NB-5350, whichever is applicable, ensure that the restored surface is free of any relevant indications.

The initial welding of the temporary attachment and high local surface temperatures that can occur during removal of the temporary attachments via grinding may lead to thermal sensitization of the material and residual stresses. Although the local temperature can be above the sensitization range at the location of the weld, the heat-affected zone (HAZ) is limited to approximately a 0.125-inch depth, which is much less than the seam welds that extend through the thickness. Thus, when the seam welds are determined to be acceptable, the suitability of all temporary attachments also is demonstrated.

Regarding the effects of grinding as compared to welding, the relatively low peak heat input limits the opportunity for carbide precipitation to occur. The depth of the grinding HAZ, generally less than 0.03 inch [3-14], is substantially less than the temporary attachment weld and small relative to the thickness of the DSC shell (0.625 inch). The tensile stress field required to promote stress corrosion cracking (SCC) would result from the heat of welding and/or grinding, causing brief local compressive yielding of the substrate at and immediately beneath the component's surface, which would revert to tensile stress once the material returns to ambient temperature. These tensile stresses would be confined to a very narrow near-surface region of the DSC shell thickness. Even considering that crack initiation could occur, any local cracking would be arrested at a very shallow depth.

There is a low risk that SCC of significant depth will occur at these temporary locations because:

1. The welding and removal of temporary attachments is performed per the provisions of the ASME B&PV Code (which includes examinations to demonstrate no relevant indications are present on the shell surface), and
2. Such cracking (if it did occur), would not propagate to sufficient depth to compromise the performance of the confinement boundary.

Furthermore, ASME B&PV Code, Section XI, excludes temporary attachments from periodic inspection, as specified in Table IWE-2500-1. Therefore, it is not necessary to search for temporary attachment locations specifically for inspection.

3.5 Aging Management Review of Material/Environment

3.5.1 Materials Evaluated

The materials of construction for the Standardized Advanced NUHOMS® System subcomponents, along with a material grouping, are listed in Table 3-11 through Table 3-17. The material groups represent a collection of individual material specifications that are susceptible to similar aging mechanisms/effects and may thus be evaluated collectively. Table 3-2 provides a summary of the material groups.

3.5.2 Environments for the Standardized Advanced NUHOMS® System SSCs

The environments to which the Standardized Advanced NUHOMS® System subcomponents are exposed are listed in Table 3-11 through Table 3-17. These environments are those that are normally (continuously) experienced by the subcomponents while in storage, and are described below. Note that some of the subcomponents are exposed to two or more environments. In Table 3-11 through Table 3-17, the symbol (I) denotes environments seen by surfaces that are internal to the subcomponent, or surfaces that face towards the interior of the DSC or HSM. The symbol (E) denotes environments seen by surfaces that are external to the subcomponent, or surfaces that face towards the exterior of the DSC or HSM.

Internal to the DSC

Most of the internal subcomponents of the DSC are exposed to the inert gas (i.e., helium) environment inside the DSC cavity. The surfaces of some subcomponents are in contact with the surface of another subcomponent or material (i.e., an embedded-in-metal environment); e.g., the BORAL® poison plate's surfaces and the guide sleeves. However, for the purposes of this AMR, if the space is not sealed, it is treated as though it is exposed to the helium environment. There are also other components that are in a fully encased environment. The maximum fuel cladding temperatures during storage are summarized in Table 3-3. The bounding normal and off-normal average helium temperature in the DSC cavity for each DSC type is shown in Table 3-4 along with the off-normal design pressure. This helium gas temperature decreases from the beginning of storage through the PEO.

The DSC internal components are exposed to significant neutron and gamma radiation.

External to the DSC

Each DSC is positioned for long-term storage inside an HSM. As such, the external surfaces of the DSC (shell, top and bottom outer cover plates, grapple assembly, and associated welds) are exposed to the HSM interior (i.e., sheltered) environment. This is a protected environment with no direct exposure to sun, wind, or precipitation. The internal HSM environment may contain moisture and salts or other contaminants from the external ambient air. The maximum initial DSC shell assembly temperatures for normal and off-normal conditions of storage are summarized in Table 3-3. These surface temperatures continuously decrease from the beginning of storage through the PEO.

Internal to the HSM

Each DSC is positioned for long-term storage inside an HSM. As such, the internal surfaces of the HSM (reinforced concrete and DSC support structure) are exposed to the DSC exterior. This is a protected sheltered environment with no direct exposure to sun, wind, or precipitation. The internal HSM environment may contain moisture and salts or other contaminants from the external ambient air. The maximum initial HSM temperatures for normal and off-normal conditions of storage are summarized in Table 3-5. These surface temperatures continuously decrease from the beginning of storage through the PEO.

External to the HSM

The HSMs are located outdoors; thus, the exterior surfaces of the HSM are exposed to all weather conditions, including insolation, wind, rain, snow, and plant-specific ambient temperature, humidity, and airborne contamination (i.e., an air-outdoor environment).

Basemat

A portion of the top surface of the basemat is exposed to the interior of the HSM (i.e., a sheltered environment), while the remainder is exposed to the air-outdoor environment. The below-grade portion of the basemat is exposed to a groundwater/soil environment.

Spent Fuel Assemblies

Since the SFAs are located within the sealed DSC, their subcomponents are exposed to the internal DSC environment (i.e., helium environment). During fabrication, each fuel pin is pressurized with helium. Hence, the internal environment of a fuel pin will consist of helium and fission gases (i.e., a helium environment).

3.5.3 Aging Effects Requiring Management

This section evaluates known aging degradation mechanisms/effects for the Standardized Advanced NUHOMS® System materials of construction. For each mechanism, a determination is made of whether the mechanism is considered "credible" in each environment that the material is exposed to during the PEO. A credible aging mechanism is one that could manifest into an aging effect that affects an important-to-safety function during the PEO. The evaluation relied upon the information in NUREG-2214 [3-2] for identifying known aging degradation mechanisms and for determining if they are credible for the material/environment combination.

3.5.3.1 Aging Mechanism of Steel Material

Table 3-11 through Table 3-17 show that the environments that the steel subcomponents are exposed to are:

- Air-Outdoor
- Sheltered
- Embedded-in-concrete
- Helium
- Fully encased

The following aging mechanisms for steel material were evaluated to determine if they are credible in the environments that steel is exposed to:

- General corrosion
- Pitting and crevice corrosion
- Galvanic corrosion
- Microbiologically influenced corrosion (MIC)
- SCC (including hydrogen embrittlement)
- Creep
- Fatigue
- Thermal aging
- Radiation embrittlement
- Stress relaxation
- Wear

3.5.3.1.1 General Corrosion of Steel Material

General corrosion, also known as uniform corrosion, proceeds at approximately the same rate over a metal surface. Freely exposed steel surfaces in contact with moist air or water are subject to general corrosion.

In an air-outdoor environment, rain, fog, snow, and dew condensation can generate moisture layers on the steel surface that cause general corrosion.

In a sheltered environment, deliquescence of airborne salts below the dew point could generate an aqueous electrolyte, initiating general corrosion. These salts may be chloride-rich and originate from marine environments, deicing salts, and condensed water from cooling towers, as well as a range of other non-chloride-rich species originating from industrial, agricultural, and commercial activities. As the temperature of the DSC steel decreases over time, it is plausible that it will reach the threshold temperature for deliquescence during the PEO. As such, the potential for general corrosion of steel subcomponents exposed to a sheltered environment is present.

In the embedded-in-concrete environment, the concrete provides an alkaline solution that passivates the steel. However, if the concrete degrades, the embedded steel could be exposed to water containing dissolved carbonates and chlorides, and general corrosion is possible.

In the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, the corrosion reaction with steel will be limited. Similarly, there is very little moisture in a fully encased environment and, thus, the corrosion reaction with steel will be limited.

Therefore, general corrosion of the steel material is considered credible in air-outdoor, sheltered, or embedded-in-concrete environments, but not credible in helium or fully encased environments.

3.5.3.1.2 Pitting and Crevice Corrosion of Steel Material

Pitting corrosion is a localized form of corrosion that is confined to a point or small area of a metal surface. It takes the form of cavities called pits. Crevice corrosion is another localized form of corrosion that occurs in a wetted environment when a crevice exists. It occurs more frequently in connections, lap joints, splice plates, bolt threads, under bolt heads, or at points of contact between metals and nonmetals. Crevice corrosion is associated with stagnant or low-flow solutions. Steel is known to be susceptible to pitting and crevice corrosion in an oxidizing and alkaline environment, especially in the presence of chlorides.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or through deliquescence of deposited salts. These electrolytes could be conducive to pitting and crevice corrosion of steel. As such, there is the potential for pitting and crevice corrosion of steel subcomponents exposed to an air-outdoor or sheltered environment.

In an embedded-in-concrete environment, if the concrete degrades with time, steel can be exposed to water containing dissolved carbonates and chlorides, which could be conducive to pitting and crevice corrosion as well.

In the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, the corrosion reaction with steel will be limited. Similarly, there is very little moisture in a fully encased environment and, thus, the corrosion reaction with steel will be limited.

Therefore, pitting and crevice corrosion of the steel material is considered credible in air-outdoor, sheltered, or embedded-in-concrete environments, but not credible in helium or fully encased environments.

3.5.3.1.3 Galvanic Corrosion of Steel Material

Galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution. Under these conditions, an electrolytic cell is formed, transmitting an electrical current between an anode (i.e., less noble material) and a cathode (i.e., more noble material). Oxidation occurs at the anode, and reduction occurs at the cathode. In a DSC, galvanic coupling exists between steel and other more noble materials such as stainless steel, graphite, nickel, and brass.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or through deliquescence of deposited salts. Because these electrolytes could initiate steel corrosion, and corrosion of steel is expected to be enhanced under galvanic coupling, loss of material due to galvanic corrosion of steel is considered credible in dissimilar metal couples.

In an embedded-in-concrete environment, the steel will not be in contact with a dissimilar metal or conductive material.

In a helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, very few aqueous electrolytes. Similarly, there is very little moisture in a fully encased environment and, thus, very few aqueous electrolytes.

Therefore, galvanic corrosion of the steel material is considered credible in air-outdoor or sheltered environments, but not credible in embedded-in-concrete, helium, or fully encased environments.

3.5.3.1.4 Microbiologically Influenced Corrosion of Steel Material

MIC is corrosion caused or promoted by the metabolic activity of microorganisms. Active microbial metabolism requires water in the form of water vapor, condensation, or deliquescence and available nutrients to support microbial activity. Biofilms can form even under radiation environments. MIC is limited where relative humidity is below 90 percent and negligible for relative humidity below 60 percent. Although most of the evidence of MIC for metallic components is from conditions under which the metal surface is kept continuously wet, microorganisms can live in many environments, such as water, soil, and air, where aerobic bacteria (e.g., iron-manganese oxidizing bacteria, sulfur/sulfide oxidizing bacteria, methane producers, organic acid-producing bacteria), fungi, and algae can develop.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or via deliquescence of deposited salts. These electrolytes have the potential to support microbial activity. However, there is no OE of MIC degradation of steel engineering components that are exposed to environments similar to those of dry storage systems, where continuous exposure to a relative humidity above 90 percent is not expected. The OE of MIC for metallic components is largely from instances in which the metal surface was kept continuously wet. Because there is no applicable OE of MIC damage of steel under relevant atmospheric conditions, MIC is not considered credible in a sheltered environment.

In an embedded-in-concrete environment, if the concrete is exposed to a groundwater/soil environment and is degraded, the steel could be exposed to groundwater or soil. Under these conditions, the steel could be susceptible to MIC.

In the helium environment, there are very little residual water and nutrients in internal environments of a DSC following drying and refilling with inert helium gas. Similarly, there are very little moisture and nutrients in a fully encased environment.

Therefore, MIC of the steel material is considered credible in an embedded-in-concrete environment if the concrete is exposed to a ground/soil environment, but is not credible in air-outdoor, sheltered, helium, or fully encased environments.

3.5.3.1.5 Stress Corrosion Cracking (Including Hydrogen Embrittlement) of Steel Material

SCC is the cracking of a metal produced by the combined action of corrosion and tensile stress (applied or residual). SCC is highly chemical-specific in that certain alloys are likely to undergo SCC only when exposed to a small number of chemical environments. SCC is the result of a combination of three factors: (1) a susceptible material, (2) exposure to a corrosive environment, and (3) tensile stresses. High-strength steels with yield strengths greater than or equal to 150,000 pounds per square inch (150 ksi) have been found to be susceptible to SCC under exposure to aqueous electrolytes.

The steels used in the construction of the Standardized Advanced NUHOMS® System are not high-strength steels (i.e., they have a yield strength less than 150 ksi) and, thus, are not susceptible to SCC.

Therefore, SCC of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.1.6 Creep of Steel Material

Creep is the time-dependent, inelastic deformation that takes place at an elevated temperature and a constant stress. Because the deformation processes that produce creep are thermally activated, the rate of this time-dependent deformation is a strong function of the temperature. The creep rate also depends on the applied stress, but does not normally vary with the environment. Generally, at temperatures below $0.4T_m$, where T_m is the melting point of the metal in Kelvin (K), thermal activation is insufficient to produce significant creep. With a melting point of 1,789 K (2,760 °F), temperatures of at least 716 K (829 °F) are required to initiate creep in steels. However, the $0.4T_m$ rule of thumb underestimates the minimum creep temperature for steels because it has been found that temperatures above 932 °F are required for creep in steels.

The highest temperatures within the Standardized Advanced NUHOMS® System are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any of the DSCs was determined to be 727 °F at the beginning of storage. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that the steel subcomponents will not approach the minimum 932 °F required for significant creep to occur in steels.

Therefore, creep of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.1.7 Fatigue of Steel Material

Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The only cyclic loading experienced by the DSC steel material is associated with thermal cycling. The only source of potential thermal fatigue of the DSC is ambient seasonal and daily temperature fluctuation. The DSC does not experience the full amplitude of ambient temperature cycles, and a gradual, long-term temperature decrease occurs during the course of storage. The seasonal and daily variations in ambient conditions are ameliorated by the thermal mass of the HSM.

Section 3.2.1.7 of NUREG-2214 [3-2] calls for a review of all fatigue analyses contained in the design basis documents to determine whether the renewal application adequately addresses the implications of extending the operating period to 60 years. It also says that, if no fatigue analysis was performed in support of the component design, no action is required. The review of the design basis documents for fatigue analyses is in Appendix 3A. The only component identified as having a fatigue analysis was the shell subcomponent for all three DSC designs. Table 3-11, Table 3-12, and Table 3-13 show that the shell subcomponents are made of stainless steel. Therefore, the design basis documents do not contain a fatigue analysis for any steel subcomponents and, per NUREG-2214 [3-2], no action is required.

Therefore, fatigue of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.1.8 Thermal Aging of Steel Material

The microstructures of most steels will change, given sufficient time at temperature, and this can affect mechanical properties. The effect of thermal aging will depend on the time at temperature and the microstructure and carbon content of the steel subcomponents.

The effects of elevated storage temperatures on material properties were evaluated during the initial license application. *The maximum steel component temperatures occur in the spacer discs of the 24PT1 and 24PT4 DSCs. The maximum temperature for these subcomponents at the beginning of the initial storage period with design basis contents is 617 °F and 653 °F, respectively, i.e., lower than the 700 °F ASME code limit. These subcomponents are constructed out of SA-537 CL 2 or SA-533 GR B CL 1. Per the ASME Code Section II materials specifications, the SA-537 CL 2 and SA-533 GR B CL 1 materials are tempered to at least 1,100 °F. From a microstructure state, further tempering or thermal treatment due to the lower temperature that occurs during the period of extended operation would lead to very insignificant changes.* Therefore, it can be concluded that thermal aging is not expected to produce degradation of the mechanical properties of steels in the PEO.

Therefore, thermal aging of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.1.9 Radiation Embrittlement of Steel Material

Embrittlement of metals may occur under exposure to neutron radiation. Depending on the neutron fluence, radiation can cause changes in mechanical properties, such as loss of ductility, reduced fracture toughness, and decreased resistance to cracking.

All changes on this page are as a result of RSI 3-1

Section 3.2.1.9 of NUREG-2214 [3-2] states that neutron fluence levels greater than 10^{19} neutrons per square centimeter (n/cm^2) are required to produce a measureable degradation of the mechanical properties. NUREG-2214 [3-2] then describes a bounding calculation that shows estimated fluence level within a DSC is three orders of magnitude below the levels reported to degrade the fracture resistance of carbon and alloy steels.

Therefore, radiation embrittlement of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

Note that while the AMR determined that radiation embrittlement is not credible, it was identified as a TLAA in Appendix 3A and dispositioned accordingly.

3.5.3.1.10 Stress Relaxation of Steel Material

Stress relaxation of bolting or other tightening subcomponents is the steady loss of elastic stress in a loaded part due to atomic movement at elevated temperature. It results in a loss of clamping forces or preload in a heavily loaded joint. Stress relaxation is a strong function of temperature and bolt material.

HSM structural component anchorages are installed snug-tight per HSM installation specifications. No specific level of installed tension is required to achieve the snug-tightened condition. This condition is achieved at relatively low levels of pretension. Therefore, there are no heavily loaded bolts in the Standardized Advanced NUHOMS® System.

Therefore, stress relaxation of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.1.11 Wear of Steel Material

Rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body.

There are no bodies rolling on another body while DSCs are in storage.

Therefore, wear of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.2 Aging Mechanism of Stainless Steel Material

Table 3-11 through Table 3-17 show that the environments that the stainless steel subcomponents are exposed to are:

- Air-Outdoor
- Sheltered
- Embedded-in-concrete

- Helium
- Fully encased

The following aging mechanisms for stainless steel material were evaluated to determine if they are credible in the environments that stainless steel is exposed to:

- General corrosion
- Pitting and crevice corrosion
- Galvanic corrosion
- Microbiologically influenced corrosion
- Stress corrosion cracking
- Creep
- Fatigue
- Thermal aging
- Radiation embrittlement
- Stress relaxation
- Wear

3.5.3.2.1 General Corrosion of Stainless Steel Material

Stainless steels exhibit passive behavior in all environments, resulting in negligible general corrosion rates.

Therefore, general corrosion of the stainless steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.2 Pitting and Crevice Corrosion of Stainless Steel Material

Pitting corrosion is a localized form of corrosion that is confined to a point or small area of a metal surface. It takes the form of cavities called pits. Crevice corrosion is another localized form of corrosion that occurs in a wetted environment when a crevice exists that allows a corrosive environment to develop. It occurs more frequently in connections, lap joints, splice plates, bolt threads, under bolt heads, or at points of contact between metals and nonmetals. Crevice corrosion is associated with stagnant or low-flow solutions. Stainless steel is known to be susceptible to pitting and crevice corrosion in an oxidizing and alkaline environment, especially in the presence of chlorides.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or through deliquescence of deposited salts. These electrolytes could be conducive to pitting and crevice corrosion of stainless steel. As such, there is the potential for pitting and crevice corrosion of stainless steel subcomponents exposed to an air-outdoor or sheltered environment.

In an embedded-in-concrete environment, there are limited amounts of water and oxygen. Therefore, stainless steel is not susceptible to pitting and crevice corrosion in an embedded environment.

In the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, the corrosion reaction with stainless steel will be limited. Similarly, there is very little moisture in a fully encased environment and, thus, the corrosion reaction with stainless steel will be limited.

Therefore, pitting and crevice corrosion of the stainless steel material is considered credible in air-outdoor or sheltered environments, but not credible in embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.3 Galvanic Corrosion of Stainless Steel Material

Galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution. Under these conditions, an electrolytic cell is formed, transmitting an electrical current between an anode (i.e., less noble material) and a cathode (i.e., more noble material). Oxidation occurs at the anode, and reduction occurs at the cathode. Galvanic coupling exists between stainless steel and other more noble materials such as graphite.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or through deliquescence of deposited salts. Because these electrolytes conducive to galvanic corrosion exist in sheltered environments, galvanic corrosion of stainless steel in contact with graphite lubricants is considered credible.

In an embedded-in-concrete environment, the stainless steel will not be in contact with a dissimilar metal of conductive material.

In the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, very few aqueous electrolytes. Similarly, there is very little moisture in a fully encased environment and, thus, very few aqueous electrolytes.

Therefore, galvanic corrosion of the steel material is considered credible in air-outdoor or sheltered environments when in contact with a graphite lubricant, but not credible in embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.4 Microbiologically Influenced Corrosion of Stainless Steel Material

As discussed in Section 3.5.3.1.4, MIC is caused or promoted by the metabolic activity of microorganisms. Microorganisms can live in many environments, such as water, soil, and air, where aerobic bacteria (e.g., iron-manganese oxidizing bacteria, sulfur/sulfide oxidizing bacteria, methane producers, and organic acid-producing bacteria), fungi, and algae can develop.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or through deliquescence of deposited salts. These electrolytes have the potential to support microbial activity. However, there has not yet been any OE of MIC in atmospheric environments where stainless steel surfaces are only intermittently wetted. Because there is no applicable OE of MIC damage of stainless steel under relevant atmospheric conditions, MIC is not considered credible in an air-outdoor or sheltered environment.

In a helium environment, there are very little residual water and nutrients in internal environments of a DSC following drying and refilling with inert helium gas. Similarly, there are very little moisture and nutrients in an embedded-in-concrete or fully encased environment.

Therefore, MIC of the stainless steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.5 Stress Corrosion Cracking of Stainless Steel Material

SCC is the cracking of a metal produced by the combined action of corrosion and tensile stress and is highly chemical-specific. Most ferritic and duplex stainless steels are either immune or highly resistant to SCC; however, all austenitic grades, especially Types 304, 304L, 304LN, 316, 316L, and 316LN, are susceptible to chloride-induced SCC in the normal wrought condition. This susceptibility increases when the material is sensitized. In the welded condition, the HAZ, which is a thin band located adjacent to the weld, can be sensitized by the precipitation of carbides that extract chromium out of the metal matrix.

As discussed in Section 3.5.3.1.1, the potential to form aqueous electrolytes on the steel surfaces exposed to air-outdoor and sheltered environments is present via direct exposure to precipitation or through deliquescence of deposited salts. These electrolytes could be conducive to SCC of stainless steel. SCC also requires the presence of a tensile stress, which commonly exists at welds originating from fabrication processes or contacts between components. Because sufficient weld residual stresses and more susceptible material conditions are present near the welds, and aqueous electrolytes conducive to SCC are present in a sheltered environment, the potential for SCC of the welds in the canister shell and other stainless steel subcomponents is present in the 60-year timeframe.

In the helium environment, there is a lack of halides and very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, SCC is not considered credible. Similarly, there is a lack of halides and very little moisture in an embedded-in-concrete or fully encased environment and, thus, SCC is not considered credible.

Therefore, SCC of the stainless steel material is considered credible in air-outdoor or sheltered environments, but not credible in embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.6 Creep of Stainless Steel Material

As discussed in Section 3.5.3.1.6, as a general rule, thermal activation is insufficient to produce significant creep at temperatures below $0.4T_m$, where T_m is the melting point of the metal in Kelvin. The term "stainless steel" covers a wide range of compositions and microstructures, including austenitic, ferritic, martensitic, duplex, and precipitation hardening stainless steels. Using the melting point temperature for austenitic or 300 series stainless steels (because they are most commonly used in the DSCs and have the lowest melting point) of 1,698 K (2,597 °F), temperatures of at least 679 K (763 °F) are required to initiate creep in the austenitic stainless steels.

The highest temperatures within the DSCs are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any of the DSCs was determined to be 727 °F at the beginning of storage. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that internal stainless steel subcomponents will not approach the minimum 763 °F temperature that has been found to be required for significant creep to occur in stainless steels.

Therefore, creep of the stainless steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.7 Fatigue of Stainless Steel Material

Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The only cyclic loading experienced by the DSC steel material is associated with thermal cycling. The only source of potential thermal fatigue of the DSC is ambient seasonal and daily temperature fluctuation. The DSC does not experience the full amplitude of ambient temperature cycles, and a gradual, long-term temperature decrease occurs during the course of storage. The seasonal and daily variations in ambient conditions are ameliorated by the thermal mass of the HSM.

Section 3.2.1.7 of NUREG-2214 [3-2] calls for a review of all fatigue analyses contained in the design basis documents to determine whether the renewal application adequately addresses the implications of extending the operating period to 60 years. It also says that if no fatigue analysis was performed in support of the component design, no action is required. The review of the design basis documents for fatigue analyses is in Appendix 3A. The only component identified as having a fatigue analysis was the shell subcomponent for all three DSC designs, which is only exposed to sheltered, helium, or fully encased environments.

Therefore, fatigue of the stainless steel shell subcomponent is considered credible in sheltered, helium, or fully encased environments. Fatigue is not credible for any other subcomponents regardless of their environment.

3.5.3.2.8 Thermal Aging of Stainless Steel Material

The microstructures of most stainless steels will change, given sufficient time at temperature, and this can affect mechanical properties. For stainless steel subcomponents, the thermal aging process differs for welded and non-welded subcomponents.

Welded austenitic stainless steel subcomponents in helium and fully encased environment

The ferrite present in austenitic stainless steel welds can transform by spinodal decomposition to form iron-rich alpha and chromium-rich alpha prime phases, and further aging can produce an intermetallic G-phase. The spinodal decomposition and the formation of the intermetallic G-phase takes place during extended exposure to temperatures between 300 °C and 400 °C (572 °F and 752 °F). The highest temperatures within the DSCs are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any of the DSCs was determined to be 727 °F at the beginning of storage. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that internal stainless steel subcomponents could be above the 300 °C (572 °F) minimum temperature required for these phase changes.

Based on Charpy impact toughness testing of cast duplex stainless steels, it is concluded that ferrite levels above 15 percent are required for significant embrittlement because ferrite resides in discrete islands below this level and does not provide a continuous low-toughness fracture path. Because most welds contain around 4 to 15 percent ferrite, substantial embrittlement of austenitic stainless steel welds is not expected. NUREG/CR-6428 [3-12] concluded that thermal aging produced moderate decreases (no more than 25 percent) in the upper shelf Charpy impact energy and relatively small decreases in the fracture toughness of a wide range of austenitic welds. Although the phase changes associated with thermal embrittlement of austenitic stainless steel welds could take place in subcomponents near the fuel within the 60-year timeframe, the minor reductions in fracture toughness that would be produced in the weld indicate that this is not a credible aging mechanism for subcomponents in proximity to the fuel rods.

Non-welded austenitic stainless steel subcomponents in helium and fully encased environment

Because the phase changes described previously occur only within the ferrite-containing HAZ of a weld, embrittlement will not occur in austenitic stainless steel subcomponents that do not contain a weld.

Precipitation-hardened martensitic stainless steel subcomponents in helium and fully encased environment

Type 17-4 precipitation-hardened (17-4PH) martensitic stainless steel operating at high temperatures may be susceptible to thermal embrittlement depending on several factors including the alloy composition within the allowable specifications, the initial heat treatment, and the operating temperature. For operating temperatures between 243 °C and 316 °C (470 to 600 °F), Section 3.2.2.8 of NUREG-2214 [3-2] recommends an evaluation of conditions on a per-component basis considering operating temperature, exposure time, operating environment, stress levels, and material composition.

The only Standardized Advanced NUHOMS® System components made of 17-4PH martensitic stainless steel are the support rods and spacer sleeves of the 24PT1 DSC [ ] For normal storage conditions, these components have a maximum temperature of 479 °F (Table 4.4-6 of [3-3]). Therefore, an evaluation was performed which determined that the maximum component temperatures were below the reported threshold temperature of 500 °F in Electrical Power Research Institute (EPRI) Report TR-1012081 [3-13]. In addition, there is conservatism in the thermal model used to estimate the temperature as noted in the UFSAR [3-3] (e.g., modeling 16 kW for 24PT1 DSC instead of the allowed heat load of 14 kW). Therefore, the evaluation concluded that thermal aging embrittlement is unlikely to affect the mechanical property of the 17-4PH steels during the PEO.

In addition, the time that the components would be above the recommended 470 °F is limited because of both the time that the ambient temperature would be at the normal maximum temperature of 104 °F and the decay of the heat source.

Therefore, thermal aging of the precipitation-hardened martensitic stainless steel is not considered a credible aging mechanism.

Stainless steel subcomponents in air-outdoor, sheltered, embedded-in-concrete, and fully encased environments

Because the peak temperatures for stainless steel subcomponents exposed to air-outdoor, sheltered, embedded-in-concrete, and fully encased environments are below the temperature required for the phase changes associated with thermal embrittlement of stainless steels, thermal aging is not considered credible for these subcomponents.

Summary

Therefore, thermal aging of the stainless steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.9 Radiation Embrittlement of Stainless Steel Material

Embrittlement of metals may occur under exposure to neutron radiation. Depending on the neutron fluence, radiation can cause changes in mechanical properties, such as loss of ductility, reduced fracture toughness, and decreased resistance to cracking.

Section 3.2.2.9 of NUREG-2214 [3-2] states that neutron fluence levels greater than 10^{20} n/cm^2 are required to produce a measureable degradation of the mechanical properties. NUREG-2214 [3-2] then describes a bounding calculation that showed estimated fluence level within a DSC is four orders of magnitude below the levels reported to degrade the fracture resistance of stainless steel.

Therefore, radiation embrittlement of the stainless steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

Note that while the AMR determined that radiation embrittlement is not credible, it was identified as a TLAA in Appendix 3A and dispositioned accordingly.

3.5.3.2.10 Stress Relaxation of Stainless Steel Material

Stress relaxation of bolting or other tightening subcomponents is the steady loss of elastic stress in a loaded part due to atomic movement at elevated temperature. It results in a loss of clamping forces or preload in a heavily loaded joint. Stress relaxation is a strong function of temperature and bolt material.

HSM structural component anchorages are installed snug-tight per HSM installation specifications. No specific level of installed tension is required to achieve the snug-tightened condition. This condition is achieved at relatively low levels of pretension. Therefore, there are no heavily loaded bolts in the Standardized Advanced NUHOMS® System.

Therefore, stress relaxation of the steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.2.11 Wear of Stainless Steel Material

Rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body. There are no bodies rolling on another body while DSCs are in storage.

Therefore, wear of the stainless steel material is not credible in air-outdoor, sheltered, embedded-in-concrete, helium, or fully encased environments.

3.5.3.3 Aging Mechanisms of Aluminum Material

Table 3-11 through Table 3-17 show that the only environment that the aluminum subcomponents are exposed to is:

- Helium

The following aging mechanisms for aluminum material were evaluated to determine if they are credible in the environment that aluminum is exposed to:

- General corrosion
- Pitting and crevice corrosion
- Galvanic corrosion
- Microbiologically influenced corrosion
- Creep
- Fatigue
- Thermal aging
- Radiation embrittlement

3.5.3.3.1 General Corrosion of Aluminum Material

General corrosion, also known as uniform corrosion, proceeds at approximately the same rate over a metal surface. Freely exposed aluminum surfaces in contact with moist air or water are subject to general corrosion. The corrosion rate depends on solution composition, pH, and temperature. The corrosion rate of aluminum is normally controlled by the formation of a passive film of Al_2O_3 at the metal and water interface.

In the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, the corrosion reaction with aluminum will be limited.

Therefore, general corrosion of the aluminum material is not credible in a helium environment.

3.5.3.3.2 Pitting and Crevice Corrosion of Aluminum Material

As discussed in Section 3.5.3.1.2, pitting corrosion is a localized form of corrosion that is confined to a point or small area of a metal surface, and crevice corrosion occurs in a wetted environment when a crevice exists that allows a corrosive environment to develop in a component. Aluminum and its alloys form a passive film on the surface. Localized corrosion in the form of pitting or crevice corrosion could occur for these passive aluminum materials, especially in the presence of halides.

In the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, the corrosion reaction with aluminum will be limited.

Therefore, pitting and crevice corrosion of the aluminum material is not credible in a helium environment.

3.5.3.3.3 Galvanic Corrosion of Aluminum Material

As discussed in Section 3.5.3.1.3, galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution. In dry storage systems, galvanic coupling exists between aluminum and steel, and stainless steel (where aluminum is less noble in each case).

In a helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, very few aqueous electrolytes.

Therefore, galvanic corrosion of the aluminum material is not credible in a helium environment.

3.5.3.3.4 Microbiologically Influenced Corrosion of Aluminum Material

MIC is corrosion caused or promoted by the metabolic activity of microorganisms. Active microbial metabolism requires water, in the form of water vapor, condensation, or deliquescence, and available nutrients to support microbial activity. Biofilms can form even under radiation environments. MIC is limited where relative humidity is below 90 percent and negligible for relative humidity below 60 percent. Although most of the evidence of MIC for metallic components is from conditions under which the metal surface is kept continuously wet, microorganisms can live in many environments, such as water, soil, and air, where aerobic bacteria (e.g., iron-manganese oxidizing bacteria, sulfur/sulfide oxidizing bacteria, methane producers, and organic acid-producing bacteria), fungi, and algae can develop.

In the helium environment, there is very little residual water and nutrients in internal environments of a DSC following drying and refilling with inert helium gas.

Therefore, MIC of the aluminum material is not credible in a helium environment.

3.5.3.3.5 Creep of Aluminum Material

Creep is the time-dependent, inelastic deformation that takes place at an elevated temperature and a constant stress. Because the deformation processes that produce creep are thermally activated, the rate of this time-dependent deformation is a strong function of the temperature. The creep rate also depends on the applied stress but does not generally vary with the environment. Generally, at temperatures below $0.4T_m$, where T_m is the melting point of the metal in Kelvin (K), thermal activation is insufficient to produce significant creep. With a melting point of 911 to 930 K (1,180 to 1,215 °F), temperatures of at least 364 to 372 K (196 to 210 °F) are required to initiate creep in aluminum.

The highest temperatures within the DSCs are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any of the DSCs was determined to be 727 °F at the beginning of storage. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that aluminum subcomponents within the canister could be exposed to temperatures above the minimum creep temperatures for aluminum.

Therefore, creep of the aluminum material is considered credible in a helium environment.

3.5.3.3.6 Fatigue of Aluminum Material

Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The only cyclic loading experienced by the DSC aluminum material is associated with thermal cycling. The only source of potential thermal fatigue of the DSC is ambient seasonal and daily temperature fluctuation. The DSC does not experience the full amplitude of ambient temperature cycles, and a gradual, long-term temperature decrease occurs during the course of storage. The seasonal and daily variations in ambient conditions are ameliorated by the thermal mass of the HSM.

Section 3.2.3.6 of NUREG-2214 [3-2] calls for a review of all fatigue analyses contained in the design basis documents to determine whether the renewal application adequately addresses the implications of extending the operating period to 60 years. It also says that if no fatigue analysis was performed in support of the component design, no action is required. The review of the design basis documents for fatigue analyses is in Appendix 3A. The only component identified has having a fatigue analysis was the shell subcomponent for all three DSC designs. Table 3-11, Table 3-12, and Table 3-13 show that the shell subcomponents are made of stainless steel. Therefore, the design basis documents do not contain a fatigue analysis for any aluminum subcomponents.

Therefore, fatigue of the aluminum material is not credible in a helium environment.

3.5.3.3.7 Thermal Aging of Aluminum Material

The microstructures of most aluminum alloys will change, given sufficient time at temperature, and this can affect mechanical properties. The effect of thermal aging will depend on the time at temperature and the microstructure and chemical composition of the aluminum subcomponents. Table 3-11, Table 3-12, and Table 3-13 show that only two types of aluminum are used in the DSCs, Type 1100 and Type 6061.

Type 6061 aluminum is a precipitation-hardened alloy. The precipitation treatment is performed between 163 and 204 °C (325 and 399 °F). Prolonged elevated temperature exposure is known to significantly reduce the strength of these alloys due to microstructural changes. Because of this sensitivity to exposure time, ASME B&PV Code, Section II, requires that time-dependent properties be used for exposures above 177 °C (350 °F) for this alloy.

The highest temperatures within the DSCs are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any of the DSCs was determined to be 727 °F at the beginning of storage. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that the Type 6061 aluminum alloys may experience significant aging at a higher temperature than that for precipitation treatment, leading to loss of strength.

As described in Section B.3.3.1 of the UFSAR [3-3] the stress evaluations for the Type 6061 subcomponents are based on mechanical properties corresponding to annealed Type 6061 (6061-O) regardless of the particular temper. The use of properties based on annealed condition (no credit taken for enhanced properties obtained by heat treatment) in the stress qualification eliminates any changes in strength that may occur under exposure to elevated temperatures and ensures no adverse impact on the properties used in the design.

Table 3-11 through Table 3-17 show that the subcomponents made of Type 1100 aluminum do not have a structural integrity safety function. Therefore, thermal aging will not affect their ability to perform their intended safety functions.

Therefore, thermal aging of the aluminum material is not credible in a helium environment.

3.5.3.3.8 Radiation Embrittlement of Aluminum Material

Embrittlement of metals may occur under exposure to neutron radiation. Depending on the neutron fluence, radiation can cause changes in mechanical properties, such as loss of ductility, reduced fracture toughness, and decreased resistance to cracking.

Section 3.2.3.8 of NUREG-2214 [3-2] describes data showing that the mechanical properties of aluminum are not degraded at neutron fluence levels on the order of 10^{20} n/cm^2. Section 3.2.1.9 of NUREG-2214 [3-2] describes a bounding calculation that showed estimated fluence level within a DSC is three orders of magnitude below the levels reported to degrade the mechanical properties of aluminum.

Therefore, radiation embrittlement of the aluminum material is not credible in a helium environment.

3.5.3.4 Aging Mechanism of Lead Material

Table 3-11 through Table 3-17 show that the lead shielding of the 24PT4 DSC is the only subcomponent made of lead. This component has a radiation shielding and heat removal intended safety function and is in a fully encased environment.

In the fully encased environment, the lead is not exposed to water or atmospheric contaminants. Lead is known to be very resistant to corrosion in a variety of environments and there are no credible aging mechanisms that could challenge the ability of lead to perform its radiation shielding and heat removal intended safety functions.

Therefore, there are no aging mechanisms identified for lead in a fully encased environment.

3.5.3.5 Aging Mechanism of BORAL® and Metal Matrix Composite Material

Table 3-11 through Table 3-17 show that the only environment that the BORAL® and MMC subcomponents are exposed to is:

- Helium

The following aging mechanisms for BORAL® and MMC material were evaluated to determine if they are credible in the environment that BORAL® and MMC is exposed to:

- General corrosion
- Galvanic corrosion
- Wet corrosion and blistering
- Boron depletion
- Creep
- Thermal aging
- Radiation embrittlement

Boron is essentially insoluble in aluminum. BORAL® consists of (1) a core of uniformly distributed boron carbide (B_4C) and aluminum alloy particles, and (2) a surface cladding of aluminum alloy on both sides of the core. In aluminum MMCs, boron is in the form of B_4C in an aluminum matrix.

Of the identified potential aging mechanisms listed above, wet corrosion and blistering are considered credible only for BORAL®, because only this material has porosity that can trap water and initiate this mechanism.

3.5.3.5.1 General Corrosion of BORAL® and MMC Material

Because aluminum is present as a continuous matrix (in MMCs) or used as an outer cladding (in BORAL®), the degree of general corrosion of each of the neutron poison plate materials is considered to be largely governed by the corrosion of aluminum.

As discussed in Section 3.5.3.3.1, in the helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, the corrosion reaction with aluminum will be limited.

Therefore, general corrosion of the BORAL® and MMC material is not credible in a helium environment.

3.5.3.5.2 Galvanic Corrosion of BORAL® and MMC Material

As discussed in Section 3.5.3.1.3, galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution. The aluminum-based neutron poison materials used inside DSCs can be in galvanic contact with the stainless steel guide sleeves, where aluminum is less noble.

In a helium environment, there is very little residual water in internal environments of a DSC following drying and refilling with inert helium gas and, thus, very few aqueous electrolytes.

Therefore, galvanic corrosion of the BORAL® and MMC material is not credible in a helium environment.

3.5.3.5.3 Wet Corrosion and Blistering of BORAL® and MMC Material

The core of aluminum-boron carbide laminate composites is not fully sintered and, as a result, can have a porosity of 1 to 8 percent with varying degrees of interconnectivity among pores. This may allow water ingress into the core, where the water can react with the aluminum to form aluminum oxide and hydrogen gas. Blistering has been observed in the BORAL® cladding in wet and dry storage applications. Tests simulating the wetting and vacuum drying cycles during canister closure operations show that BORAL® can form blisters in the aluminum cladding because of water ingress through its exposed edges. The blisters are characterized by a local area where the aluminum cladding separates from the underlying boron carbide-aluminum core, and the cladding is physically deformed outward.

Although wet corrosion and blistering may occur, this aging mechanism has not been observed to reduce the neutron absorbing capability of BORAL® in spent fuel pool surveillance coupons. It is important to note that, because only a trace amount of water will be left in a dry storage canister after drying and helium backfill, the occurrence of wet corrosion and blistering will be minimal in a dry canister environment during the PEO.

Therefore, wet corrosion and blistering of the BORAL® material is not credible in a helium environment.

3.5.3.5.4 Boron Depletion of BORAL® and MMC Material

Boron depletion refers to the loss of the capability of a material to absorb neutrons when the neutron fluence significantly consumes boron-10 atoms. At typical levels of neutron flux and boron-10 concentration, the neutron dose after 60 years would deplete at most 0.0002 percent of the available boron-10 atoms. Using the highest expected neutron flux and the lowest boron-10 concentration as a worst-case scenario, only 0.02 percent of the available boron-10 atoms would be depleted after 60 years, which is too small to challenge the criticality control function of the neutron poisons.

Therefore, boron depletion of the BORAL® and MMC material is not credible in a helium environment.

Note that while the AMR determined that boron depletion is not credible, it was identified as a TLAA in Appendix 3A and dispositioned accordingly.

3.5.3.5.5 Creep of BORAL® and MMC Material

Creep is the time-dependent inelastic deformation that takes place at an elevated temperature and a constant stress. Because the deformation processes that produce creep are thermally-activated, the rate of this time-dependent deformation is a strong function of the temperature. Because aluminum is present as a continuous matrix and as an external cladding in the neutron poison plates, and aluminum has a lower melting point than the other portions of the material microstructures, the creep behavior of poison materials is considered to be governed by the behavior of aluminum.

As discussed in Section 3.5.3.3.5, as a general rule, significant creep occurs at temperatures above $0.4T_m$, where T_m is the melting point of the metal in Kelvin. Applying the $0.4T_m$ rule, the critical creep temperature for aluminum is 100 °C (212 °F). The highest temperatures within the DSCs are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any of the DSCs was determined to be 727 °F at the beginning of storage. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that the BORAL® and MMC subcomponents within the canister could be exposed to temperatures above the minimum creep temperatures for aluminum.

Because temperatures within dry storage systems have the potential to exceed the minimum creep temperature of aluminum, it is necessary to consider the load applied to the subcomponent to determine whether significant creep deformation will occur, as well as the specific application, to determine whether the creep affects safety. As shown in Table 3-11 through Table 3-17, the BORAL® and MMC subcomponents do not serve a structural function and are thus not expected to be under loads other than their own weight. In addition, the BORAL® and MMC plates are supported by adjacent subcomponents. Because of the minimal applied loads and presence of adjacent supporting structures, the impact of creep on the intended safety functions of the BORAL® and MMC subcomponents is not considered credible.

Therefore, creep of the BORAL® and MMC material is not credible in a helium environment.

3.5.3.5.6 Thermal Aging of BORAL® and MMC Material

Prolonged exposure to elevated temperatures can lead to a loss of fracture toughness and ductility in some materials as a result of changes to their microstructure. Testing of aluminum-based neutron poison plates, however, has shown that these materials typically increase in ductility when they are aged at high temperatures. Qualification tests performed on neutron poisons demonstrate that microstructural changes induced by aging typically make the aluminum softer and more ductile as it is annealed, while the boron and carbide particulates are thermally stable at DSC internal temperatures.

Also, as discussed in Section 3.5.3.5.5 above, the BORAL® and MMC subcomponents do not serve a structural function and are supported by adjacent subcomponents. Therefore, decreases in strength due to thermal aging are not expected to affect the intended safety functions of the BORAL® and MMC subcomponents.

Therefore, thermal aging of the BORAL® and MMC material is not credible in a helium environment.

3.5.3.5.7 Radiation Embrittlement of BORAL® and MMC Material

Embrittlement of metals may occur under exposure to neutron radiation. Depending on the neutron fluence, radiation can cause changes in mechanical properties, such as loss of ductility, reduced fracture toughness, and decreased resistance to cracking.

Section 3.2.3.8 of NUREG-2214 [3-2] describes data showing that the mechanical properties of aluminum are not degraded at neutron fluence levels on the order of 10^{20} n/cm^2. Section 3.2.1.9 of NUREG-2214 [3-2] describes a bounding calculation that showed estimated fluence level within a DSC is three orders of magnitude below the levels reported to degrade the mechanical properties of aluminum-based neutron poisons.

Therefore, radiation embrittlement of the BORAL® and MMC material is not credible in a helium environment.

3.5.3.6 Aging Mechanism of Concrete Material

Table 3-11 through Table 3-17 show that the environments that the concrete subcomponents are exposed to are:

- Air-Outdoor
- Sheltered
- Groundwater/Soil

The following aging mechanisms for concrete material were evaluated to determine if they are credible in the environments that concrete is exposed to:

- Freeze-thaw

- Creep
- Reaction with aggregates
- Differential settlement
- Aggressive chemical attack
- Corrosion of reinforcing steel
- Shrinkage
- Leaching of calcium hydroxide
- Radiation damage
- Fatigue
- Dehydration at high temperature
- Microbiological degradation
- Delayed ettringite formation
- Salt scaling

3.5.3.6.1 Freeze-Thaw of Concrete Material

Concretes that are nearly or fully saturated with water can be damaged by repeated freezing and thawing cycles. The degradation mode would initiate at the outer concrete surface exposed to outdoor environments, primarily at horizontal surfaces where water ponding can occur. For below-grade concrete structures, water that resides in soil can also be subject to freezing conditions, potentially promoting freeze-thaw damage. Because water expands when freezing, fully or mostly saturated concrete will experience internal stresses from the expanding ice, which can cause concrete cracking or scaling when pressures exceed the concrete tensile strength.

In a sheltered environment, there is low availability of water and, therefore, the freeze-thaw degradation is not considered credible.

Therefore, freeze-thaw of concrete material is considered credible in air-outdoor or groundwater/soil environments, but is not credible in a sheltered environment.

3.5.3.6.2 Creep of Concrete Material

Creep in concrete is the time-dependent deformation resulting from sustained loads. While there are several factors that affect creep in concrete, the most important parameter controlling creep is sustained loading. The creep rate in concrete decreases exponentially with time (i.e., creep would be more of a concern during the initial license period rather than the PEO). In addition, the creep in concrete is largely mitigated by proper design practices, in accordance with ACI 318-05 or ACI 349-06. Furthermore, creep-induced concrete cracks are not generally large enough to reduce the compressive strength of concrete, cause deterioration of concrete, or cause exposure of reinforcing steel to the environment.

Therefore, creep of concrete material is not credible in air-outdoor, groundwater/soil, or sheltered environments.

3.5.3.6.3 Reaction with Aggregates of Concrete Material

The two most common alkali-aggregate reactions are alkali-silica reaction (ASR) and alkali-carbonate reaction, with ASR being the most common and damaging. ASR is a chemical reaction between hydroxyl ions (present in the alkaline cement pore solution) and reactive forms of silica present in some aggregates. ASR damage in the concrete manifests itself as a characteristic map cracking on the concrete surface. The internal damage results in the degradation of concrete mechanical properties and, in severe cases, the expansion can result in undesirable dimensional changes and popouts. In general, ASR is a slow degradation mechanism that can cause serviceability issues and may exacerbate other deterioration mechanisms. The requisite conditions for initiation and propagation of ASR include:

- A sufficiently high alkali content of the cement (or alkali from other sources, such as deicing salts, seawater, and groundwater);
- A reactive aggregate; and
- Available moisture, generally accepted to be relative humidity greater than 80 percent.

ASR may take from three to more than 25 years to develop in concrete structures, depending on the nature (reactivity level) of the aggregates, the moisture and temperature conditions to which the structures are exposed, and the concrete alkali content. The delay in exhibiting deterioration indicates that there may be less reactive forms of silica that can eventually cause deterioration. Recent OE has revealed degradation of the concrete at a nuclear power plant as a result of ASR even though the concrete used at the plant passed all industry standard ASR screening tests at the time of construction. In addition, ASR screening tests are not conducted on each aggregate source but rather in select batches.

Because of the uncertainties in screening tests that can effectively be used to eliminate the potential for ASR and previous ASR OE at a nuclear facility, the aging mechanism is considered credible in concrete exposed to any environment with available moisture.

Therefore, reaction with aggregates of concrete material is considered credible in air-outdoor, groundwater/soil, or sheltered environments.

3.5.3.6.4 Differential Settlement of Concrete Material

Differential settlement is a result of the uneven deformation of the supporting foundation soil. Differential settlement, which causes distortion (loss of form) and damage (cracking) to concrete structures, is a function of the uniformity of the soil, stiffness of the structure, stiffness of the soil, and distribution of loads within the structure. The settlement of saturated cohesive soil consists of three components: (1) immediate settlement occurring due to the applied load, (2) consolidation settlement occurring gradually due to dissipation of the excess pore pressures generated by the applied load, and (3) secondary compression that depends on the composition and structure of the soil skeleton. The settlement of course-grained granular soils subject to applied load occurs immediately, primarily from the compression of the soil skeleton due to rearrangement of particles. As more HSMs are placed on a basemat, applied loads on the basemat are expected to increase over time, increasing the potential for differential settlement regardless of the environment.

Therefore, differential settlement of concrete material is considered credible in air-outdoor, groundwater/soil, or sheltered environments.

3.5.3.6.5 Aggressive Chemical Attack of Concrete Material

The intrusion of aggressive ions or acids into the pore network of the concrete can cause various degradation phenomena. The aggressive chemical attack typically originates from an external source of sulfate or magnesium ions as well as acidic environmental conditions.

In an air-outdoor or groundwater/soil environment, groundwater, seawater, and rainwater may contain sulfate species that penetrate the concrete and chemically react with alkali and calcium ions to form a precipitate of calcium sulfate in addition to other forms of calcium and sulfate-based compounds. The manifestation of sulfate attack is cracking, increase in concrete porosity and permeability, loss of strength, and surface scaling generated by the expansion associated with the formation of ettringite within the concrete and the pressure generated by the precipitated calcium and sulfate-base compounds inside the concrete pore network. Acids from groundwater and acid rain can dissolve both hydrated and unhydrated cement compounds (e.g., calcium hydroxide, calcium silicate hydrates, and calcium aluminate hydrates), as well as calcareous aggregate in concrete without any significant expansion reaction. In most cases, the chemical reaction forms water-soluble calcium compounds, which are then leached away by aqueous solutions. The dissolution of concrete commences at the surface and propagates inward as the concrete degrades. The signs of acidic attack are loss of alkalinity (also disturbing of electrochemical passive conditions for the embedded steel reinforcement), loss of material (i.e., concrete cover), and loss of strength.

NUREG-1801, [3-4], states that continued or frequent cyclic exposure to the following aggressive chemical environments is necessary to cause significant aggressive chemical attack degradation:

- Acidic solutions with pH < 5.5
- Chloride solutions > 500 ppm
- Sulfate solutions > 1500 ppm

Since the groundwater/soil and air-outdoor may contain solutions that exceed these criteria, aggressive chemical attack is considered possible.

In a sheltered environment, external sources of sulfate, magnesium, chloride, and acid entering concrete are considered to be insignificant. In addition, the heat load from the spent fuel is expected to aid in drying the interior concrete surfaces, decreasing water availability at the concrete surface (which is necessary to promote this degradation mode).

Therefore, aggressive chemical attack of concrete material is considered credible in air-outdoor or groundwater/soil environments, but is not credible in a sheltered environment.

3.5.3.6.6 Corrosion of Reinforcing Steel of Concrete Material

Corrosion of the reinforcing steel embedded in the concrete is mainly caused by the presence of chloride ions in the concrete pore solution and carbonation of the concrete. The highly alkaline environment provided by the concrete (normally with pore water pH > 13.0) results in the formation of a metal-adherent oxide film on the reinforcement steel bar surface, which passivates the steel. However, chloride ions may penetrate the concrete matrix and break down the steel passive layer once the chloride concentration at the reinforcing steel surface exceeds a threshold value, triggering corrosion of the reinforcing steel and shortening the service life of a concrete structure. Concrete durability is directly related to the quality of the concrete, the external concentration of chlorides on the concrete surface, and the reinforcement material. The service life of concretes exposed to chloride attack depends on the concrete cover, the surface chloride concentration, the chloride diffusion coefficient, the type of cementitious material, and the reinforcing steel material.

In an air-outdoor or groundwater/soil environment, chloride ions may penetrate the concrete from the outside environment, such as when using deicing salts, aggressive groundwater, or marine environments. Although no cases of corrosion-induced damage have been reported, *NUREG-2214 [3-2] states that* the results of a durability model show that corrosion of the reinforcing steel in concrete can potentially initiate and propagate within the 60-year timeframe for concretes of moderate to low quality. *Although the HSMs are designed and constructed in accordance with ACI standards (see Section 1.2.2.2), this AMR evaluation will conservatively assume that corrosion of the HSM reinforcing steel is possible.* Therefore, corrosion of reinforcing steel in concrete exposed to outdoor and groundwater or soil (below-grade) environments is considered credible.

In a sheltered environment, chloride ingress is expected to be insignificant for steel reinforcement due to the limited exposure to water. In addition, the heat load from the fuel is expected to aid in drying the interior concrete surfaces, thus decreasing water availability at the concrete surface (which is necessary to promote this degradation mode). Thus, corrosion of reinforcing steel is not considered credible.

Therefore, corrosion of reinforcing steel of concrete material is considered credible in air-outdoor or groundwater/soil environments, but is not credible in a sheltered environment.

3.5.3.6.7 Shrinkage of Concrete Material

Shrinkage occurs when hardened concrete dries from a saturated condition to a state of equilibrium in about 50 percent relative humidity. As excess concrete water evaporates, tensile stresses are induced in the concrete due to internal pressure from the capillary action of water movement, which results in cracking. The factors affecting shrinkage are cement content, water-to-cement ratio, degree of hydration, elastic modulus of aggregates, amount and characteristics of concrete admixtures, temperature and humidity during curing, and size and shape of concrete.

All changes on this page are as a result of OBS 3-2

Shrinkage of concrete occurs initially during curing, which can be controlled through concrete formulation and the density and distribution of internal reinforcement. Over 90 percent of the shrinkage occurs during the first year, reaching 98 percent by the end of the first 5 years. Thus, shrinkage is not expected to influence concrete performance during the PEO, because most of the shrinkage will take place early on in the life of the concrete. As a result, shrinkage of concrete is not considered credible.

Therefore, shrinkage of concrete material is not credible in air-outdoor, groundwater/soil, or sheltered environments.

3.5.3.6.8 Leaching of Calcium Hydroxide of Concrete Material

A constant or intermittent flux of water through a concrete surface can result in the removal or leaching of calcium hydroxide. Calcium hydroxide leaching is observed in the form of white leachate deposits (calcium carbonate) on the concrete surface. The extent of the leaching depends on the environmental salt content and temperature, and it can take place above and below ground.

In an air-outdoor or groundwater/soil environment, the concrete surface may be exposed to intermittent fluxes of water, thus making leaching of calcium hydroxide credible.

Operating experience indicates that leaching of calcium hydroxide is a mechanism that can be exacerbated by other degradation mechanisms or designs that do not adequately prevent ingress of precipitation into a sheltered structure.

Therefore, leaching of calcium hydroxide of concrete material is considered credible in air-outdoor, groundwater/soil, or sheltered environments.

3.5.3.6.9 Radiation Damage of Concrete Material

Radiation effects on concrete properties will depend on the gamma and neutron radiation doses, temperature, and exposure period. Gamma radiation can decompose and evaporate water in concrete. Because most of the water is contained in the cement paste, the effect of gamma radiation on cement paste is more significant than on the aggregates. Gamma radiation can also decompose the Si-O bond within calcium silicate hydrate. Neutron radiation deteriorates concrete by reducing stiffness, forming cracks by swelling, and changing the microstructure of the aggregates.

Section 3.5.1.9 of NUREG-2214 [3-2] describes data showing that the mechanical properties of concrete are not degraded at neutron fluence levels on the order of 10^{19} n/cm^2 and 10^{10} rad for gamma rays. Section 3.2.1.9 of NUREG-2214 [3-2] describes a bounding calculation that showed estimated fluence level within a DSC is three orders of magnitude below the levels reported to degrade the mechanical properties of concrete. The gamma dose is also expected to be several orders of magnitude less than the 10^{10} rad limit.

Therefore, radiation damage of concrete material is not credible in air-outdoor, sheltered, or groundwater/soil environments.

Note that while the AMR determined that radiation damage is not credible, it was identified as a TLAA in Appendix 3A and dispositioned accordingly.

3.5.3.6.10 Fatigue of Concrete Material

Concrete fatigue strength is defined as the maximum stress that the concrete can sustain without failure under a given number of stress cycles. Because the Standardized Advanced NUHOMS® System is a static application, mechanical cyclic loading is not expected. However, restraint of the concrete from expanding and contracting as it is exposed to rapid changes in temperature will lead to internal stresses in the structure. If the changes in temperature are severe and the resulting strains are sufficient, local plastic deformation can occur. Repeated application of this thermal loading can lead to crack initiation and propagation in low-cycle fatigue. Concrete fatigue in the HSM reinforced concrete may be caused by diurnal and seasonal temperature gradients through the wall. The inside surface of the concrete wall is hotter than the outside surface of the concrete wall, which causes compressive stresses in the concrete near the inside of the concrete wall and tensile stresses in the rebar near the outside of the concrete wall.

Section 3.5.1.10 of NUREG-2214 [3-2] discusses a generic evaluation of concrete fatigue over 60 years of storage considering an extreme seasonal ambient temperature variation from -40 to 125 °F. This range bounds the off-normal temperature range for the Standardized Advanced NUHOMS® System of -40 to 117 °F. The evaluation concluded that fatigue of concrete exposed to sheltered, outdoor, groundwater or soil (below-grade), and fully encased environments is not considered credible.

Therefore, fatigue of concrete material is not credible in air-outdoor, sheltered, or groundwater/soil environments.

3.5.3.6.11 Dehydration at High Temperature of Concrete Material

Exposure of concrete to elevated temperatures can affect its mechanical and physical properties. It is well known that concretes can degrade at high temperatures due to dehydration of the hydrated cement paste, thermal incompatibility between the cement and aggregates, and physicochemical deterioration of the aggregates.

The effects of thermal dehydration were addressed during the initial licensing of the Standardized Advanced NUHOMS® System. Since the fuel temperature decreases over time, the concrete temperature will also decrease over time, including the PEO. Therefore, the design temperature considerations during the initial licensing are expected to remain adequate during the PEO.

Therefore, dehydration at high temperature of concrete material is not credible in air-outdoor, sheltered, or groundwater/soil environments.

3.5.3.6.12 Microbiological Degradation of Concrete Material

Biodeterioration is caused by colonization of microbes and microorganisms that grow on concrete surfaces that offer favorable environmental conditions (e.g., available moisture, near neutral pH, presence of nutrients). Conducive environments may have elevated relative humidity (i.e., greater than about 60 percent), long cycles of humidification and drying, freezing and thawing, high carbon dioxide concentrations, high concentrations of chloride ions or other salts, or high concentrations of sulfates and small amounts of acids. Biodeterioration may lead to reduction of the protective cover depth and increase both concrete porosity and the transport of aggressive chemicals. In addition, this degradation mode can promote a reduction in concrete pH, loss of concrete strength, and spalling/scaling. Evidence shows that a wide variety of organisms can cause concrete deterioration in polluted soils and groundwater. The biodeterioration of concrete typically is confined to the surface. The rate of deterioration is slow, but the degradation mode has been observed within 40 years of exposure.

Although no cases of microbiological degradation of concrete have been reported in nuclear applications, the degradation mode is considered credible, as below-grade environments may be conducive to microbe and bacteria growth.

In air-outdoor or sheltered environments, favorable conditions for microbiological degradation mechanisms may exist because of the potential presence of moisture. However, the conditions would be intermittent, and there is no evidence that actual concrete subcomponents in these environments microbiologically degrade.

Therefore, microbiological degradation of concrete material is considered credible in a groundwater/soil environment, but is not credible in air-outdoor or sheltered environments.

3.5.3.6.13 Delayed Ettringite Formation of Concrete Material

At the initial stage of fresh concrete curing, ettringite, commonly referred to as "naturally occurring ettringite," is formed by the reaction of tricalcium aluminate and gypsum in the presence of water. The formation of naturally occurring ettringite in fresh concrete is not detrimental to the overall concrete performance. At the still-early stage of concrete curing, the naturally occurring ettringite may convert to monosulfoaluminate if curing temperatures are greater than about 70 °C (158 °F). After concrete hardens, if the temperature decreases below this value, the monosulfoaluminate becomes unstable and, in the presence of sulfates released by the C-S-H gel, ettringite will reform. This mechanism is called "delayed ettringite formation" (DEF), which results in volume expansion and increased internal pressures in the concrete.

The conditions necessary for the occurrence of DEF are excessive temperatures during concrete placement and curing, the presence of internal sulfates, and a moist environment. ACI 318-05 indicates that inspection reports shall document concrete temperature and protection during placement when the ambient temperature is above 35 °C (95 °F). Protection measures during concrete placement include lowering the temperature of the batch water, cement, and aggregates as referenced in ACI 305R-10. As such, following the ACI 318-05, ACI 305R-10, and ACI 308R-01 guidelines during concrete placement and curing can effectively limit the concrete temperature to below 70 °C (158 °F), therefore preventing the development of DEF.

As stated in Section 3.4.2, the HSMs are constructed in accordance with ACI 318-89 (for the AHSM) or ACI 318-08 (for the AHSM-HS) and, thus, DEF is not expected to occur.

As noted in Section 3.3.3, the basemat is designed and constructed in accordance with codes and standards set by the general licensee. Construction practices for the concrete basemat may vary from ISFSI to ISFSI. Therefore, DEF may be an applicable concrete aging mechanism for the basemat, unless ruled out by the general licensee based on an ISFSI-specific evaluation.

Therefore, delayed ettringite formation of the basemat concrete material is considered credible in air-outdoor, sheltered, or groundwater/soil environments, but is not credible for the HSM concrete material in air-outdoor or sheltered environments.

3.5.3.6.14 Salt Scaling of Concrete Material

Salt scaling is defined as superficial damage caused by freezing a saline solution on the surface of a concrete body. The damage is progressive and consists of the removal of small chips or flakes of material. Similar to freeze-thaw damage, salt scaling takes place when concrete is exposed to freezing temperatures, moisture, and dissolved salts. The degradation is maximized at a moderate concentration of salt (e.g., from deicing salts).

Similar to freeze-thaw damage, the degradation initiates at the outer concrete surface exposed to outdoor environments, primarily at horizontal surfaces where water ponding can occur. For below-grade concrete structures, water that resides in soil may contain salt and, thus, the concrete may be susceptible to salt scaling.

Concretes exposed to sheltered environments with low water availability or below-grade concrete maintained above freezing temperatures are not susceptible to salt scaling degradation.

Therefore, salt scaling of concrete material is considered credible in air-outdoor or groundwater/soil environments, but is not credible in a sheltered environment.

3.5.3.7 Aging Mechanism of Spent Fuel Assembly Cladding

Table 3-17 shows the environment that the SFA cladding is exposed to is:

- Helium

The following aging mechanisms for SFA cladding were evaluated to determine if they are credible in the environment that SFA cladding is exposed to:

- Hydride-induced embrittlement
- Delayed hydride cracking
- Thermal creep
- Low temperature creep
- Mechanical overload
- Oxidation
- Pitting corrosion
- Galvanic corrosion
- Stress corrosion cracking
- Radiation embrittlement
- Fatigue

3.5.3.7.1 Hydride-Induced Embrittlement of Spent Fuel Assembly Cladding

In reactor service, the zirconium-based fuel cladding absorbs hydrogen, which leads to the precipitation of hydride platelets as the dissolved hydrogen exceeds the solubility limit of the cladding. The primary source of the hydrogen is water-side corrosion (oxidation) of the cladding. The total concentration of hydrogen absorbed by the cladding (i.e., dissolved in the zirconium matrix and in precipitated hydrides) increases with burnup and varies axially across the fuel rods. When discharged from the reactor and during wet storage, the hydride platelets are mostly oriented in the circumferential-axial direction, with a smaller fraction oriented in the radial-axial direction.

During vacuum drying of the DSC, the temperature of the SFAs and the temperature-dependent solubility limit of hydrogen in the cladding will also increase. As a result, some of the hydrides present in the cladding will redissolve as hydrogen. Once the loaded canister is dried and backfilled, the cladding temperature will decrease over time and, upon a sufficient temperature drop, some of the hydrogen in solution will reprecipitate as new hydrides. During this process, the orientation of these precipitated hydrides may change from the circumferential-axial to the radial-axial direction. The degree of reorientation is primarily driven by the metallurgical microstructure of the cladding alloy and the cladding hoop stresses during drying operations and subsequent cooling, which are determined by the rod internal pressure at a given gas temperature. Cladding with a high concentration of radial hydrides (determined by the dry storage system drying conditions) has been shown to have reduced ductility under pinch-load stresses at sufficiently low temperatures. Section 3.6.1.1 of NUREG-2214 [3-2] contains more discussion of the hydride reorientation phenomenon, including expected ranges of dissolved hydrogen, drying temperatures, solubility limits, hoop stresses, and experimental studies.

Considering the hydrogen content, peak drying temperatures, and corresponding hoop stresses, hydride reorientation in zirconium-based high burnup (HBU) cladding is credible during the 60-year service timeframe. Furthermore, depending on the specific fuel contents, it is possible for some of the cladding to reach temperatures near or below the ductile-to-brittle transition temperatures reported in the literature.

Therefore, degradation of mechanical properties during pinch-type stresses due to hydride-induced embrittlement is considered a credible aging mechanism for zirconium-based HBU (i.e., > 45 GWd/MTU) fuel claddings. Hydride-induced embrittlement is not credible for low burnup (i.e., ≤ 45 GWd/MTU) fuel with stainless steel or zirconium-based alloy cladding.

3.5.3.7.2 Delayed Hydride Cracking of Spent Fuel Assembly Cladding

Delayed hydride cracking (DHC) is a time-dependent mechanism traditionally thought to occur by the diffusion of hydrogen to an incipient crack tip (notch, flaw) in the cladding, followed by nucleation, growth, and subsequent fracture of the precipitated hydrides at the crack tip. Hydrogen dissolved in the cladding (see Section 3.5.3.7.1) can diffuse up a stress gradient in the crystalline lattice or into the stress field at the core of an edge dislocation. The concentration gradient established by the stress gradient may lead to hydrogen supersaturation (i.e., solubility limit being exceeded), leading to the precipitation of hydrides at the crack tip. The precipitated hydride will continue to grow by the dissolution of hydrides in the low-stress regions of the material and by the continued diffusion of hydrogen up the stress gradient. Once the hydride reaches a critical size, it will crack and propagate to the end of the hydride, where it will blunt. The cycle could then repeat until the crack propagates through the thickness of the material.

Requisite conditions for DHC are the presence of: (1) hydrides, (2) existing crack tips (notch, flaws) that act as initiating sites, and (3) sufficient cladding hoop stresses. Section 3.6.1.2 of NUREG-2214 [3-2] discusses the availability of hydrides, initial depth of existing crack tips, and hoop stresses in zirconium-based fuel claddings. NUREG-2214 [3-2] goes on to determine that the critical flaw size needed to initiate DHC is larger than the initial depth of potentially existing cracks. Therefore, it is concluded that the DHC is not credible for zirconium-based fuel cladding.

Hydride formation is not a concern in stainless steel materials, thus, DHC is not credible in stainless steel cladding.

Therefore, delayed hydride cracking is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.3 Thermal Creep of Spent Fuel Assembly Cladding

Creep is the time-dependent deformation of a material under stress. Creep in zirconium-based cladding is caused by the hoop stresses from the rod internal pressure at a given fuel temperature. Therefore, the mechanism is expected to be self-limiting due to the decreasing temperatures and creep-induced volume expansion, which results in lower internal rod pressures with time. Excessive creep of the cladding during dry storage could lead to thinning, hairline cracks, or gross ruptures. Section 3.6.1.3 of NUREG-2214 [3-2] contains an evaluation of cladding hoop stresses during dry storage for HBU fuel. The evaluation estimated the maximum cladding strain to be near 2.1 percent. The elastic strain limit for various zirconium-based cladding alloys with circumferential hydrides is less than 1 percent and is expected to be lower for cladding containing both circumferential and radial hydrides. Therefore, zirconium-based cladding in HBU fuel is expected to undergo creep strains during the 60-year timeframe.

ISG-11, Revision 3 [3-10], provides the basis why thermal creep of low burnup (i.e., ≤ 45GWd/MTU) zirconium-based cladding is not a concern provided the peak normal cladding temperature is below 752 °F. As shown in Table 3-3, the maximum cladding temperature for normal condition (i.e., 70 °F ambient) for fuel stored in the 24PT1 DSC (i.e., the only DSC limited to storing low burnup fuel per Table 3-1) is 604 °F. Therefore, creep of low burnup fuel stored in a 24PT1 DSC is not a concern.

The stainless steel fuel cladding long-term average temperature limit of 690 °F was based on preventing creep failure. It was determined by using a steady state shear strain rate for irradiated fuel rods from curves for shear stress vs. temperature for a 50-year time to failure from EPRI TR-106440 [3-11] (refer to Section 3.5.1.2.1 of the UFSAR [3-3]). Since the maximum cladding temperature for normal condition (i.e., 70°F ambient) for fuel stored in the 24PT1 DSC (i.e., the only DSC allowed to store fuel with stainless steel cladding per Table 3-1) is 604 °F (Table 3-3), and this temperature will decrease during storage, it is reasonable to concluded that an extra 10 years of dry storage will not result in creep failure of the stainless steel cladding.

Therefore, thermal creep is considered a credible aging mechanism for zirconium-based HBU (i.e., > 45 GWd/MTU) fuel claddings. Thermal creep is not credible for low burnup (i.e., ≤ 45 GWd/MTU) fuel with stainless steel or zirconium-based alloy cladding.

3.5.3.7.4 Low Temperature Creep of Spent Fuel Assembly Cladding

Low-temperature creep (also called "athermal creep") may occur when sustained hoop stresses operate on the cladding material at or near ambient temperature. Various athermal creep mechanisms have been proposed at low stresses, although there is no evidence or literature information to support that these will be operational on zirconium-based alloys. However, the literature shows that low-temperature creep has been shown to occur in titanium and its alloys, which leads to deformation twinning. Since both titanium and zirconium have the same crystalline structure (hexagonal close packed crystalline), Section 3.6.1.4 of NUREG-2214 [3-2] performed an evaluation using the titanium threshold stress for low-temperature creep of 25 percent of the yield strength as the threshold stress for zirconium-based cladding.

The evaluation concluded that the room temperature hoop stresses on the zirconium-based cladding are expected to be less than 25 percent of the yield strength during the 60-year storage timeframe. Therefore, the low-temperature (athermal) creep mechanism is not considered credible.

Low temperature creep is not a concern in stainless steel materials, thus it is not credible in stainless steel cladding.

Therefore, low temperature creep is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.5 Mechanical Overload of Spent Fuel Assembly Cladding

Mechanical overload is generally associated with pellet-to-cladding mechanical interaction (PCMI), which could compromise the cladding integrity during storage. PCMI is likely during reactor operations when the reactivity transient during a reactivity-initiated accident results in a rapid increase in a fuel rod power, leading to a nearly adiabatic heating of the fuel pellets and potential failure of the fuel cladding. Data generated in experimental reactors conducting ramp testing of heavily hydrided fuel claddings (i.e., associated with HBU fuel) indicate that hydride rims with large hydride number density at the cladding outer surface may lead to crack initiation. The cracks could propagate from the outside toward the inner cladding surface, potentially resulting in failures. During dry storage, PCMI stresses could develop due to pellet swelling and release of fission gases to the gap between the fuel and cladding.

Section 3.6.1.5 of NUREG-2214 [3-2] contains a generic evaluation showing that the strain rates during storage of HBU zirconium-based cladding are expected to be five to seven orders of magnitude lower than the threshold strain rate needed for PCMI-induced failures.

Due to the expected lower hydride concentration in low burnup fuel (≤ 45 GWd/MTU), PCMI-induced failures are not considered credible.

Therefore, mechanical overload is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.6 Oxidation of Spent Fuel Assembly Cladding

There is very little residual water in the internal environments of a DSC following drying and refilling with inert helium gas, thus, the oxidation of the external surface of the cladding will be limited. Similarly, there is no moisture internal to the fuel pin that could contribute to the oxidation of the cladding.

Therefore, oxidation is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.7 Pitting Corrosion of Spent Fuel Assembly Cladding

Because there is very little residual water in the internal environments of a DSC following drying and refilling with inert helium gas, pitting corrosion of the external surface of the cladding will be limited. Similarly, there is no moisture internal to the fuel pin that could contribute to pitting corrosion of the cladding.

Therefore, pitting corrosion is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.8 Galvanic Corrosion of Spent Fuel Assembly Cladding

Galvanic corrosion can occur due to a mismatch in corrosion potentials between two metals in an aqueous solution. In fuel assemblies, the mismatch can occur when the cladding is in contact with other metallic components, which could result in the formation of a galvanic cell, provided there is an aqueous solution between the two subcomponents.

Because there is very little residual water in the internal environments of a DSC following drying and refilling with inert helium gas, oxidation of the external surface of the cladding will be limited. Similarly, there is no moisture internal to the fuel pin that could contribute to corrosion of the cladding.

Therefore, galvanic corrosion is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.9 Stress Corrosion Cracking of Spent Fuel Assembly Cladding

SCC occurs as a result of a synergistic combination of a susceptible material, an aggressive environment, and sufficiently high tensile stress. The corrosive environment associated with SCC of fuel rods has been attributed to specific fission products, such as iodine, cesium, and cadmium, generated during reactor irradiation. SCC of the cladding can occur at the rod's inner surface, where the fuel pellet and cladding mechanically interact, and is related to PCMI hoop stresses on the cladding.

Section 3.6.1.9 of NUREG-2214 [3-2] contains an evaluation showing that hoop stresses during a 60-year period of storage, including those due to PCMI, will remain below that needed for inducing SCC in zirconium-based cladding.

For low-burnup fuel, pellet expansion stresses will be minimal because the gap between the cladding and the pellet will accommodate the swelling. Since the stainless steel cladding is limited to low burnup fuel, it is not expected to experience SCC.

Therefore, SCC is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.10 Radiation Embrittlement of Spent Fuel Assembly Cladding

Radiation embrittlement of cladding can result in degradation of the mechanical properties of the cladding, such as ductility and strength. This can lead to the reduction in the maximum load that the cladding can withstand, potentially leaving the cladding vulnerable to failure under external loads. Radiation embrittlement of the cladding is mostly observed during reactor operation due to cumulative fast neutron fluence on the order of 10^{22} n/cm^2.

Section 3.2.1.9 of NUREG-2214 [3-2] describes a bounding calculation that showed estimated fluence after 100 years of storage, which is six orders of magnitude below the fluence seen during reactor operations. Therefore, 100 years of storage has a negligible contribution to the overall fast neutron fluence.

Therefore, radiation embrittlement is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.7.11 Fatigue of Spent Fuel Assembly Cladding

Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The only cyclic loading experienced by the spent fuel cladding is associated with thermal cycling. The only source of potential thermal fatigue of the spent fuel cladding is ambient seasonal and daily temperature fluctuation. The spent fuel cladding does not experience the full amplitude of ambient temperature cycles, and a gradual, long-term temperature decrease occurs during the course of storage. The seasonal and daily variations in ambient conditions are ameliorated by the thermal mass of the HSM and DSC.

Section 3.6.1.11 of NUREG-2214 [3-2] contains a very conservative evaluation of the cyclic stresses in zirconium-based spent fuel cladding due to thermal cycles over a 60-year storage period. It concludes that the cumulative cyclic stresses are well below the threshold needed for fatigue-induced failure of the zirconium-based cladding.

Because stainless steel cladding is stronger than the zirconium-based cladding, the conclusion that the cumulative cyclic stresses are well below the threshold needed for fatigue-induced failure would also apply to the stainless steel cladding.

Therefore, fatigue is not credible for stainless steel or zirconium-based alloy SFA cladding.

3.5.3.8 Aging Mechanism of Spent Fuel Assembly Hardware Materials

Table 3-17 shows the environment that the SFA hardware materials are exposed to is:

- Helium

The following aging mechanisms for SFA hardware materials were evaluated to determine if they are credible in the environment that SFA hardware materials are exposed to:

- Creep
- Hydriding
- General corrosion
- Stress corrosion cracking
- Radiation embrittlement
- Fatigue

3.5.3.8.1 Creep of Spent Fuel Assembly Hardware Materials

As discussed in Section 3.5.3.1.6, as a general rule of thumb, thermal activation is insufficient to produce significant creep at temperatures below $0.4T_m$, where T_m is the melting point of the metal in Kelvin. The melting temperature of various zirconium*, Inconel, and stainless steel alloys is above 3,272 °F, 2,300 °F, and 2,597 °F, respectively*. Appling the $0.4T_m$ criterion yields a creep threshold of 1,033 °F for zirconium alloys*,* 644 °F for Inconel alloys*, and 763 °F for stainless steel*.

The highest temperatures within the DSCs are at locations close to the fuel rods. As shown in Table 3-3, the maximum fuel cladding temperature for any DSC at the beginning of storage was determined to be 727 °F. Because the fuel rods are the only heat source within the system, they provide upper temperature limits for all subcomponents regardless of their environment. It is apparent from the temperatures in Table 3-3 that SFA hardware made with zirconium alloys will not approach the minimum 1,033 °F creep threshold temperature *and the stainless steel SFA hardware will not approach the 763 °F creep threshold temperature*.

All changes on this page are as a result of OBS 3-3

While the maximum fuel cladding at the beginning of storage is greater than the creep threshold for Inconel, it will continue to decrease during the initial 20 years of storage. By the end of the initial 20 years of storage, the maximum cladding temperature will be on the order of 362 °F, which is below the 644 °F creep threshold for the Inconel Alloys.

Therefore, creep is not credible for the SFA hardware materials.

3.5.3.8.2 Hydriding of Spent Fuel Assembly Hardware Materials

Hydriding may occur in zirconium alloys that experience hydrogen pickup in reactor service. As the temperature of the assembly hardware decreases, zirconium hydrides precipitate due to the decreasing hydrogen solubility in the zirconium matrix. The hydride precipitation will occur when the hardware cools in the spent fuel pools after reactor discharge. Some of the hydride will dissolve during the drying process and will reprecipitate due to subsequent cooling during storage. Unlike fuel rods with cladding, there is no hoop stress for the zirconium-based assembly hardware to cause hydride reorientation. Any load on the assembly hardware is predominantly due to its own weight, which is not sufficient to cause hydride reorientation. Because there is limited load during storage on assembly hardware, it is unlikely that hydriding will affect the ability of the assembly hardware to ensure that the spent fuel remains in the as-analyzed configuration.

Hydride formation is not a concern in stainless steel materials, thus hydriding is not credible in stainless steel cladding.

Therefore, hydriding is not credible for the SFA hardware materials.

3.5.3.8.3 General Corrosion of Spent Fuel Assembly Hardware Materials

There is very little residual water in the internal environments of a DSC following drying and refilling with inert helium gas, thus general corrosion of the SFA hardware will be limited.

Therefore, general corrosion is not credible for the SFA hardware materials.

3.5.3.8.4 Stress Corrosion Cracking of Spent Fuel Assembly Hardware Materials

SCC of SFA hardware made of zirconium alloys is not considered credible based on the discussion in Section 3.5.3.7.9.

All changes on this page are as a result of OBS 3-3

Various stainless steel and Inconel assembly hardware components could be susceptible to SCC in the presence of an aggressive environment and sufficient residual tensile stresses. Residual tensile stresses are expected to be present in the assembly hardware, primarily in welded areas. Regarding the chemical environment, the SFA hardware is exposed to the inert helium environment within the DSC. In addition, there is very little residual water in the internal environments of a DSC following drying and refilling with inert helium gas. Because of the lack of halides and the small amount of water in the helium environments, SCC of stainless steel and Inconel hardware components is not considered credible.

Therefore, SCC is not credible for the SFA hardware materials.

3.5.3.8.5 Radiation Embrittlement of Spent Fuel Assembly Hardware Materials

Radiation embrittlement of SFA hardware, such as guide tubes and spacer grid materials made from zirconium alloys, is excluded using the basis provided in Section 3.5.3.7.10. Similarly, radiation embrittlement of assembly hardware made of stainless steel or Inconel is not considered credible per the technical bases provided in Section 3.5.3.1.9.

Therefore, radiation embrittlement is not credible for the SFA hardware materials.

3.5.3.8.6 Fatigue of Spent Fuel Assembly Hardware Materials

Fatigue of SFA hardware, such as guide tubes and spacer grid materials made from zirconium alloys, is excluded using the basis provided in Section 3.5.3.7.11. Similarly, fatigue of assembly hardware made of stainless steel or Inconel is not considered credible per the technical bases provided in Sections 3.5.3.1.7 and 3.5.3.2.7, and Section 3.2.4.5 of NUREG-2214 [3-2].

Therefore, fatigue is not credible for the SFA hardware materials.

3.5.3.9 Aging Mechanism of Poison Rodlets

Table 3-11 through Table 3-17 show that the only environments that the poison rodlets are exposed to are:

- Fully encased
- Helium

The poison rodlets consist of B_4C pellets or powder encased in a stainless steel tube. The only aging mechanism applicable to the B_4C is depletion of the boron. The aging mechanisms of the stainless steel tube are the same as those evaluated for the SFA hardware in Section 3.5.3.8.

3.5.3.9.1 Boron Deletion of the Boron Carbide Material

Depletion of the Boron-10 atoms in the neutron poison materials used in the DSCs was evaluated in Section 3.5.3.5.4. That evaluation is also applicable to the B_4C material in the poison rodlets. The evaluation concluded that only [ ] percent of the available Boron-10 atoms would be depleted after 60 years, which is too small to challenge the criticality control function of the B_4C material.

Therefore, boron depletion of the B_4C material is not credible.

3.5.3.10 Summary of Aging Mechanism of Materials

Table 3-6 provides a summary of the aging mechanisms for materials used in the Standardized Advanced NUHOMS® System. The table also lists the environments where the aging mechanism could manifest into an aging effect that affects an important-to-safety function (i.e., is considered credible.) Table 3-6 also identifies the aging effect into which each credible aging mechanism could manifest (based on Table 2-4 of NUREG-2214 [3-2]).

3.6 Aging Management Review for DSC

Table 3-11, Table 3-12, and Table 3-13 provide the detailed results of the AMR for the subcomponent parts of the 24PT1, 24PT4, and 32PTH2 DSCs, respectively. For each material group/environment combination and each part, the table lists the credible aging mechanisms and effects based on the information in Table 3-6. A summary of the aging effects that require management for the DSCs is provided in Table 3-7.

The following aging effects/mechanisms will be managed via a TLAA, as dispositioned in Appendix 3A:

- Stainless Steel
  - Cracking of the cylindrical shell due to fatigue
- Aluminum
  - Change in dimensions due to creep

The following aging effects/mechanisms will be managed via the DSC AMP:

- Stainless Steel
  - Loss of material due to pitting, crevice, and galvanic corrosion
  - Cracking due to SCC

3.7 Aging Management Review for HSM

Table 3-14 and Table 3-15 provide the detailed results of the AMR for the subcomponent parts of the AHSM and AHSM-HS, respectively. For each material group/environment combination and each part, the table lists the credible aging mechanisms and effects based on the information in Table 3-6. A summary of the aging effects that require management for the HSMs is provided in Table 3-8.

The following aging effects/mechanisms will be managed via the HSM AMP:

- Steel
  - Loss of material due to general, pitting, crevice, and galvanic corrosion
- Stainless Steel
  - Loss of material due to pitting, and crevice corrosion
  - Cracking due to SCC
- Concrete
  - Loss of material due to freeze-thaw, aggressive chemical attack, corrosion of reinforcing steel, and salt scaling
  - Cracking due to freeze-thaw, reaction with aggregates, differential settlement, aggressive chemical attack, and corrosion of reinforcing steel
  - Loss of strength due to reaction with aggregates, aggressive chemical attack, corrosion of reinforcing steel, and leaching of calcium hydroxide
  - Reduction of concrete pH due to aggressive chemical attack and leaching of calcium hydroxide
  - Loss of concrete/steel bond due to corrosion of reinforcing steel
  - Increase in porosity and permeability due to leaching of calcium hydroxide

3.8 Aging Management Review for Basemat

Table 3-16 provides the detailed results of the AMR for the subcomponent parts of the basemat. For each material group/environment combination and each part, the table lists the credible aging mechanisms and effects based on the information in Table 3-6. A summary of the aging effects that require management for the basemat is provided in Table 3-9.

The following aging effects/mechanisms will be managed via the basemat AMP:

- Steel
  - Loss of material due to general, pitting, and crevice corrosion
- Concrete
  - Loss of material due to freeze-thaw, aggressive chemical attack, corrosion of reinforcing steel, delayed ettringite formation [1], salt scaling, and microbiological degradation
  - Cracking due to freeze-thaw, reaction with aggregates, differential settlement, aggressive chemical attack, corrosion of reinforcing steel, and delayed ettringite formation [1]
  - Loss of strength due to reaction with aggregates, aggressive chemical attack, corrosion of reinforcing steel, leaching of calcium hydroxide, delayed ettringite formation [1], and microbiological degradation
  - Reduction of concrete pH due to aggressive chemical attack, leaching of calcium hydroxide, and microbiological degradation
  - Loss of concrete/steel bond due to corrosion of reinforcing steel
  - Increase in porosity and permeability due to leaching of calcium hydroxide and microbiological degradation

[1] Delayed ettringite formation may be ruled out as a credible aging mechanism by the general licensee based on an ISFSI-specific evaluation.

3.9 Aging Management Review for Spent Fuel Assemblies

Table 3-17 provides the detailed results of the AMR for the subcomponent parts of the SFAs. For each material group/environment combination and each part, the table lists the credible aging mechanisms and effects based on the information in Table 3-6. A summary of the aging effects that require management for the SFAs is provided in Table 3-10.

The following aging effects/mechanisms for HBU fuel will be managed via the HBU AMP:

- Zirconium-Based Alloy
  - Loss of ductility due to hydride-induced embrittlement
  - Changes in dimensions due to thermal creep

3.10 Operating Experience Review Results – Aging Effects Identification

The review of various sources of OE discussed in Appendix 3C did not identify any aging mechanisms and/or effects that were not already identified in NUREG-2214 [3-2]. In addition, no incidents were identified where aging effects lead to the loss of intended safety functions of Standardized NUHOMS® System SSCs. Therefore, it is concluded that the effects of aging will be managed adequately so that the SSC intended safety functions will be maintained during the PEO.

3.11 References

3-1 NUREG-1927, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel," Revision 1, U.S. Nuclear Regulatory Commission, June 2016 (ADAMS Accession Number ML16179A148).

3-2 NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report," Draft report for comment, U.S. Nuclear Regulatory Commission, October 2017 (ADAMS Accession Number ML17289A237).

3-3 TN Americas LLC, ANUH-01.0150, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 9, March 2019.

3-4 NUREG-1801, "Generic Aging Lessons Learned (GALL) Report—Final Report," Revision 2, U.S. Nuclear Regulatory Commission, December 2010.

3-5 ACI 349-97, "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute.

3-6 ACI-318, "Building Code Requirements for Reinforced Concrete," American Concrete Institute, 1989 (92).

3-7 ACI 349-06, "Code Requirements for Nuclear Safety Related Concrete Structures," American Concrete Institute.

3-8 ACI-318, "Building Code Requirements for Reinforced Concrete," American Concrete Institute, 2008.

3-9 U.S. Nuclear Regulatory Commission, CoC 1029, Appendix A, "Technical Specifications for the Standardized Advanced NUHOMS System Operation Controls and Limits," Amendment 4, March 12, 2019, Docket No. 72-1029.

3-10 NRC, Spent Fuel Project Office, Interim Staff Guidance 11,"Cladding Considerations for the Transportation and Storage of Spent Fuel," Revision 3, November 17, 2003.

3-11 Electric Power Research Institute, "Evaluation of Expected Behavior of LWR Stainless Steel-Clad Fuel in Long-Term Dry Storage," EPRI-TR-106440, April 1996.

3-12 NUREG/CR-6428, "Effects of Thermal Aging on Fracture Toughness and Charpy-Impact Strength of Stainless Steel Pipe Welds," U.S. Nuclear Regulatory Commission, May 1996.

3-13 Electrical Power Research Institute, "Materials Reliability Program: PWR Internals Material Aging Degradation Mechanism Screening and Threshold Values (MRP-175)," EPRI-TR-1012081, 2005.

3-14 A. Turnbull et al., "Sensitivity of stress corrosion cracking of stainless steel to surface machining and grinding procedure," Corrosion Science 53, 2011, 3398-3415.

Table 3-1
Approved Fuel Designs

DSC Type	Fuel Type	Fissile Material	Cladding Material	Burnup Limit	Source
24PT1	WE 14x14	UO_2	Stainless Steel	45 GWd/MTU	[3-9]
	WE 14x14	MOX	Zircaloy-4	25 GWd/MTU	[3-9]
24PT4	CE 16x16	UO_2 $(U, Er)O_2$ $(U, Gd)O_2$	Zircaloy-4 ZIRLO™	60 GWd/MTU	[3-9]
32PTH2	CE 16x16	UO_2 (UO_2, Er_2O_3) (UO_2, Gd_2O_3) (UO_2, ZrB_2)	Zirconium-Based Alloy	62.5 GWd/MTU	[3-9] and [3-3]

Table 3-2
Material Groupings

Material Group	Description
Steel	Various carbon steels, alloy steels, and high-strength, low-alloy steels. Galvanized steel, aluminum-coated steel, and electroless nickel-plated steel are also included in the category of steel.
Stainless Steel	Stainless steel includes austenitic stainless steels and martensitic stainless steel. Chrome-plated stainless steel is also included in the category of steel.
Aluminum	Includes commercially pure aluminum 1100 and precipitation-hardened alloys 6061 and 6063.
Lead	Material that meets American Society of Testing Materials (ASTM) B29 Specification.
BORAL® and MMC	BORAL® is a laminate composite that is used as a neutron poison material. It consists of a core of aluminum and B_4C powder sandwiched between sheets of aluminum. MMC is a B_4C-aluminum metal matrix composite for neutron poison applications.
Concrete	A mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibers, or other cementitious materials.
Spent Fuel Assembly Cladding	Various zirconium-based materials used such as Zircaloy-2, Zircaloy-4, ZIRLO™, and M5™ are included in this category. This material type also includes stainless steel.
Spent Fuel Assembly Hardware	This group includes stainless steel, zirconium-based alloys, and nickel alloys.
Boron Carbide	A B_4C compound in a powder or pellet form.

Table 3-3
Maximum DSC Shell and Fuel Cladding Temperatures

HSM Model	DSC Type	Ambient Temperature (°F)	Max DSC Shell Temperature (°F)	Max Fuel Cladding Temperature (°F)	UFSAR Source
AHSM	24PT1 (16 kW)	0	230	566	Table 4.4-4 for Shell Temperature Table 4.4-7 for Fuel Cladding Temperature
		70	297	604	
		104	322	618	
		-40	192	545	
		117	332	624	
AHSM	24PT4 (24 kW)	104	459.3	697	Table A.4.4-4 for Shell Temperature Table A.4.4-7 for Fuel Cladding Temperature
		-40	358.7	636	
		117	469.3	707	
AHSM-HS	32PTH2 (37.2 kW)	-40	292	613	Table B.4.4-3 for Shell Temperature Table B.4.6-14 for Fuel Cladding Temperature
		117	421	727	

Table 3-4
Average Helium temperature in DSCs

DSC Type	Average Helium Temperature (°F)	Off-Normal Design Pressure (psig)	UFSAR Source
24PT1	483	20	Table 4.4-11
24PT4	550.1	26	Table A.4.4-10
32PTH2	577	20	Table B.4.7-1

Table 3-5
Maximum HSM Temperatures

HSM Model	DSC Type	Ambient Temperature (°F)	Max Concrete Temperature (°F)	Max Heat Shield Temperature (°F)	Max DSC Support Structure Temperature (°F)	UFSAR Source
AHSM	24PT1 (16 kW)	0	103	136	268	Table 4.4-3
		70	187	225	328	
		104	219	258	351	
		-40	56	87	233	
		117	231	270	360	
AHSM	24PT4 (24 kW)	104	232	314	281	Table A.4.4-3
		-40	80	180	170	
		117	242	324	291	
AHSM-HS	32PTH2 (37.2 kW)	-40	117	61	213	Table B.4.4-3
		117	274	249	353	

Table 3-6
Summary of Potential Aging Mechanisms
(4 Pages)

Material Grouping	Aging Mechanism	Credible Environments	Section	Aging Effect
Steel	General Corrosion	Air-Outdoor Sheltered Embedded-in-Concrete	3.5.3.1.1	Loss of Material
	Pitting and Crevice Corrosion	Air-Outdoor Sheltered Embedded-in-Concrete	3.5.3.1.2	Loss of Material
	Galvanic Corrosion	Air-Outdoor (6) Sheltered (6)	3.5.3.1.3	Loss of Material
	Microbiologically Influenced Corrosion	Embedded-in-Concrete (3)	3.5.3.1.4	Loss of Material
	Stress Corrosion Cracking	None	3.5.3.1.5	None
	Creep	None	3.5.3.1.6	None
	Fatigue	None	3.5.3.1.7	None
	Thermal Aging	None	3.5.3.1.8	None
	Radiation Embrittlement	None	3.5.3.1.9	None
	Stress Relaxation	None	3.5.3.1.10	None
	Wear	None	3.5.3.1.11	None
Stainless Steel	General Corrosion	None	3.5.3.2.1	None
	Pitting and Crevice Corrosion	Air-Outdoor Sheltered	3.5.3.2.2	Loss of Material
	Galvanic Corrosion	Air-Outdoor (1) Sheltered (1)	3.5.3.2.3	Loss of Material
	Microbiologically Influenced Corrosion	None	3.5.3.2.4	None
	Stress Corrosion Cracking	Air-Outdoor Sheltered	3.5.3.2.5	Cracking
	Creep	None	3.5.3.2.6	None
	Fatigue	Sheltered (2) Helium (2) Fully Encased (2)	3.5.3.2.7	Cracking
	Thermal Aging	None	3.5.3.2.8	None
	Radiation Embrittlement	None	3.5.3.2.9	None
	Stress Relaxation	None	3.5.3.2.10	None
	Wear	None	3.5.3.2.11	None

Table 3-6
Summary of Potential Aging Mechanisms
(4 Pages)

Material Grouping	Aging Mechanism	Credible Environments	Section	Aging Effect
Aluminum	General Corrosion	None	3.5.3.3.1	None
	Pitting and Crevice Corrosion	None	3.5.3.3.2	None
	Galvanic Corrosion	None	3.5.3.3.3	None
	Microbiologically Influenced Corrosion	None	3.5.3.3.4	None
	Creep	Helium	3.5.3.3.5	Change in Dimensions
	Fatigue	None	3.5.3.3.6	None
	Thermal Aging	None	3.5.3.3.7	None
	Radiation Embrittlement	None	3.5.3.3.8	None
Lead	None Identified	None	3.5.3.4	None
BORAL® and MMC	General Corrosion	None	3.5.3.5.1	None
	Galvanic Corrosion	None	3.5.3.5.2	None
	Wet Corrosion and Blistering	None	3.5.3.5.3	None
	Boron Depletion	None	3.5.3.5.4	None
	Creep	None	3.5.3.5.5	None
	Thermal Aging	None	3.5.3.5.6	None
	Radiation Embrittlement	None	3.5.3.5.7	None
Concrete	Freeze-Thaw	Air-Outdoor Groundwater/Soil	3.5.3.6.1	Cracking Loss of Material
	Creep	None	3.5.3.6.2	
	Reaction with Aggregates	Air-Outdoor Groundwater/Soil Sheltered	3.5.3.6.3	Cracking Loss of Strength
	Differential Settlement	Air-Outdoor Groundwater/Soil Sheltered	3.5.3.6.4	Cracking
	Aggressive Chemical Attack	Air-Outdoor Groundwater/Soil	3.5.3.6.5	Cracking Loss of Strength Loss of Material Reduction of Concrete pH

Table 3-6
Summary of Potential Aging Mechanisms
(4 Pages)

Material Grouping	Aging Mechanism	Credible Environments	Section	Aging Effect
	Corrosion of Reinforcing Steel	Air-Outdoor Groundwater/Soil	3.5.3.6.6	Loss of Concrete/Steel Bond
				Loss of Material
				Cracking
				Loss of Strength
	Shrinkage	None	3.5.3.6.7	None
	Leaching of Calcium Hydroxide	Air-Outdoor Groundwater/Soil Sheltered	3.5.3.6.8	Loss of Strength
				Increase in Porosity and Permeability
				Reduction of Concrete pH
	Radiation Damage	None	3.5.3.6.9	None
	Fatigue	None	3.5.3.6.10	None
	Dehydration at High Temperature	None	3.5.3.6.11	None
	Microbiological Degradation	Groundwater/Soil	3.5.3.6.12	Loss of Strength
				Loss of Material
				Increase in Porosity and Permeability
				Reduction of Concrete pH
	Delayed Ettringite Formation	Air-Outdoor (4) Groundwater/Soil (4) Sheltered (4)	3.5.3.6.13	Loss of Material
				Loss of Strength
				Cracking
	Salt Scaling	Air-Outdoor Groundwater/Soil	3.5.3.6.14	Loss of Material
Spent Fuel Assembly Cladding	Hydride-Induced Embrittlement	Helium (5)	3.5.3.7.1	Loss of Ductility
	Delayed Hydride Cracking	None	3.5.3.7.2	None
	Thermal Creep	Helium (5)	3.5.3.7.3	Changes in Dimensions
	Low Temperature Creep	None	3.5.3.7.4	None

Table 3-6
Summary of Potential Aging Mechanisms
(4 Pages)

Material Grouping	Aging Mechanism	Credible Environments	Section	Aging Effect
	Mechanical Overload	None	3.5.3.7.5	None
	Oxidation	None	3.5.3.7.6	None
	Pitting Corrosion	None	3.5.3.7.7	None
	Galvanic Corrosion	None	3.5.3.7.8	None
	Stress Corrosion Cracking	None	3.5.3.7.9	None
	Radiation Embrittlement	None	3.5.3.7.10	None
	Fatigue	None	3.5.3.7.11	None
Spent Fuel Assembly Hardware	Creep	None	3.5.3.8.1	None
	Hydriding	None	3.5.3.8.2	None
	General Corrosion	None	3.5.3.8.3	None
	Stress Corrosion Cracking	None	3.5.3.8.4	None
	Radiation Embrittlement	None	3.5.3.8.5	None
	Fatigue	None	3.5.3.8.6	None
Boron Carbide	Depletion	None	3.5.3.9.1	None

Notes:

1. Only for stainless steel in contact with a graphite lubricant.
2. Fatigue is only credible for the DSC shell subcomponent.
3. Only if the concrete is exposed to a groundwater/soil environment.
4. DEF is credible for the basemat only, unless ruled out by the general licensee based on ISFSI-specific evaluation.
5. Only for HBU fuel.
6. Only for steel in contact with more noble materials such as stainless steel.

All changes on this page are as a result of OBS 3-4

Table 3-7
Aging Management Review Results for DSCs
(3 Pages)

Subcomponent Parts		Intended Safety Function(s) [1]	Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Cylindrical Shell		CO, SH, SR, TH, RT	Stainless Steel	(I) Helium	Fatigue	Cracking	TLAA
				(I) Fully Encased	Fatigue	Cracking	TLAA
				(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Galvanic Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP
					Fatigue	Cracking	TLAA
Outer Bottom Cover Plate		SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Galvanic Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP

Table 3-7
Aging Management Review Results for DSCs
(3 Pages)

Subcomponent Parts		Intended Safety Function(s) [(1)]	Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Grapple Ring and Support		SR, RT	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP
Shear Key		SR	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP
Outer Top Cover Plate and Test Port plug		CO, SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP

Table 3-7
Aging Management Review Results for DSCs
(3 Pages)

Subcomponent Parts		Intended Safety Function(s) [(1)]	Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Bottom Shield Plug Outer Casing		SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Galvanic Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP
Inner Bottom Cover Plate		CO, SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
					Galvanic Corrosion	Loss of Material	DSC AMP
					Stress Corrosion Cracking	Cracking	DSC AMP
Basket Plates		SH, CR, TH	Aluminum	Helium	Creep	Change in Dimensions	TLAA
Shims		SR	Aluminum	Helium	Creep	Change in Dimensions	TLAA
Basket Transition Rails		SH, CR, SR, TH	Aluminum	Helium	Creep	Change in Dimensions	TLAA

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT). Note that not all of the subcomponents in a group have all of the listed intended safety functions for that group.
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to an internal (or towards the interior of the DSC) environment and (E) refers to an external (or towards the exterior of the DSC) environment.

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Base Walls, Roof, Door Concrete Core		SH, SR, TH, RT	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
			Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
						Loss of Material	HSM AMP
					Reaction with Aggregates	Cracking	HSM AMP
						Loss of Strength	HSM AMP
					Differential Settlement	Cracking	HSM AMP
					Aggressive Chemical Attack	Cracking	HSM AMP
						Loss of Strength	HSM AMP
						Loss of Material	HSM AMP
						Reduction of Concrete pH	HSM AMP
					Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
						Loss of Material	HSM AMP
						Cracking	HSM AMP
						Loss of Strength	HSM AMP
					Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
						Increase in Porosity and Permeability	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
						Reduction of Concrete pH	HSM AMP
					Salt Scaling	Loss of Material	HSM AMP
				Sheltered	Reaction with Aggregates	Cracking	HSM AMP
						Loss of Strength	HSM AMP
					Differential Settlement	Cracking	HSM AMP
					Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
						Increase in Porosity and Permeability	HSM AMP
						Reduction of Concrete pH	HSM AMP
Outlet Vent Cover, End Walls, Rear Walls, Lower Vent Cover, Transition Roof, Transition Walls		SH, SR, TH	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
			Concrete	Air-outdoor	Freeze-Thaw	Cracking	HSM AMP
						Loss of Material	HSM AMP
					Reaction with Aggregates	Cracking	HSM AMP
						Loss of Strength	HSM AMP
					Differential Settlement	Cracking	HSM AMP
					Aggressive Chemical Attack	Cracking	HSM AMP
						Loss of Strength	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
						Loss of Material	HSM AMP
						Reduction of Concrete pH	HSM AMP
					Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
						Loss of Material	HSM AMP
						Cracking	HSM AMP
						Loss of Strength	HSM AMP
					Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
						Increase in Porosity and Permeability	HSM AMP
						Reduction of Concrete pH	HSM AMP
					Salt Scaling	Loss of Material	HSM AMP
DSC Support Structure Assembly Hardware		SR	Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
				Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
DSC Support Structure Assembly		SR, TH, RT	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Adjustable DSC Axial Retainer		SR	Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts	[ ]	Intended Safety Functions (3)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Heat Shield Assemblies Attachment Hardware		SR	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
				Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Heat Shields		SH, TH	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Rear Wall and Shield Door Attachment Embedment Hardware		SR	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
				Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Shield Door Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
				Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
				Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts	[ ]	Intended Safety Functions [3]	Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Shield Door Backing Plate		SH, SR	Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Deformed Bar Anchors, Mechanical Splice, Rebar		SR	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
Upper and Lower Vent Cover Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
				Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts	[ ]	Intended Safety Functions [3]	Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Module-to Module-Wall Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
				Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
				Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
AHSM Roof Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP

Table 3-8
Aging Management Review Results for HSMs
(9 Pages)

Subcomponent Parts	[ ]	Intended Safety Functions [3]	Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS Roof Connection Hardware		SR	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
AHSM Liner Plates		SH, TH	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP
Transition Wall Attachment Hardware		SR	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
				Sheltered	General Corrosion	Loss of Material	HSM AMP
					Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Galvanic Corrosion	Loss of Material	HSM AMP
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
					Stress Corrosion Cracking	Cracking	HSM AMP

Notes:

1. UFSAR Drawing NUH-03-4011 does not assign a part number to these subcomponents; however, the drawing does call them out and specifies the design and construction standards (i.e., Note 1 on Drawing NUH-03-4011).
2. UFSAR Drawings NUH-03-4012 and NUH 03-4013 do not assign a part number to these subcomponents; however, the drawings do show them.
3. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT). Note that not all of the subcomponents in a group have all of the listed intended safety functions for that group.

Table 3-9
Aging Management Review Results for Basemat
(3 Pages)

Subcomponent Parts	Intended Safety Function(s) (2)	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Basemat	SR, RT	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	Basemat AMP
				Pitting and Crevice Corrosion	Loss of Material	Basemat AMP
		Concrete	Air-Outdoor	Freeze-Thaw	Cracking	Basemat AMP
					Loss of Material	Basemat AMP
				Reaction with Aggregates	Cracking	Basemat AMP
					Loss of Strength	Basemat AMP
				Differential Settlement	Cracking	Basemat AMP
				Aggressive Chemical Attack	Cracking	Basemat AMP
					Loss of Strength	Basemat AMP
					Loss of Material	Basemat AMP
					Reduction of Concrete pH	Basemat AMP
				Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	Basemat AMP
					Loss of Material	Basemat AMP
					Cracking	Basemat AMP
					Loss of Strength	Basemat AMP
				Leaching of Calcium Hydroxide	Loss of Strength	*Basemat AMP*
					Increase in Porosity and Permeability	*Basemat AMP*
					Reduction of Concrete pH	*Basemat AMP*

All changes on this page are as a result of OBS 3-5

Table 3-9
Aging Management Review Results for Basemat
(3 Pages)

Subcomponent Parts	Intended Safety Function(s) (2)	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
				Delayed Ettringite Formation (1)	Loss of Material	Basemat AMP
					Loss of Strength	Basemat AMP
					Cracking	Basemat AMP
				Salt Scaling	Loss of Material	Basemat AMP
			Sheltered	Reaction with Aggregates	Cracking	Basemat AMP
					Loss of Strength	Basemat AMP
				Differential Settlement	Cracking	Basemat AMP
				Leaching of Calcium Hydroxide	Loss of Strength	Basemat AMP
					Increase in Porosity and Permeability	Basemat AMP
					Reduction of Concrete pH	Basemat AMP
				Delayed Ettringite Formation (1)	Loss of Material	Basemat AMP
					Loss of Strength	Basemat AMP
					Cracking	Basemat AMP
			Groundwater/ Soil	Freeze-Thaw	Cracking	Basemat AMP
					Loss of Material	Basemat AMP
				Reaction with Aggregates	Cracking	Basemat AMP
					Loss of Strength	Basemat AMP
				Differential Settlement	Cracking	Basemat AMP
				Aggressive Chemical Attack	Cracking	Basemat AMP
					Loss of Strength	Basemat AMP

Table 3-9
Aging Management Review Results for Basemat
(3 Pages)

Subcomponent Parts	Intended Safety Function(s) (2)	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
					Loss of Material	Basemat AMP
					Reduction of Concrete pH	Basemat AMP
				Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	Basemat AMP
					Loss of Material	Basemat AMP
					Cracking	Basemat AMP
					Loss of Strength	Basemat AMP
				Leaching of Calcium Hydroxide	Loss of Strength	Basemat AMP
					Increase in Porosity and Permeability	Basemat AMP
					Reduction of Concrete pH	Basemat AMP
				Microbiological Degradation	Loss of Strength	Basemat AMP
					Loss of Material	Basemat AMP
					Increase in Porosity and Permeability	Basemat AMP
					Reduction of Concrete pH	Basemat AMP
				Delayed Ettringite Formation (1)	Loss of Material	Basemat AMP
					Loss of Strength	Basemat AMP
					Cracking	Basemat AMP
				Salt Scaling	Loss of Material	Basemat AMP

Notes:

1. Delayed Ettringite formation may be ruled out as a credible aging mechanism by the general licensee based on an ISFSI-specific evaluation.

2. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT). Note that not all of the subcomponents in a group have all of the listed intended safety functions for that group.

Table 3-10
Aging Management Review Results for Spent Fuel Assemblies

Subcomponent	Intended Safety Function(s) (4)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Fuel Cladding and End Plugs	CO, CR, SR, TH	Spent Fuel Assembly Cladding (1)	(I) Helium	Hydride-Induced Embrittlement (3)	Loss of Ductility (3)	HBU AMP
				Thermal Creep (3)	Changes in Dimensions (3)	HBU AMP
			(E) Helium	Hydride-Induced Embrittlement (3)	Loss of Ductility (3)	HBU AMP
				Thermal Creep (3)	Changes in Dimensions (3)	HBU AMP

Notes:

1. Zirconium alloy claddings only, including Zircaloy-4, OPTIN™, M5™, or Zirlo™.
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to the internal environment of the fuel pin and (E) refers to an external environment of the fuel pin.
3. For high burnup fuel only.
4. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT). Note that not all of the subcomponents in a group have all of the listed intended safety functions for that group.

Table 3-11
Aging Management Review for 24PT1 DSC
(4 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT1			Spacer Disc Type "A", Plate	SH, CR, SR, TH		Steel	Helium	None	None	No
24PT1			Spacer Disc Type "B", Plate	SH, CR, SR, TH		Steel	Helium	None	None	No
24PT1			Top End Spacer Sleeve	SR		Stainless Steel	Helium	None	None	No
24PT1			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Bottom End Spacer Sleeve	SR		Stainless Steel	Helium	None	None	No
24PT1			Support Rod	SR		Stainless Steel	Helium	None	None	No
24PT1			Pin	SR		Stainless Steel	Helium	None	None	No
24PT1			Cylindrical Shell	CO, SH, SR, TH, RT		Stainless Steel	(I) Helium	Fatigue	Cracking	TLAA
							(I) Fully Encased	Fatigue	Cracking	TLAA
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
								Fatigue	Cracking	TLAA
24PT1			Outer Bottom Cover Plate	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Bottom Shield Plug	SH, SR, TH		Steel	Fully Encased	None	None	No
24PT1			Grapple Ring	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP

Table 3-11
Aging Management Review for 24PT1 DSC
(4 Pages)

Component	[	]	Subcomponent Parts	Intended Safety Function (1)	[ ]	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT1			Grapple Ring Support	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Inner Bottom Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
24PT1			Shear Key	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Key	SR		Stainless Steel	Helium	None	None	No
24PT1			Siphon and Vent Block	CO, SH, SR		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
24PT1			Lifting Lug	SR		Stainless Steel	Helium	None	None	No
24PT1			Support Ring, Bar Stock	SR		Stainless Steel	Helium	None	None	No
24PT1			Top Shield Plug	SH, SR, TH		Steel	Helium	None	None	No
24PT1			Outer Top Cover Plate	CO, SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Siphon and Vent Port Cover Plate	CO, SH, SR		Stainless Steel	(E) Fully Encased	None	None	No
							(I) Helium	None	None	No
24PT1			Inner Top Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
24PT1			Guide Sleeve	CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Neutron Absorber Sheet	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
24PT1			Oversleeve	CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT1			Shim Plate	SR		Stainless Steel	Helium	None	None	No
24PT1			Liner Damaged Fuel Can	CR, SR		Stainless Steel	Helium	None	None	No

Table 3-11
Aging Management Review for 24PT1 DSC
(4 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT1			Top Lid	CR, SR		Stainless Steel	Helium	None	None	No
24PT1			Liner Block	CR, SR		Stainless Steel	Helium	None	None	No
24PT1			Lid Liner	CR, SR		Stainless Steel	Helium	None	None	No
24PT1			Lid Liner Closure Plate	CR, SR		Stainless Steel	Helium	None	None	No
24PT1			Bottom Lid	CR, SR		Stainless Steel	Helium	None	None	No
24PT1			Washer Plate	CR		Stainless Steel	Helium	None	None	No
24PT1			Mesh	CR		Stainless Steel	Helium	None	None	No
24PT1			Spacer Bar	CR		Stainless Steel	Helium	None	None	No
24PT1			Spacer Tube	SR		Stainless Steel	Helium	None	None	No
24PT1			Spacer Baseplate	SR		Stainless Steel	Helium	None	None	No
24PT1			Spacer Fuel Support Plate	SR		Stainless Steel	Helium	None	None	No
24PT1			Round Bar	SR		Stainless Steel	Helium	None	None	No
24PT1			Test Port Plug	CO		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Bottom Shield Plug Outer Casing	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Alternative Outer Bottom Plate	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP

Table 3-11
Aging Management Review for 24PT1 DSC
(4 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT1			Alternative Inner Bottom Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT1			Shim	SR		Stainless Steel	Helium	None	None	No
24PT1			Screw, Socket HD Cap	SR		Steel	Helium	None	None	No
24PT1			Alternate Bottom Shield Plug	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to an internal (or towards the interior of the DSC) environment and (E) refers to an external (or towards the exterior of the DSC) environment.

Table 3-12
Aging Management Review for 24PT4 DSC
(4 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT4			Top Spacer Disc	SH, CR, SR, TH		Steel	Helium	None	None	No
24PT4			Spacer Disc	SH, CR, SR, TH		Steel	Helium	None	None	No
24PT4			Outer Top End Spacer Sleeve	SR		Stainless Steel	Helium	None	None	No
24PT4			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Spacer Sleeve	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Bottom End Spacer Sleeve	SR		Stainless Steel	Helium	None	None	No
24PT4			Support Rod	SR		Stainless Steel	Helium	None	None	No
24PT4			Bottom Spacer Disc	SH, CR, SR, TH		Steel	Helium	None	None	No
24PT4			Inner Top End Spacer Sleeve	SR		Stainless Steel	Helium	None	None	No
24PT4			Pin	SR		Stainless Steel	Helium	None	None	No
24PT4			Cylindrical Shell	CO, SH, SR, TH, RT		Stainless Steel	(I) Helium	Fatigue	Cracking	TLAA
							(I) Fully Encased	Fatigue	Cracking	TLAA
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
								Fatigue	Cracking	TLAA
24PT4			Outer Bottom Cover Plate	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT4			Lead Shielding	SH, TH		Lead	Fully Encased	None	None	No
24PT4			Grapple Ring	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT4			Grapple Ring Support	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP

Table 3-12
Aging Management Review for 24PT4 DSC
(4 Pages)

Component				Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT4				Inner Bottom Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
								(E) Fully Encased	None	None	No
								(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
									Galvanic Corrosion	Loss of Material	DSC AMP
									Stress Corrosion Cracking	Cracking	DSC AMP
24PT4				Bottom Shield Plug Rod	SH, SR, TH		Stainless Steel	Fully Encased	None	None	No
24PT4				Top Shield Plug Casing	SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
								(E) Fully Encased	None	None	No
24PT4				Bottom Shield Plug Outer Casing	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
								(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
									Galvanic Corrosion	Loss of Material	DSC AMP
									Stress Corrosion Cracking	Cracking	DSC AMP
24PT4				Basket Key	SR		Stainless Steel	Helium	None	None	No
24PT4				Siphon and Vent Block	CO, SH, SR		Stainless Steel	(I) Helium	None	None	No
								(E) Fully Encased	None	None	No
24PT4				Lifting Lug	SR		Stainless Steel	Helium	None	None	No
24PT4				Support Ring, Bar Stock	SR		Stainless Steel	Helium	None	None	No
24PT4				Inner Grapple Ring Support	SR, RT		Stainless Steel	Fully Encased	None	None	No
24PT4				Inner Top Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Fully Encased	None	None	No
								(E) Helium	None	None	No
								(E) Fully Encased	None	None	No
24PT4				Alternative Outer Bottom Cover Plate	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
								(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
									Galvanic Corrosion	Loss of Material	DSC AMP
									Stress Corrosion Cracking	Cracking	DSC AMP
24PT4				Top Shield Plug Assembly Rod	SH, SR, TH		Stainless Steel	Fully Encased	None	None	No

Table 3-12
Aging Management Review for 24PT4 DSC
(4 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT4			Outer Top Cover Plate	CO, SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT4			Siphon and Vent Port Cover Plate	CO, SH, SR		Stainless Steel	(E) Fully Encased	None	None	No
							(I) Helium	None	None	No
24PT4			Guide Sleeve	CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Neutron Absorber Sheet	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
24PT4			Neutron Absorber Sheet	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
24PT4			Oversleeve	CR, SR, TH		Stainless Steel	Helium	None	None	No
24PT4			Shim Plate	SR		Stainless Steel	Helium	None	None	No
24PT4			Shim Plate	SR		Stainless Steel	Helium	None	None	No
24PT4			Alternate Inner Bottom Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT4			Test Port plug	CO		Stainless Steel	(I) Fully Encased	None	None	None
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
24PT4			Liner Failed Fuel Can	CR, SR		Stainless Steel	Helium	None	None	No
24PT4			Bottom Lid	CR, SR		Stainless Steel	Helium	None	None	No
24PT4			Top Cap Liner	CR, SR		Stainless Steel	Helium	None	None	No
24PT4			Tool Socket	CR		Stainless Steel	Helium	None	None	No
24PT4			Tool Socket Closure Plate	CR		Stainless Steel	Helium	None	None	No
24PT4			Top Plate	CR, SR		Stainless Steel	Helium	None	None	No
24PT4			Washer Plate	CR		Stainless Steel	Helium	None	None	No
24PT4			Mesh	CR		Stainless Steel	Helium	None	None	No

Table 3-12
Aging Management Review for 24PT4 DSC
(4 Pages)

Component	[	]	Subcomponent Parts	Intended Safety Function (1)	[ ]	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
24PT4			Liner Block	CR, SR		Stainless Steel	Helium	None	None	No
24PT4			Top Lid Block	CR, SR		Stainless Steel	Helium	None	None	No
24PT4			Screw, Socket HD Cap	SR		Steel	Helium	None	None	No

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to an internal (or towards the interior of the DSC) environment and (E) refers to an external (or towards the exterior of the DSC) environment.

Table 3-13
Aging Management Review for 32PTH2 DSC
(3 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
32PTH2			Top Shield Plug	SH, SR, TH		Steel	Helium	None	None	No
32PTH2			Inner Top Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
32PTH2			Outer Top Cover Plate	CO, SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Test Port Plug	CO		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Siphon and Vent Port Cover Plate	CO, SH, SR		Stainless Steel	(E) Fully Encased	None	None	No
							(I) Helium	None	None	No
32PTH2			Siphon and Vent Block	CO, SH, SR		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
32PTH2			Support Ring, Bar Stock Or Plate	SR		Stainless Steel	Helium	None	None	No
32PTH2			Cylindrical Shell	CO, SH, SR, TH, RT		Stainless Steel	(I) Helium	Fatigue	Cracking	TLAA
							(I) Fully Encased	Fatigue	Cracking	TLAA
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
								Fatigue	Cracking	TLAA
32PTH2			Inner Bottom Cover Plate	CO, SH, SR, TH, RT		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Outer Bottom Cover Plate	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Bottom Shield Plug	SH, SR, TH		Steel	Fully Encased	None	None	No

Table 3-13
Aging Management Review for 32PTH2 DSC
(3 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
32PTH2			Bottom Shield Plug Outer Casing Plate	SH, SR, TH, RT		Stainless Steel	(I) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Inner Bottom Cover Plate	CO, SH, SR, TH, RT		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
							(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Galvanic Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Grapple Ring	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Grapple Ring Support	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	DSC AMP
								Stress Corrosion Cracking	Cracking	DSC AMP
32PTH2			Key	SR		Stainless Steel	Helium	None	None	No
32PTH2			Inner Bottom Cover Plate	CO, SH, SR, TH		Stainless Steel	(I) Helium	None	None	No
							(E) Fully Encased	None	None	No
32PTH2			Fuel Compartment	SH, CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Outer Bottom Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Center Bottom Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Center Bottom Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Outer Top Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Center Top Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Center Top Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Outer Basket Support Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Center Basket Support Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Center Basket Support Plate	CR, SR, TH		Stainless Steel	Helium	None	None	No
32PTH2			Outer Basket Plate	SH, CR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA

Table 3-13
Aging Management Review for 32PTH2 DSC
(3 Pages)

Component			Subcomponent Parts	Intended Safety Function [(1)]		Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
32PTH2			Center Basket Plate	SH, CR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			Poison Plate	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
32PTH2			Center Basket Plate	SH, CR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			Poison Plate	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
32PTH2			Outer Top Basket Plate	SH, CR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			Top Poison Plate	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
32PTH2			Center Top Basket Plate	SH, CR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			Top Poison Plate	SH, CR, TH		BORAL® and MMC	Helium	None	None	No
32PTH2			Center Top Basket Plate	SH, CR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			Rail Stud	SR		Stainless Steel	Helium	None	None	No
32PTH2			Oversized Washer	SR		Stainless Steel	Helium	None	None	No
32PTH2			Std Washer	SR		Stainless Steel	Helium	None	None	No
32PTH2			Rail Hex Nut	SR		Stainless Steel	Helium	None	None	No
32PTH2			Shims	SR		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			R90 Basket Transition Rail	SH, CR, SR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			R90 Basket Transition Rail	SH, CR, SR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			R45 Basket Transition Rail	SH, CR, SR, TH		Aluminum	Helium	Creep	Change in Dimensions	TLAA
32PTH2			Top Lid Body	CR, SR		Stainless Steel	Helium	None	None	No
32PTH2			Top Lid Cover	CR, SR		Stainless Steel	Helium	None	None	No
32PTH2			Bottom Lid Body	CR, SR		Stainless Steel	Helium	None	None	No
32PTH2			Bottom Lid Cover	CR, SR		Stainless Steel	Helium	None	None	No

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to an internal (or towards the interior of the DSC) environment and (E) refers to an external (or towards the exterior of the DSC) environment.

Table 3-14
Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Plate	SH, SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Deformed Bar Anchors	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Support Rail	SR, TH, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			DSC Stop Plate	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			DSC Stop Plate Stiffener	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Rail Extension Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Leading Rail Extension Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Rail Extension Base Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stiffener Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Gusset Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Baseplate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Cross beam	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
							Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Embedded-in-Concrete	None	None	No
							Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-14
Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Coupling Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Washer	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Washer Plate	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-14
Aging Management Review for AHSM
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Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Threaded Insert Dayton Superior	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM			Dayton Superior Straight Bar Splicer	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Stud	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Threaded Insert Dayton Superior	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Threaded Insert Dayton Superior	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Stud	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
							Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Embedded-in-Concrete	None	None	No
							Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-14
Aging Management Review for AHSM
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Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Coupling Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Expanded Coil Insert Dayton Superior	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM			Stud	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Washer	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
							Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
							Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

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Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Washer Plate	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Top Shield Block Attachment Bolt, Short Rod	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Top Shield Block Attachment Bolt, Long Rod	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Washer	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Washer Plate	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			DSC Stop Plate Extension	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

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Aging Management Review for AHSM
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Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Adjustable DSC Axial Retainer	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM			Jam Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Bolt	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Jam Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

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Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Washer Plate	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Inner Heat Shield	TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Outer Heat Shield	TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Support Structure Heat Shield	TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Zee Bracket	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Self-Drilling Hex Head Screw	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Hex Flange Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

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Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Washer Plate	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
							Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
							Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
							Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
							Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Washer	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
							Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
							Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

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Aging Management Review for AHSM
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Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Stud	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
							Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
							Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM			Mechanical Splice #8 Rebar	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Mechanical Splice #9 Rebar	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM			Door Concrete Core	SH, SR, TH, RT		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP

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Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
							Sheltered	Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
AHSM			Outlet Vent Cover	SH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP

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Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM			Base Walls	SH, SR, TH, RT		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
							Sheltered	Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP

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Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Roof	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
							Sheltered	Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
AHSM			End Wall RF	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP

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Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM			End Wall RR	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP

Table 3-14
Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Rear Wall	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM			End Wall LF	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP

Table 3-14
Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM			End Wall LR	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP

Table 3-14
Aging Management Review for AHSM
(16 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM			Lower Vent Cover	SH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to an internal (or towards the interior of the HSM) environment and (E) refers to an external (or towards the exterior of the HSM) environment.
3. UFSAR Drawing NUH-03-4011 does not assign a part number to these subcomponents; however, the drawing does call them out and specifies the design and construction standards (i.e., Note 1 on Drawing NUH-03-4011).
4. Load bearing alloy or carbon steel subcomponents of the adjustable DSC axial retainer shall have a minimum 0.20% copper content; otherwise, corrosion resistant steel such as stainless steel is to be used.

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Base	SH, SR, TH, RT		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
							Sheltered	Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
AHSM-HS			Roof	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [(1)]		Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
							Sheltered	Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
AHSM-HS			End Wall Left-Front	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			End Wall Left-Rear	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Rear Wall	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [(1)]		Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Corner Wall	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			End Wall Right-Front	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			End Wall Right-Rear	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Wall Embedment	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Wall Embedment	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Door Attachment Embedment	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Door Attachment Embedment	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Rear Shield Wall Embedment	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Door	SH, SR, TH, RT		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
							Sheltered	Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
AHSM-HS			Backing Plate	SH, SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Roof Vent-Liner Plate	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Base-Top Liner Plate	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Base-Bottom Liner Plate	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Rail Extension Embedment	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Support Rail	SR, TH, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Rail Extension Base Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Gusset Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Crossbeam	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Stiffener Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Extension Plate	SR, RT		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			DSC Stop Plate	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Door Attachment Nut – Upper	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Door Attachment Stud – Upper	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Door Attachment Standard Washer – Upper	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Door Attachment Square Washer – Upper	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Door Attachment Nut – Lower	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Door Attachment Stud – Lower	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Door Attachment Standard Washer – Lower	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Door Attachment Square Washer – Lower	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Front Support Attachment Bolt	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Adjustable Axial Retainer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Roof Connection Angle Assembly	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Roof Connection – Stud	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Roof Connection – Nut	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Roof Connection – Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Roof Connection – Bolt	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Roof Connection Embedment	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Outlet Vent Cover	SH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Outlet Vent Cover – Stud	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Outlet Vent Cover – Nut	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Outlet Vent Cover – Standard Washer	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Outlet Vent Cover – Square Washer	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Outlet Vent Cover Liner Plate	SH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Stud	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Stud	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Stud	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Shield Wall Attachment – Nut	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Nut	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Nut	SR		Steel	Air-Outdoor	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Shield Wall Attachment – Square Washer	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Back To Back Module Connection – Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Back to Back Module Connection – Square Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Module Connection – Standard Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Back to Back Module Connection – Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Side to Side Module Connection – Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Side to Side Module Connection – Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Side to Side Module Connection – Square Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Side Heat Shield Connection	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Side Heat Shield Type A	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Side Heat Shield Type B	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Top Heat Shield	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Top Heat Shield Connection	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Mechanical Splice	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Outlet Vent Cover Embedment	SR		Stainless Steel	Embedded-in-Concrete	None	None	No

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Side Heat Shield Type C	SH, TH		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Square Washer	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Shield Wall Attachment – Square Washer	SR		Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Rebar	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			AHSM-HS Transition Roof – Right	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [(1)]		Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			AHSM-HS Transition Roof – Left	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Transition Wall, Left – Front	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Transition Wall, Left – Rear	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Transition Wall, Right – Front	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [1]		Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP
AHSM-HS			Transition Wall, Right – Rear	SH, SR, TH		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
						Concrete	Air-Outdoor	Freeze-Thaw	Cracking	HSM AMP
									Loss of Material	HSM AMP
								Reaction with Aggregates	Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Differential Settlement	Cracking	HSM AMP
								Aggressive Chemical Attack	Cracking	HSM AMP
									Loss of Strength	HSM AMP
									Loss of Material	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	HSM AMP
									Loss of Material	HSM AMP
									Cracking	HSM AMP
									Loss of Strength	HSM AMP
								Leaching of Calcium Hydroxide	Loss of Strength	HSM AMP
									Increase in Porosity and Permeability	HSM AMP
									Reduction of Concrete pH	HSM AMP
								Salt Scaling	Loss of Material	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function [(1)]		Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Wall Embedment	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Bolt	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Square Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Module Connection – Standard Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Mechanical Splice	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Bolt	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Wall Attachment – Nut	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Wall Attachment – Round Washer	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Standard Washer	SR		Stainless Steel	Embedded-in-Concrete	None	None	No
AHSM-HS			Transition Roof Connection Rebar	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Stud	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Nut	SR		Steel	Sheltered	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Galvanic Corrosion	Loss of Material	HSM AMP
AHSM-HS			Wall Attachment – Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP

Table 3-15
Aging Management Review for AHSM-HS
(17 Pages)

Component			Subcomponent Parts	Intended Safety Function (1)		Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
AHSM-HS			Module Connection – Standard Washer	SR		Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material	HSM AMP
								Stress Corrosion Cracking	Cracking	HSM AMP
AHSM-HS			Rebar	SR		Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	HSM AMP
								Pitting and Crevice Corrosion	Loss of Material	HSM AMP

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to an internal (or towards the interior of the HSM) environment and (E) refers to an external (or towards the exterior of the HSM) environment.
3. UFSAR Drawing NUH-03-4012 does not assign a part number to these subcomponents; however, the drawing does show them.

Table 3-16
Aging Management Review for Basemat
(4 Pages)

Subcomponent Parts	Intended Safety Function [(1)]	Material	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Basemat	SR, RT	Reinforced Concrete	Steel	Embedded-in-Concrete	General Corrosion	Loss of Material	Basemat AMP
					Pitting and Crevice Corrosion	Loss of Material	Basemat AMP
			Concrete	Air-Outdoor	Freeze-Thaw	Cracking	Basemat AMP
						Loss of Material	Basemat AMP
					Reaction with Aggregates	Cracking	Basemat AMP
						Loss of Strength	Basemat AMP
					Differential Settlement	Cracking	Basemat AMP
					Aggressive Chemical Attack	Cracking	Basemat AMP
						Loss of Strength	Basemat AMP
						Loss of Material	Basemat AMP
						Reduction of Concrete pH	Basemat AMP
					Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	Basemat AMP
						Loss of Material	Basemat AMP
						Cracking	Basemat AMP
						Loss of Strength	Basemat AMP
					Leaching of Calcium Hydroxide	Loss of Strength	Basemat AMP
						Increase in Porosity and Permeability	Basemat AMP

Table 3-16
Aging Management Review for Basemat
(4 Pages)

Subcomponent Parts	Intended Safety Function [1]	Material	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
						Reduction of Concrete pH	Basemat AMP
					Delayed Ettringite Formation [2]	Loss of Material	Basemat AMP
						Loss of Strength	Basemat AMP
						Cracking	Basemat AMP
					Salt Scaling	Loss of Material	Basemat AMP
				Sheltered	Reaction with Aggregates	Cracking	Basemat AMP
						Loss of Strength	Basemat AMP
					Differential Settlement	Cracking	Basemat AMP
					Leaching of Calcium Hydroxide	Loss of Strength	Basemat AMP
						Increase in Porosity and Permeability	Basemat AMP
						Reduction of Concrete pH	Basemat AMP
					Delayed Ettringite Formation [2]	Loss of Material	Basemat AMP
						Loss of Strength	Basemat AMP
						Cracking	Basemat AMP
				Groundwater/ Soil	Freeze-Thaw	Cracking	Basemat AMP
						Loss of Material	Basemat AMP
					Reaction with Aggregates	Cracking	Basemat AMP
						Loss of Strength	Basemat AMP

Table 3-16
Aging Management Review for Basemat
(4 Pages)

Subcomponent Parts	Intended Safety Function [1]	Material	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
					Differential Settlement	Cracking	Basemat AMP
					Aggressive Chemical Attack	Cracking	Basemat AMP
						Loss of Strength	Basemat AMP
						Loss of Material	Basemat AMP
						Reduction of Concrete pH	Basemat AMP
					Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond	Basemat AMP
						Loss of Material	Basemat AMP
						Cracking	Basemat AMP
						Loss of Strength	Basemat AMP
					Leaching of Calcium Hydroxide	Loss of Strength	Basemat AMP
						Increase in Porosity and Permeability	Basemat AMP
						Reduction of Concrete pH	Basemat AMP
					Microbiological Degradation	Loss of Strength	Basemat AMP
						Loss of Material	Basemat AMP
						Increase in Porosity and Permeability	Basemat AMP
						Reduction of Concrete pH	Basemat AMP

Table 3-16
Aging Management Review for Basemat
(4 Pages)

Subcomponent Parts	Intended Safety Function [1]	Material	Material Group	Environment	Credible Aging Mechanism	Aging Effect	Aging Management Activity
					Delayed Ettringite Formation [2]	Loss of Material	Basemat AMP
						Loss of Strength	Basemat AMP
						Cracking	Basemat AMP
					Salt Scaling	Loss of Material	Basemat AMP

Notes:

1. The intended safety functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).
2. Delayed ettringite formation may be ruled out as a credible aging mechanism by the general licensee based on an ISFSI-specific evaluation.

Table 3-17
Aging Management Review for Spent Fuel Assemblies
(2 Pages)

Subcomponent	Intended Safety Function [1]	Material of Construction	Material Group	Environment [2]	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Fuel Cladding and End Plugs [1][4]	CO, CR, SR, TH	Type 304 Stainless Steel	Spent Fuel Assembly Cladding	(I) Helium	None	None	No
				(E) Helium	None	None	No
		Zirconium-Based Alloy [1]	Spent Fuel Assembly Cladding	(I) Helium	Hydride-Induced Embrittlement [3]	Loss of Ductility [3]	HBU AMP
					Thermal Creep [3]	Changes in Dimensions [3]	HBU AMP
				(E) Helium	Hydride-Induced Embrittlement [3]	Loss of Ductility [3]	HBU AMP
					Thermal Creep [3]	Changes in Dimensions [3]	HBU AMP
Spacer Grid Assemblies	CR, SR	Inconel 718	Spent Fuel Assembly Hardware	Helium	None	None	No
		Zirconium-Based Alloy [1]	Spent Fuel Assembly Hardware	Helium	None	None	No
		Inconel 625	Spent Fuel Assembly Hardware	Helium	None	None	No
Upper End Fitting/Nozzle (and Related Subcomponents)	SR	Type 304 SS	Spent Fuel Assembly Hardware	Helium	None	None	No
		Inconel 718	Spent Fuel Assembly Hardware	Helium	None	None	No

Table 3-17
Aging Management Review for Spent Fuel Assemblies
(2 Pages)

Subcomponent	Intended Safety Function (1)	Material of Construction	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect	Aging Management Activity
Lower End Fitting/Nozzle (and Related Subcomponents)	SR	Type 304 SS	Spent Fuel Assembly Hardware	Helium	None	None	No
Guide Tubes	SR	Zirconium-Based Alloy (1)	Spent Fuel Assembly Hardware	Helium	None	None	No
Reconstituted Fuel Rods	CR	Stainless Steel	Spent Fuel Assembly Hardware	Helium	None	None	No
Poison Rod Assemblies (24PT4 DSC Only)	CR	B_4C	Spent Fuel Assembly Hardware	Fully Encased	None	None	No
		Stainless Steel	Spent Fuel Assembly Hardware	(I) Fully Encased	None	None	No
				(E) Helium	None	None	No

Notes:

1. Zirconium alloy claddings, including Zircaloy-4, OPTIN™, M5™, or Zirlo™.
2. If the subcomponent has an internal and external surface exposed to different environments, (I) refers to the internal environment of the fuel pin and (E) refers to an external environment of the fuel pin.
3. For HBU fuel only.
4. The cladding of failed fuel assemblies is not able to provide any intended safety function and is, therefore, not considered in scope for renewal.

APPENDIX 3A
TLAA Identification and Disposition

CONTENTS

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3A.1 Introduction

Per Code of Federal Regulations (CFR) 10 CFR 72.240(c)(2) [3A-1], a certificate of compliance (CoC) renewal application must include time-limited aging analyses (TLAAs) that demonstrate that structures, systems, and components (SSCs) important to nuclear safety will continue to perform their intended safety functions for the requested period of extended operation (PEO). For an analysis to be considered a TLAA, it must meet the six selection criteria listed in NUREG-1927 [3A-2].

This appendix describes the process used to identify and disposition TLAAs. It also summarizes the TLAAs that were updated to demonstrate that they have been projected to the end of the PEO.

Note that the initial license for CoC 1029 was for a 20-year period and that the CoC renewal application requests an additional 40 years. Therefore, the total PEO will be 60 years.

3A.2 Methodology for Identification and Disposition of TLAAs.

3A.2.1 Identification of TLAAs

TLAAs are calculations or analyses used to demonstrate that in-scope SSCs will maintain their intended safety function throughout an explicitly stated period of operation. To be considered "in-scope" for TLAAs, the calculations/analyses must meet all six of the following criteria as defined in 10 CFR Part 72 [3A-1]:

1. Involve SSCs important-to-safety within the scope of the spent fuel storage certificate renewal, as delineated in Subpart L of 10 CFR Part 72 [3A-1];
2. Consider the effects of aging;
3. Involve time-limited assumptions defined by the current operating term;
4. Were determined to be relevant by the certificate holder in making a safety determination;
5. Involve conclusions or basis of conclusions related to capability of the SSCs to perform their intended safety functions; and
6. Are contained or incorporated by reference in the design bases.

Potential TLAAs were identified via a review of the updated final safety analysis report (UFSAR) [3A-3] and the Standardized Advanced NUHOMS® System design calculations.

The review of the UFSAR involved performing word searches for key words (i.e., year, yr, hour, life, cycle, aging).

The context of the key word, as used in the UFSAR, was then reviewed to determine if a time-limited assumption used in an analysis was involved (i.e., TLAA criterion 3). If it was determined that a time limiting assumption was not involved, the review stopped at that point. If a time-limited assumption was involved, then the context was reviewed until another criterion was not met. If all criteria were met, then the item involved a TLAA.

The review of the design basis calculations was performed by first determining if a time-limited assumption was involved (i.e., TLAA criterion 3). If it was determined that a time-limited assumption was not involved, the review stopped at that point. If a time-limited assumption was involved, then the calculation was reviewed until another criterion was not met. If all the criteria were met, then the calculation involved a TLAA.

3A.2.2 Disposition of Identified TLAAs

The identified TLAAs were dispositioned using one of the following three methods listed in Section 3.5.1 of NUREG-1927 [3A-2]:

- Demonstrate that the existing analysis remains valid for the PEO, has already considered the requested period of extended operation, and concludes that the SSC will continue to perform its intended safety function through the end of the requested PEO.
- Revise or update the existing analysis to demonstrate that it has been projected to the end of the requested PEO and concludes that the SSC will continue to perform its intended safety function through the end of the requested PEO.
- Manage the effects of aging on the SSC for the requested PEO through an aging management program (AMP).

3A.3 Identified TLAAs

Table 3A-1 provides a summary of the identified TLAAs. These TLAAs are grouped into the following subject areas for disposition:

- Boron depletion in the BORAL® plates in the 24PT1 and 24PT4 dry shielded canisters (DSCs)
- Creep analysis for aluminum components in the 32PTH2 basket
- Fatigue analyses for the 24PT1, 24PT4, and 32PTH2 DSC shells
- Irradiation embrittlement of metals in the 24PT1, 24PT4, and 32PTH2 DSCs
- Irradiation effects on the concrete in the Advanced Horizontal Storage Modules (AHSM) and AHSM-HS
- Establishment of cladding temperature limits for fuel stored in the 24PT1 DSC

3A.4 Disposition of Identified TLAAs

3A.4.1 Boron Depletion in the BORAL® Plates in the 24PT1 and 24PT4 DSCs

Standardized Advanced NUHOMS® System UFSAR [3A-3] Sections 6.3.2 and A.6.3.2 evaluated the potential of B-10 depletion due to neutron capture in the poison plates of the 24PT1 and 24PT4 baskets, respectively. Although the license period of the DSC is 20 years, the evaluation determined that the fraction of the original B-10 that would be depleted (1.1×10^{-6}) after 1000 years would be negligible.

Note that the approved design basis for the 32PTH2 DSC does not include an analysis of the B-10 depletion (i.e., there is no TLAA). As demonstrated by the analyses for the 24PT1 and 24PT4 DSCs, along with the generic evaluation in Section 3.4.2.4 of NUREG-2214 [3A-4], boron depletion is not a significant aging mechanism. Therefore, no aging management activity (e.g., a B-10 depletion analysis) is required for the poison plates in the 32PTH2 DSC.

Since the existing analyses for the 24PT1 and 24PT4 DSCs assumed 1000 years of service, they remain valid for the PEO, have already considered the PEO, and demonstrate that the boron poison plates will continue to perform their intended safety functions through the end of the PEO.

3A.4.2 Creep Analysis for Aluminum Components in the 32PTH2 Basket

Standardized Advanced NUHOMS® System UFSAR [3A-3] Section B.3.6.1.2.8 evaluated the creep strain effects due to long-term storage of the 32PTH2 basket aluminum components. In the creep strain analysis, the basis for maximum allowable stress for all basket materials is 100% of the average stress that produces a cumulative 1% strain in 555,000 hours for Aluminum 1100 material. Aluminum 1100 is used in the creep strain effect analysis since the Aluminum 1100 stress limits were determined to bound stress limits for Aluminum Type 6061. The analysis validated that the basket assembly design is structurally adequate for long-term storage loads and determined that the creep strain effect is negligible.

As stated above, the analysis is based on a cumulative 1% strain in 555,000 hours or 63.3 years (555,000 hrs ÷ 24 hr/day ÷ 365.25 days/yr).

Since the existing analysis assumed 63.3 years, it remains valid for the PEO, has already considered the PEO, and demonstrates that the basket will continue to perform its intended safety functions through the end of the PEO.

3A.4.3 Fatigue Analyses for the 24PT1, 24PT4, and 32PTH2 DSC Shells

Standardized Advanced NUHOMS® System UFSAR [3A-3] Sections 3.6.1.3, A.3.6.1.3, and B.3.6.1.1.8 state that the DSC shells were evaluated for fatigue in accordance with the rules of ASME BPV Code, Section III, Division 1 [3A-9], Subsection NB-3222.4 to show that a detailed fatigue evaluation is not required. The detailed fatigue analysis is not required if six criteria specified in Subsection NB-3222.4(d) are met.

The design basis calculations for the 24PT1 and 24PT4 contain an assumption that [ ] These [ ] pressure cycles are used to obtain a value for S_a (stress value from applicable design fatigue curve), which is then used to determine the allowed pressure fluctuation. Since the 50-year assumption is less than the 60-year PEO, the analysis for the second criterion must be updated. Note that, while the fatigue analysis for the 32PTH2 shell also used the rules of Subsection NB-3222.4 [3A-9], it used a different approach to address the second criterion that wasn't dependent upon an assumed number of thermal cycles during the service life of the DSC (i.e., it shows that there were no significant pressure fluctuations). The fatigue analysis for the second criterion for the 32PTH2 shell did not involve a TLAA and, therefore, does not need to be updated or revised.

When evaluating the fourth criterion, the design basis calculations for all three DSCs contained the assumption that [ ] However, all three evaluations used a conservative [ ] cycles when obtaining a value for S_a. The use of [ ] cycles in the evaluations is sufficient to bound a 60-year PEO [ ] Therefore, the fatigue analysis for the fourth criterion for the 24PT1, 24PT4, and the 32PTH2 shells does not need to be updated or revised.

In summary, the 24PT1 and 24PT4 fatigue analyses must be revised or updated to demonstrate that the analyses have been projected to the end of the PEO (i.e., a total of 60 years) and conclude that the DSC shells will continue to perform their intended safety functions through the end of the PEO.

3A.4.4 Irradiation Embrittlement of Metals in the 24PT1, 24PT4, and 32PTH2 DSCs

Standardized Advanced NUHOMS® System UFSAR [3A-3] Sections 3.3.1.1 and A.3.3.1.1 evaluated the radiation effects from fast neutrons on the metals in the 24PT1 and 24PT4 DSCs. These UFSAR sections state that the integrated fast neutron fluence inside the DSCs after 50 years of service is on the order of 1×10^{15} n/cm^2. The UFSAR used a threshold of 10^{17} n/cm^2 as the fluence value below which damage is not expected to occur. Since the 50-year assumption is less than the 60-year PEO, the evaluation for irradiation embrittlement for the 24PT1 and 24PT4 DSC metals must be updated or revised.

Standardized Advanced NUHOMS® System UFSAR [3A-3] Section B.3.3.1.1 evaluated the radiation effects from fast neutrons on the metals in the 32PTH2 DSC. This UFSAR section states that the integrated fast neutron fluence inside the 32PTH2 DSC after 60 years of service is on the order of 1×10^{15} n/cm^2. The UFSAR used a threshold of 10^{17} n/cm^2 as the fluence value below which damage is not expected to occur. Since the evaluation is based on a 60-year service life, it remains valid for the PEO.

In summary, the 24PT1 and 24PT4 analyses for irradiation embrittlement must be revised or updated to demonstrate that the analyses have been projected to the end of the PEO (i.e., a total of 60 years) and conclude that the DSC shells will continue to perform their intended safety functions through the end of the PEO.

3A.4.5 Irradiation Effects on the Concrete in the AHSM and AHSM-HS

Standardized Advanced NUHOMS® System UFSAR [3A-3] Sections 3.3.2.1 and A.3.3.2.1 evaluated the radiation effects from fast neutrons and gamma rays on the concrete in the AHSM. These UFSAR sections state that the accumulated neutron flux over a 40-year period service life is estimated to be 1.5×10^{14} n/cm^2, and a gamma energy flux of 3.0×10^{-4} watt/cm^2. The UFSAR also states that radiation levels of these magnitudes will not affect the concrete. Since the 40-year assumption is less than the 60-year PEO, the evaluation for irradiation embrittlement for the AHSM concrete must be updated or revised.

Standardized Advanced NUHOMS® System UFSAR [3A-3] Section B.3.3.3.1 evaluated the radiation effects from fast neutrons and gamma rays on the concrete in the AHSM-HS concrete. This UFSAR section states that the accumulated neutron flux over a 60-year period service life is estimated to be 2.27×10^{14} n/cm^2, and a gamma energy flux of 1.57 x10^{-2} watt/cm^2. Since the evaluations are based on a 60-year service life, it remains valid for the PEO.

In summary, the AHSM evaluation for the radiation effects on the concrete must be revised or updated to demonstrate that it has been projected to the end of the PEO (i.e., a total of 60 years) and concludes that the AHSM concrete will continue to perform its intended safety function through the end of the PEO.

3A.4.6 Establishment of Cladding Temperature Limits for Fuel Stored in the 24PT1 DSC

Standardized Advanced NUHOMS® System UFSAR [3A-3] Section 3.5.1.1.1 states that the peak cladding temperature limit at the beginning of long-term storage for the Westinghouse 14x14 mixed-oxide (MOX) Zircaloy clad fuel in the 24PT1 DSC was determined in accordance with the methodology in PNL-6189 [3A-5]. The limit of 618 °F was derived based on a 50-year design life.

Standardized Advanced NUHOMS® System UFSAR [3A-3] Section 3.5.1.2.1 states that the peak cladding temperature limit at the beginning of long-term storage for the Westinghouse 14x14 stainless steel clad fuel in the 24PT1 DSC was determined in accordance with the methodology in Electrical Power Research Institute (EPRI) TR-106440 [3A-7]. The limit of 690 °F was derived based on a 50-year design life.

While both of the above clad temperature limits were based on a 50-year storage design life, the methodology used pre-dates the current accepted limit for low burnup fuel in Interim Staff Guidance (ISG)-11 [3A-6], which is 752 °F. Note that the CoC 1029 Technical Specifications [3A-8] for the 24PT1 DSC limits the burnup of the Zircaloy clad fuel to 25 GWd/MTU and stainless steel clad fuel to 45 GWd/MTU.

Since the fuel clad temperature limits applied to the fuel stored in the 24PT1 DSC are less than (i.e., more restrictive than) the current accepted limit in ISG-11, they remain valid for the PEO and demonstrate that the cladding will continue to perform its intended safety function through the end of the PEO.

3A.5 Summary of TLAA Identification and Disposition

The review of the CoC 1029 approved design basis identified the following TLAAs:

- Boron depletion in the BORAL® plates in the 24PT1 and 24PT4 DSCs
- Creep analysis for aluminum components in the 32PTH2 basket
- Fatigue analyses for the 24PT1, 24PT4, and 32PTH2 DSC shells
- Irradiation embrittlement of metals in the 24PT1, 24PT4, and 32PTH2 DSCs (neutron fluence and gamma exposure)
- Irradiation effects on the concrete in the AHSM and AHSM-HS (neutron fluence and gamma exposure)
- Establishment of cladding temperature limits for fuel stored in the 24PT1 DSC

Of these TLAAs, it was determined that the existing analysis remains valid for the PEO, has already considered the PEO, and concludes that the SSC will continue to perform its intended safety function through the end of the PEO for the following analyses:

- Boron depletion in the BORAL® plates in the 24PT1 and 24PT4 DSCs
- Creep analysis for aluminum components in the 32PTH2 basket
- Fatigue analyses for the 32PTH2 DSC shell
- Irradiation embrittlement of metals in the 32PTH2 DSC
- Irradiation effects on the concrete in the AHSM-HS
- Establishment of cladding temperature limits for fuel stored in the 24PT1 DSC

The following TLAAs must be revised or updated to demonstrate that they have been projected to the end of the PEO and conclude that the SSC will continue to perform its intended safety function through the end of the PEO.

- Fatigue analyses for the 24PT1 and 24PT4 DSC shells (see Section 3A.6)
- Irradiation embrittlement of metals in the 24PT1 and 24PT4 DSCs (see Section 3A.7)
- Irradiation effects on the concrete in the AHSM (see Section 3A.7)

3A.6 Fatigue Analysis for 24PT1 and 24PT4 DSC Shells

This section summarizes the fatigue exemption evaluation of the 24PT1 and 24PT4 DSC shells for a service life of 100 years. The evaluation is performed in accordance with the provisions of Subsection NB-3222.4(d) of the ASME B&PV Code, “Rules to Determine Need for Fatigue Analysis of Integral Parts of Vessels” [3A-9].

Subsection NB-3222.4(d) of the ASME B&PV Code [3A-9] is used to determine if fatigue effects need to be evaluated. Fatigue effects need not be specifically evaluated provided the six criteria contained in Subsection NB-3222.4(d) are met. The evaluation uses bounding S_m, E, and α values from the ASME B&PV Code edition applicable to the DSCs. Maximum temperatures and pressures are obtained from the applicable sections of the Standardized Advanced NUHOMS® System UFSAR and/or design calculations.

Proprietary Information on Pages 3A-11 through 3A-13
Withheld Pursuant to 10 CFR 2.390

3A.6.8 Results and Conclusions of Fatigue Evaluation

The evaluation for the Standardized Advanced NUHOMS® System DSCs shows that fatigue analysis exemption criteria given in ASME B&PV Code Subsection NB-3222.4(d) [3A-9] are met for a 100-year service life for the 24PT1 and 24PT4 DSCs. No additional fatigue evaluations are required for the DSCs.

3A.7 Irradiation Effects on 24PT1 DSC, 24PT4 DSC, and AHSM

This section summarizes the evaluation of the irradiation embrittlement of metals in the 24PT1 and 24PT4 DSCs and the irradiation effects on the concrete in the AHSM. The evaluation is based on showing that the source terms in a reference analysis bound those in a 24PT1 DSC or 24PT4 DSC. The evaluation also removed some conservatism that was inherent in the reference analysis.

[ ]

3A.7.4 Results and Conclusions of Irradiation Effects Evaluation

The reference analysis calculated a neutron fluence of [ ] for the fuel compartment. Since the fuel compartment will see the highest neutron flux of all DSC components, its fluence value will bound all other components. Applying the 1.44 factor determined in Section 3A.7.3 results in a bounding neutron fluence of [ ] for the 24PT1 and 24PT4 DSCs. This is less than the 1×10^{17} n/cm^2 value used in the Standardized Advanced NUHOMS® System UFSAR [3A-3] as the fluence below which fast neutron damage is not significant.

The reference analysis calculated a neutron fluence of [ ] and a gamma dose of [ ] for the concrete in the HSM. Applying the 1.44 factor to the neutron fluence and the 1.22 factor to the gamma dose determined in Section 3A.7.3 results in a bounding neutron fluence of [ ] and a gamma dose of [ ] for the HSM concrete. These are less than the 1×10^{19} n/cm^2 neutron fluence value and 1×10^{10} Rad value used in NUREG-2214 [3A-4] as the fluence below which concrete structures are regarded as being sound.

Therefore, irradiation embrittlement of metals in the 24PT1 and 24PT4 DSCs and irradiation effects on the concrete in the AHSM will not lead to a loss of intended safety functions for a 100-year service life.

3A.8 References

3A-1 Title 10 Code of Federal Regulations Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste."

3A-2 NUREG-1927, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel," Revision 1, U.S. Nuclear Regulatory Commission, June 2016.

3A-3 TN Americas LLC, ANUH-01.0150, "Updated Final Safety Analysis Report for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 9, March 2019.

3A-4 NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report," Draft report for comment, U.S. Nuclear Regulatory Commission, October 2017 (ADAMS Accession Number ML17289A237).

3A-5 Pacific Northwest Laboratory, "Recommended Temperature Limits for Dry Storage of Spent Light Water Reactor Zircaloy-Clad Fuel Rods in Inert Gas," PNL-6189, May 1987.

3A-6 NRC Interim Staff Guidance 11, "Cladding Considerations for the Transportation and Storage of Spent Fuel," Revision 3, November 17, 2003.

3A-7 Electric Power Research Institute, "Evaluation of Expected Behavior of LWR Stainless Steel-Clad Fuel in Long-Term Dry Storage," EPRI-TR-106440, April 1996.

3A-8 CoC 1029, Appendix A, "Technical Specifications for the Standardized Advanced NUHOMS System Operation Controls and Limits," Amendment 4, March 12, 2019, Docket No. 72-1029.

3A-9 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section III, Division 1, 1992 Edition, with 1994 Addenda.

Table 3A-1
Identified TLAAs

SSC Involved	Aging Effect Involved	UFSAR Section	Comment
24PT1 DSC: BORAL® Plates	Loss of criticality control due to boron depletion	UFSAR Section 6.3.2	Ensured a negligible change in neutron poison efficacy
24PT4 DSC: BORAL® Plates	Loss of criticality control due to boron depletion	UFSAR Section A.6.3.2	Ensured a negligible change in neutron poison efficacy
32PTH2 DSC: Aluminum Components	Change in dimensions due to creep	UFSAR Section B.3.6.1.2.8	Evaluated limiting aluminum basket components
24PT1 DSC: Shell	Cracking due to fatigue	UFSAR Section 3.6.1.3	Evaluated in accordance with rules of NB-3222.4
24PT4 DSC: Shell	Cracking due to fatigue	UFSAR Section A.3.6.1.3	Evaluated in accordance with rules of NB-3222.4
32PTH2 DSC: Shell	Cracking due to fatigue	UFSAR Section B.3.6.1.1.8	Evaluated in accordance with rules of NB-3222.4
24PT1 DSC: Metals	Change in material properties due to irradiation embrittlement	UFSAR Section 3.3.1.1	Ensured fluence was less than 10^{17} n/cm^2
24PT4 DSC: Metals	Change in material properties due to irradiation embrittlement	UFSAR Section A.3.3.1.1	Ensured fluence was less than 10^{17} n/cm^2
32PTH2 DSC: Metals	Change in material properties due to irradiation embrittlement	UFSAR Section B.3.3.1.1	Ensured fluence was less than 10^{17} n/cm^2
AHSM: Concrete	Cracking and change in material properties due to irradiation embrittlement	UFSAR Section 3.3.2.1	Ensured neutron fluence does not affect strength and modulus of elasticity
AHSM: Concrete	Cracking and change in material properties due to irradiation embrittlement	UFSAR Section A.3.3.2.1	Ensured neutron fluence does not affect strength and modulus of elasticity
AHSM–HS: Concrete	Cracking and change in material properties due to irradiation embrittlement	UFSAR Section B.3.3.3.1	Ensured neutron fluence does not affect strength and modulus of elasticity
Fuel Cladding for fuel Stored in 24PT1 DSC	Change in dimensions due to thermal creep	UFSAR Sections 3.5.1.1.1 and 3.5.1.1.2	Established fuel cladding temperature limits

Proprietary Information on Pages 3A-20 through 3A-23
Withheld Pursuant to 10 CFR 2.390

APPENDIX 3B
Supplemental Evaluations

CONTENTS

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3B.1 Introduction

The purpose of this supplemental evaluation is to provide a reasonable expectation that chloride-induced stress corrosion cracking (CISCC) will not result in a loss of confinement or prevent retrieval of a Certificate of Compliance (CoC) No. 1029 Dry Shielded Canister (DSC) during the period of extended operation (PEO), for a total of 60 years of storage. This evaluation is not intended to be used as an aging management activity (AMA), but rather to support the proposed inspection frequency for the DSC aging management program (AMP).

The supplemental evaluation was performed by reviewing the CISCC supporting analyses performed for the Renewal Application for CoC 1004 [3B-1] to determine if its results/conclusions are applicable to the DSCs licensed under CoC 1029. The applicability review determined whether the CoC 1004 evaluation was dependent upon the DSC/horizontal storage module (HSM) design or literature data. For those that were dependent on the DSC/HSM design, the evaluation shows that the dimensions/parameters of the CoC 1029 DSC/HSM were within the range of dimensions/parameters used in the CoC 1004 analyses.

3B.2 DSC Shell Temperatures

Appendix 3G of the CoC 1004 renewal application [3B-1] summarizes an analysis that determined the minimum and maximum DSC shell weld temperatures for DSCs for a range of initial decay heat loads. The analysis evaluated DSCs stored in three different HSM types (i.e., the Standardized HSM, HSM Model 152, and HSM-H).

For a given decay heat load, the temperatures of the DSC shell welds are dependent upon the surface area of the DSC and the airflow through the storage module. Table 3B-1 shows that the dimensions of the DSCs licensed under CoC 1029 are within the range of dimensions considered in the analysis that supports the evaluation in Appendix 3G of the CoC 1004 renewal application [3B-1]. Comparing Figure 3B-1 to Figure 3B-2 shows that the configuration (and hence the airflow path) of an Advanced Horizontal Storage Module (AHSM)-HS is very similar to that of the modeled HSM-H (i.e., air enters the DSC cavity along the side of the module, flows up around the DSC shell, then out the cavity along the side of the module). Similarly, comparing Figure 3B-3 to Figure 3B-4 shows that the configuration (and hence the airflow path) of the AHSM is very similar to the Model 152 HSM (i.e., air enters the DSC cavity at the front of the module, flows up around the DSC shell, out the center of the cavity, then out the back of the module). Therefore, the range of temperatures determined in Appendix 3G of the CoC 1004 renewal application [3B-1] are applicable to the Standardized Advanced NUHOMS® System DSC shell weld temperatures.

3B.3 Critical Temperatures, Relative Humidity, and Chloride Concentration

Appendix 5A of the CoC 1004 renewal application [3B-1] summarizes a review of available literature, such as tests and experiments, associated with the formation of CISCC. Based on the information reviewed, Appendix 5A of the CoC 1004 renewal application [3B-1] identified the critical temperature, relative humidity, and chloride concentration environmental parameters needed for CISCC initiation on a DSC. Because the laboratory tests were performed on austenitic stainless steel specimens, they are not dependent on a particular DSC design. Therefore, the critical parameters determined in Appendix 5A of the CoC 1004 renewal application [3B-1] are applicable to the Standardized Advanced NUHOMS® System.

3B.4 Time for CISCC Initiation

Using the critical environmental parameters and an empirical equation of chloride salt deposition, Appendix 5A of the CoC 1004 renewal application [3B-1] summarizes a scoping calculation performed to estimate the time to CISCC initiation depending on the DSC shell temperatures determined in Appendix 3G of the CoC 1004 renewal application [3B-1].

The first part of the scoping calculation was to determine when the localized relative humidity would exceed the critical condition. The calculation then examined when the chloride concentration deposited on the canister surface would exceed the critical concentration. The chloride salt deposition rate depends on canister surface temperature, exposure time, and airborne chloride salt concentration. The calculation used the minimum and maximum surface temperatures from Appendix 3G of the CoC 1004 renewal application [3B-1] along with a range of airborne chloride salt concentrations from Appendix 5A of the CoC 1004 renewal application [3B-1]. Based on these scoping calculations, an approximate time required to initiate CISCC of austenitic stainless steel was determined for the minimum and maximum temperatures for each initial decay heat loading for each airborne salt concentration. Using an average wind speed of [ ] the calculated airborne salt concentration can range from [ ] (an average of [ ]) at the distance of [ ] from the sea. Using this average value of [ ] Appendix 5A of the CoC 1004 renewal application [3B-1] estimated the time for CISCC initiation to occur would be greater than [ ]

As stated above, the estimated time for CISCC initiation was based on the critical environmental parameters and an empirical equation of chloride salt deposition, along with the range of temperatures discussed in Section 3B.2. Therefore, the estimated times for CISCC initiation determined in Appendix 5A of the CoC 1004 renewal application [3B-1] are applicable to the Standardized Advanced NUHOMS® System.

3B.5 CISCC Crack Growth Rate

Appendix 5B of the CoC 1004 renewal application [3B-1] evaluated crack growth behavior due to CISCC and estimated crack growth rate (CGR) considering environmental condition, stress, and material condition. Additionally, the operating experience (OE) associated with external outer diameter stress corrosion cracking (ODSCC) of the stainless steel components at the nuclear power plants (NPPs) located near the ocean was also evaluated to determine whether or not the OE was applicable to the canister CISCC in the dry storage system.

The evaluation was based on a review of literature data on crack growth behavior of austenitic stainless steel. The review looked at temperature dependency, effects of stress and stress intensity factor (SIF), humidity effects, sensitization, and comparison of the CGRs reported in the literature. It was determined that the CGR was strongly dependent on the canister temperature (for the range of SIF considered). Using an Arrhenius-type temperature-dependent CGR model, the CGR was estimated as a function of canister surface temperature and activation energy by extrapolating the CGR at 80 °C to the low temperature regions. Based on the empirical data measured for stainless steel, the changes of the CGR with time was assumed to follow two stages. Once a crack is initiated, an initially high CGR was assumed for a relatively short period of time (42 days) and then a steady-state low CGR was assumed.

The CGRs were then calculated for the maximum and minimum temperature cases for a range of initial heat loads as a function of storage based on the canister temperatures determined in Appendix 3G of the CoC 1004 renewal application [3B-1]. The crack penetration depth was then determined by multiplying the CGR by the crack propagation time.

The evaluation showed that the maximum temperature results in a rapid increase in the crack penetration depth, while the minimum temperature case shows a relatively very slow increase in the crack penetration depth. Although the crack initiation can occur earlier for the minimum temperature case, the resultant depth is very small compared to the maximum temperature conditions. The results of the evaluation (with the low end of the activation energy of [ ]) showed the crack penetration depth ranged from [ ] at 60 years of storage.

Appendix 5B of the CoC 1004 renewal application [3B-1] also provided an evaluation of OE for ODSCC at NPPs. The evaluation focused on events at three power plants: Turkey Point Nuclear Generation Station, St. Lucie Nuclear Power Plant, and San Onofre Nuclear Generation Station. It noted that stress corrosion cracking requires three synergistic components to occur: (1) susceptible material; (2) aggressive environment; and (3) sustained tensile stress. Since the material and stress level of the NPP piping and a DSC shell are generally similar, the environmental component is the primary reason the NPP piping is more susceptible to stress corrosion cracking relative to the canister shell. However, the environmental conditions for the canisters in dry storage is more benign compared to those for the piping at the NPPs, such as lower relative humidity due to internal heating, and no significant temperature cycling inside the HSM. Therefore, the evaluation concluded that direct application of the ODSCC at NPPs to the canister CISCC is not appropriate in estimating the crack initiation time and CGR.

Other than the range of DSC temperatures, the information and conclusions in Appendix 5B of the CoC 1004 LRA [3B-1] are independent of the design of the dry fuel storage system. Section 3B.2 concluded that the range of DSC shell temperatures determined in Appendix 3G of the CoC 1004 renewal application [3B-1] are applicable to the Standardized Advanced NUHOMS® System. Therefore, the results of Appendix 5B of the CoC 1004 renewal application [3B-1] are also applicable to the Standardized Advanced NUHOMS® System.

3B.6 DSC Shell Thickness to Maintain *the ASME* Code *Limits During Retrieval*

Appendix 3N of the CoC 1004 renewal application [3B-1] demonstrated that a DSC shell thickness of [ ] was adequate to maintain *ASME Code Limits* of the DSC from horizontal storage modules. The evaluation shows that the DSC with a [ ] thickness can accommodate the stresses due to normal and off-normal loads (using an internal pressure of [ ]) while meeting the ASME B&PV Code stress limits. A review of the analysis determined that the key parameters for the Standardized Advanced NUHOMS® System (except the off-normal design pressure for the 24PT4 DSC) are bounded by or are equivalent to those used in the analysis summarized in Appendix 3N of the CoC 1004 renewal application [3B-1]. By crediting the decay in internal pressure during the initial license period of 20 years, it was shown that the off-normal pressure for the 24PT4 would be less than the [ ] assumed in the evaluation summarized in Appendix 3N of the CoC 1004 renewal application [3B-1]. Therefore, the conclusion in Appendix 3N of the CoC 1004 renewal application [3B-1] that a DSC with a [ ] thickness can accommodate the stresses due to normal and off-normal loads while meeting the ASME B&PV Code stress limits, is also applicable to the Standardized Advanced NUHOMS® System.

All changes on this page are as a result of OBS A-2

3B.7 Conclusions

The CISCC evaluations in Appendices 3G, 5A, 5B, and 3N of the CoC 1004 renewal application [3B-1] are applicable to the DSCs licensed under CoC 1029. Therefore, it is reasonable to expect that CISCC initiation would not occur until after at least 30 years of storage, and crack penetration depth after 60 years will be less than [ ] This means that the shell thickness at the crack would still be [ ] which is adequate to maintain confinement and retrievability of the DSC during the PEO.

While the evaluations show that it is reasonable to expect that CISCC will not lead to a loss of intended safety functions during the PEO, they are not being used as an AMA. However, they do support the use of a five-to-ten year inspection frequency for an AMP to provide reasonable assurance that there will not be a loss of intended safety function between AMP inspections.

3B.8 References

3B-1 Letter E-46190 from Jayant Bondre (AREVA Inc.) to U.S. NRC Document Control Desk (NRC), "Response to Re-Issue of Second Request for Additional Information – AREVA Inc. Renewal application for Standardized NUHOMS® System – CoC 1004 (Docket No. 72-1004, CAC No. L24964)," September 29, 2016, (Adams Accession Number ML16279A367).

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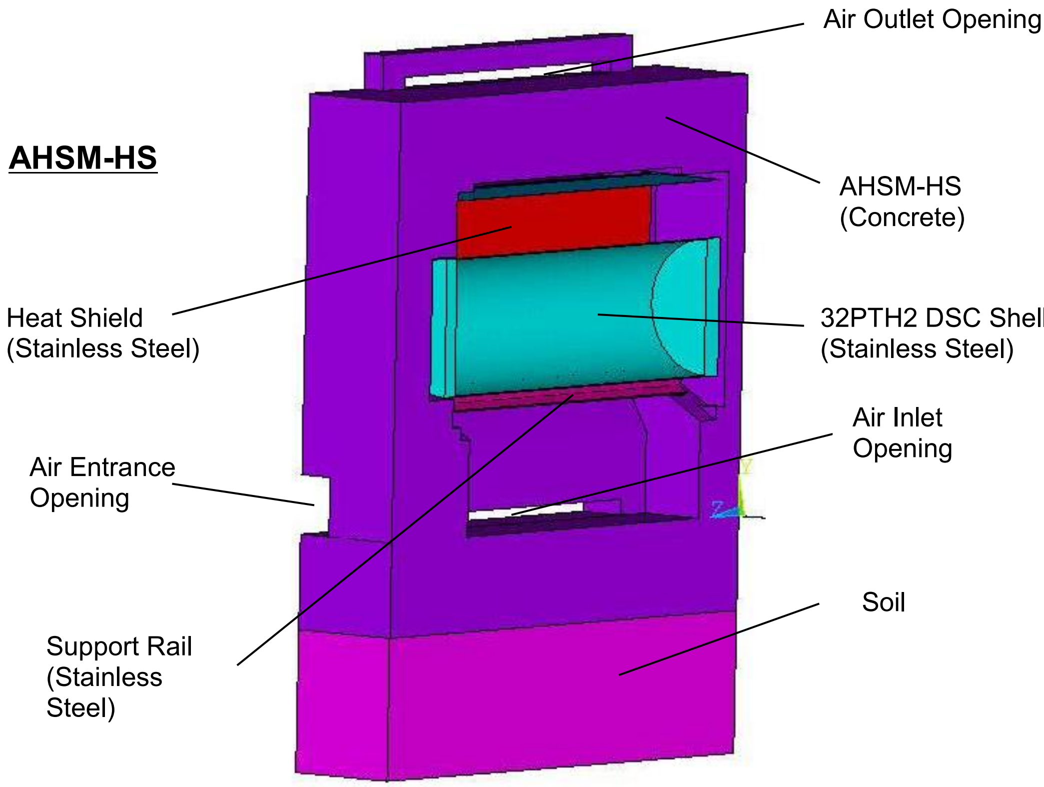

Figure 3B-1
AHSM-HS Configuration

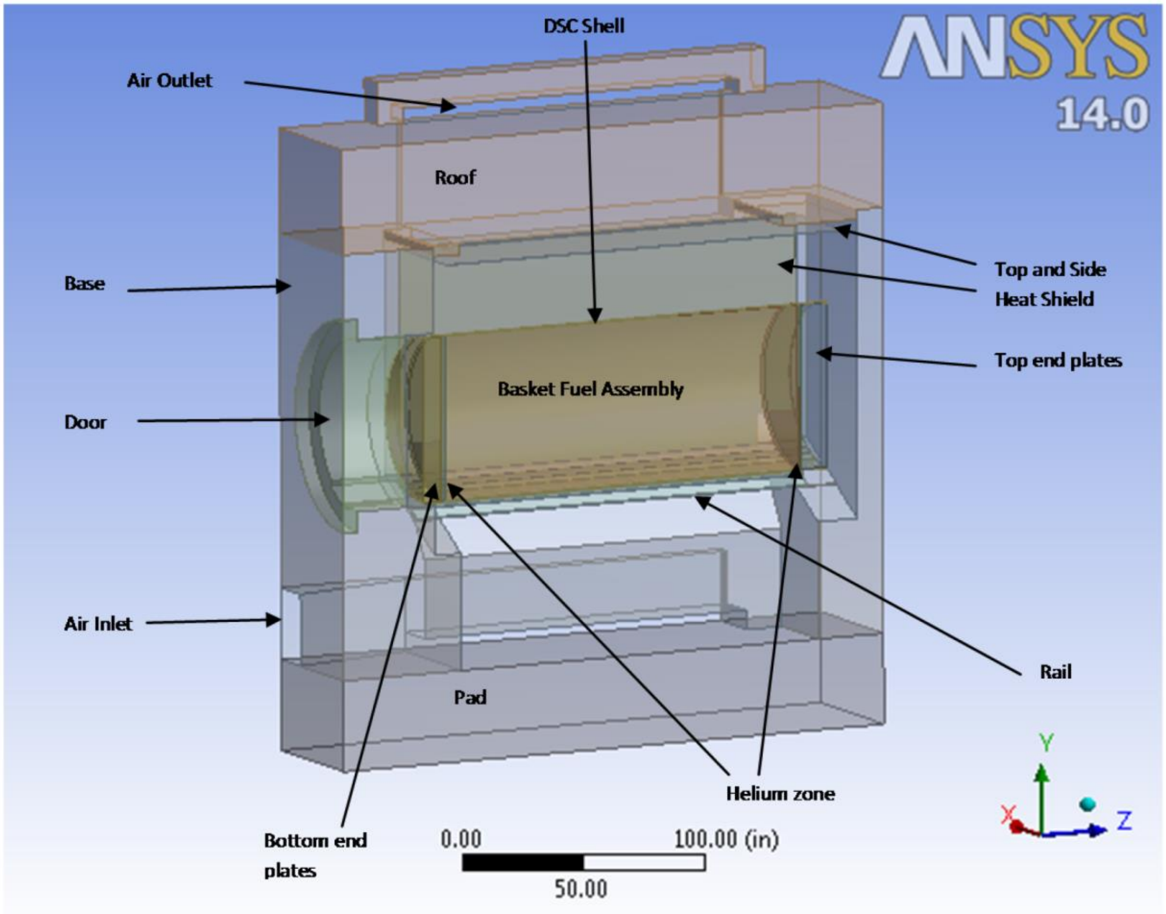

Figure 3B-2
HSM-H Configuration

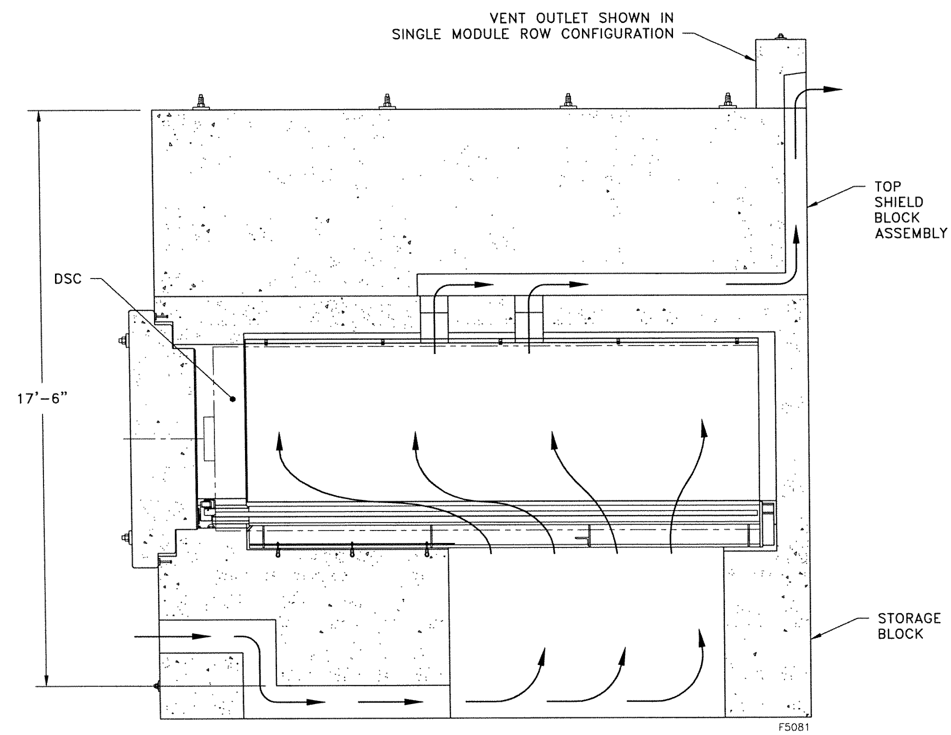

Figure 3B-3
AHSM Air Flow

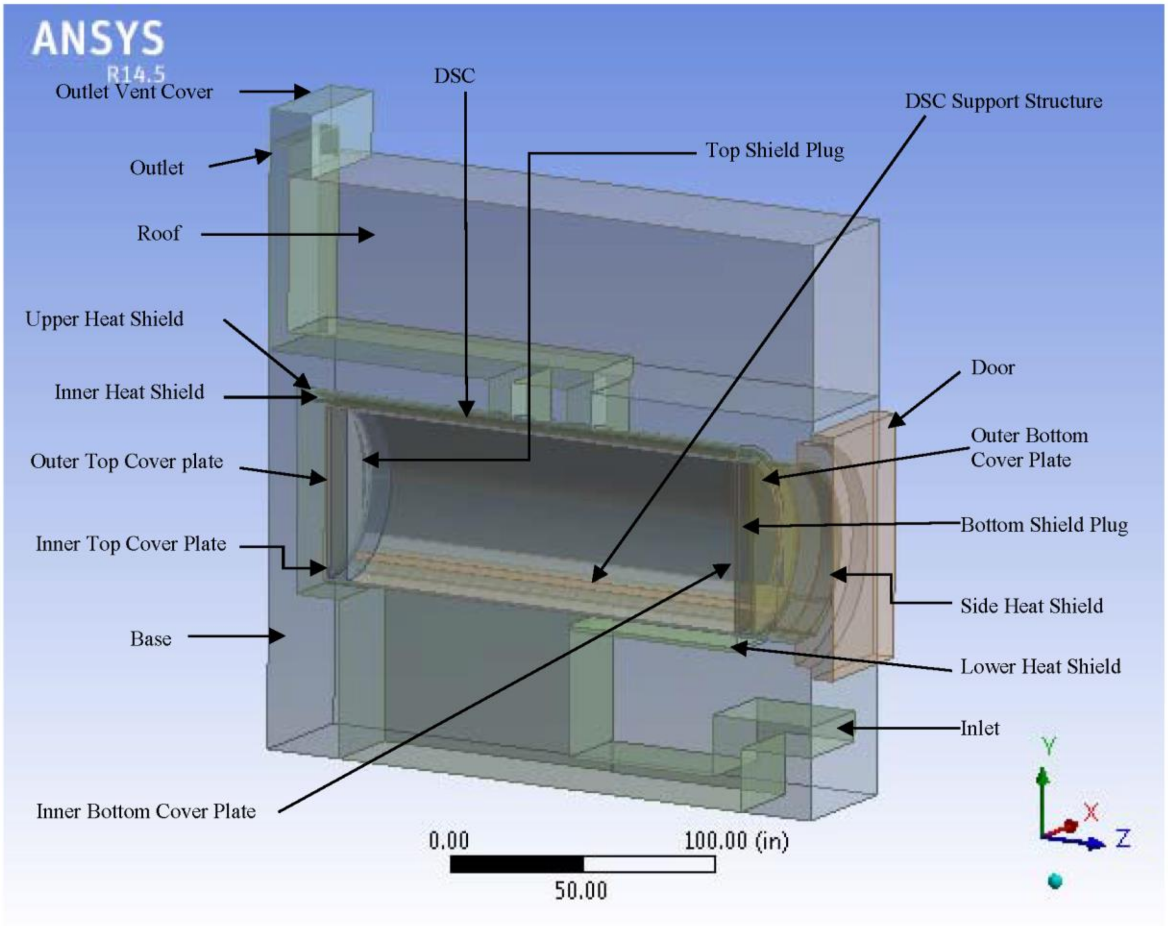

Figure 3B-4
HSM Model 152 Configuration

APPENDIX 3C
Operating Experience Review

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LIST OF TABLES

3C.1 Introduction

This Appendix summarizes the operating experience (OE) review conducted for the renewal of Certificate of Compliance (CoC) No. 1029. The OE review is intended to provide objective evidence to support (or refute) the conclusion that the effects of aging will be managed adequately so that the in-scope structures, systems, and components (SSCs) intended safety functions will be maintained during the period of extended operation.

3C.2 Operating Experience Review Approach

This is a document review of the sources of OE listed below looking for age-related (versus event-driven) degradation.

Since the Standardized Advanced NUHOMS® System is very similar to the Standardized NUHOMS® System (licensed under CoC 1004), this review takes credit for the OE review conducted as part of the CoC Renewal Application for CoC 1004 [3C-1]. It also reviews the various sources for new age-related degradation OE subsequent to the review conducted in the CoC 1004 LRA [3C-1].

The sources of potential OE reviewed are:

- Internal and industrywide condition reports
- Relevant international and non-nuclear OE
- Previous independent spent fuel storage installation (ISFSI) inspection results
- Licensee event reports
- Vendor-issued safety bulletins
- U.S. Nuclear Regulatory Commission (NRC) Generic Communications
- Updated consensus codes, standards, or guides
- Applicable industry-initiatives

3C.3 Internal and Industry Condition Reports

3C.3.1 Review of Condition Reports Summarized in CoC 1004 LRA

The CoC 1004 LRA [3C-1] summarizes the review of a wide range of records pertaining to the operating experience for the Standardized NUHOMS® System to identify age-related degradation. These records included TN Americas LLC's internal corrective action reports (CARs), licensing reviews, and nonconformance reports. Any unusual or abnormal results were reviewed, along with the CARs and condition reports pertaining to these abnormalities, to identify any aging or age-related degradation effects. Other industry wide data, such as OE from the Institute of Nuclear Power Operations (INPO) database, were also reviewed to identify any aging effects/mechanisms that would be relevant to the aging management review process.

[

e.]

3C.3.2 Review of Internal Condition Reports Since CoC 1004 LRA

Table 3C-1 provides a summary of the TN Americas LLC CARs that occurred subsequent to the submittal of CoC 1004 renewal. As shown in Table 3C-1, most conditions involved aging mechanisms/effects already identified as requiring management (e.g., cracking due to freeze-thaw and corrosion of carbon steel). There were also a few conditions that were either event-driven or involved subcomponents that are not in-scope for the renewal of CoC 1029.

3C.3.3 Review of CoC Users Condition Reports

Currently, there is a single ISFSI storing spent fuel using CoC 1029, the San Onofre Nuclear Generating Station (SONGS). Table 3C-2 provides a summary of the SONGS ISFSI condition reports. As shown in Table 3C-2, all conditions were either event-driven or involved subcomponents that are not in-scope for the renewal of CoC 1029.

3C.3.4 Review of Industry Condition Reports Since CoC 1004 LRA

A review of the Aging Management INPO Database (AMID) identified reported OE that is discussed elsewhere in this appendix (e.g., the inspections performed at the Calvert Cliffs ISFSI). The review did not identify any aging mechanism and/or effects that were not already identified in NUREG-2214 [3C-8]. In addition, no incidents were identified where aging effects led to the loss of intended safety functions.

3C.4 Relevant International and Non-Nuclear Operating Experience

The Aging Management Review (AMR) conducted for the renewal of CoC 1029 is based on the aging mechanisms/effects described in NUREG-2214 [3C-8]. Since the information in NUREG-2214 [3C-8] is based in part on international and non-nuclear operating experience, the AMR is also based in part on international and non-nuclear operating experience. In addition, the evaluations related to chloride-induced stress corrosion cracking (CISCC) discussed in Appendix 3B also relied upon international and non-nuclear OE.

3C.5 Previous ISFSI Inspection Results

The CoC 1004 LRA [3C-1] summarized inspections performed as part of other NUHOMS® storage system ISFSI renewal applications. These inspections include the site-specific renewal application inspection reports for Calvert Cliffs Nuclear Power Plant ISFSI (conducted in 2012), Oconee Nuclear Station ISFSI (conducted in 2006), and H.B. Robinson Steam Electric Plant ISFSI (conducted in 1993 and 1999). These inspection reports are considered relevant because the ISFSIs are based on similar NUHOMS® storage system designs.

The conclusion of these reviews is that the previous NUHOMS® System-based site-specific ISFSI lead canister and baseline inspection reports demonstrate that NUHOMS® System canisters and HSMs have not undergone unanticipated degradation.

Subsequent to the review in CoC 1004 renewal application [3C-1], additional inspections have been performed on NUHOMS® storage system designs similar to the Standardized Advanced NUHOMS® storage system design licensed under CoC 1029. These, additional inspections are summarized below.

3C.5.1 Rancho Seco

In May of 2017, the Sacramento Municipal Utility District (SMUD) conducted a license renewal pre-application inspection [3C-6] of a NUHOMS® storage system design similar to the Standardized Advanced NUHOMS® storage system design. The inspection included direct visual inspection of the HSM doors (exterior), roofs, and exterior concrete surfaces as well as the above-ground basemat concrete surfaces. The inspection also included remote visual inspection of:

- DSC shell, lower half;
- HSM heat shields;
- HSM side walls, floor (all interior); and
- DSC steel support structure.

The inspection was performed on the DSC with the longest time in service (i.e., over 15 years), and had an initial decay heat of 9.005 kW. This low heat load results in low DSC shell surface temperatures and progressively continues to lower the DSC shell temperatures over the 15-year operating period, thus increasing relative humidity inside the HSM and potentially promoting incubation of ambient contaminants.

The inspection concluded that the surfaces of the HSM walls, floor, roof, heat shields, doors, birdscreens, DSC support structure, DSC shell lower half, and basemat do not show any age-related degradation effects. Minor spall was identified on the upper corner of one HSM that likely occurred during transport and assembly. The spall did not appear to be part of active deterioration.

3C.5.2 2017 Calvert Cliffs Inspection

In 2017, Calvert Cliffs performed their renewed license (SNM-2505) required aging management program (AMP) inspections for the NUHOMS® System HSMs and DSCs [3C-12].

The inspections included visual inspections of accessible exterior surfaces of a minimum of five targeted HSMs, and visual inspections of the interior surfaces of the two HSMs that were inspected in 2012. The HSM interior and exterior surface inspections were considered to be acceptable based on being within the Tier 1 quantitative limits of American Concrete Institute (ACI) 349.3R-02. There were no noteworthy changes from the conditions seen during the 2012 inspections [3C-12].

The 2017 inspection also included inspecting the DSCs that were inspected in 2012. The DSC accessible surfaces were considered to be acceptable using the established acceptance criteria. No evidence of crevice corrosion, pitting, or stress corrosion cracking was observed. There were no noteworthy changes from the conditions seen during the 2012 inspections [3C-12].

3C.6 Licensee Event Reports

A search was performed of the NRC's Licensee Event Report database using the following key words:

- DSC
- HSM
- Cask
- Aging
- Dry Fuel Storage
- ISFSI

No Licensee Event Reports associated with age-related degradation of ISFSI SSCs were found.

3C.7 Vendor-Issued Safety Bulletins

Table 3C-3 provides a summary of the TN Americas LLC User's Group (TNUG) Technical Bulletins. As shown in Table 3C-3, most conditions were either event-driven or involved subcomponents that are not in-scope for the renewal of CoC 1029. The few conditions that were age-related involved aging mechanisms/effects already identified as requiring management (e.g., cracking due to freeze-thaw and chloride-induced stress corrosion cracking).

3C.8 NRC Generic Communications

The CoC 1004 LRA [3C-1] reviewed the following NRC generic communications:

- NRC Information Notice 2011-20: Concrete Degradation by Alkali-Silica Reaction [3C-2]
- NRC Information Notice 2012-20: Potential Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canisters [3C-3]
- NRC Information Notice 2013-07: Premature Degradation of Spent Fuel Storage Cask Structures and Components from Environmental Moisture [3C-4]
- NRC Bulletin 96-04: Chemical, Galvanic or other Reactions in Spent Fuel Storage and Transportation Casks [3C-5]

A review of the NRC website showed that no NRC bulletins, generic letters, or information notices related to age-related degradation of ISFSI SSCs have been issued since IN-2013-07 [3C-4].

Note that the AMR conducted for the renewal of CoC 1029 is based on the aging mechanisms/effects described in NUREG-2214 [3C-8]. Since the information in NUREG-2214 [3C-8] is based on OE, there is a direct connection from the OE to the AMR.

3C.9 Updated Consensus Codes, Standards, or Guides

3C.9.1 Aging Management Reviews

The AMR conducted for the renewal of CoC 1029 is based on the aging mechanisms/effects described in NUREG-2214 [3C-8]. Therefore, the AMR is based on the version/edition/revision of the codes, standards, and guides referenced in NUREG-2214 [3C-8].

3C.9.2 Aging Management Programs

The AMPs for the renewal of CoC 1029 will use the most up-to-date (as of the time the AMPs are developed) version/edition/revision of the applicable codes, standards, and guidelines.

3C.10 Applicable Industry Initiatives

3C.10.1 High Burnup Fuel Demonstration Project

The Electrical Power Research Institute (EPRI) and Department of Energy (DOE) are conducting a joint High Burnup Fuel Dry Storage Cask Research and Development Project (HDRP) [3C-7] that monitors the performance of high burnup (HBU) fuel in dry storage. The HDRP is a program designed to collect data from a spent nuclear fuel storage system containing HBU fuel in a dry helium environment. The program entails loading and storing a TN-32B bolted lid cask (the "Research Project Cask") at Dominion Virginia Power's North Anna Power Station with intact HBU fuel (of nominal burnups ranging between 53 GWd/MTU and 58 GWd/MTU). The fuel used in the program includes four kinds of cladding (Zircaloy-4, low-tin Zircaloy-4, ZIRLO™, and M5™). The Research Project Cask was loaded and placed in service in November 2017.

3C.10.2 Chloride-Induced Stress Corrosion Cracking

EPRI has undertaken various initiatives to improve the understanding of the chloride-induced stress corrosion cracking phenomena in terms of susceptibility [3C-9], risk [3C-10], and aging management guidance [3C-11]. The AMP for the DSCs utilizes some of the guidance in EPRI Report 3002008193 [3C-11].

3C.11 Conclusion

The review of various sources of operating experience did not identify any aging mechanism and/or effects that were not already identified in NUREG-2214 [3C-8]. In addition, no incidents were identified where aging effects led to the loss of intended safety functions of NUHOMS® System SSCs. Therefore, it is concluded that the effects of aging will be managed adequately so that the SSCs' intended safety functions will be maintained during the period of extended operation.

3C.12 References

3C-1 Letter E-46190 from Jayant Bondre (AREVA Inc.) to Document Control Desk (NRC), "Response to Re-Issue of Second Request for Additional Information – AREVA Inc. Renewal application for Standardized NUHOMS® System – CoC 1004 (Docket No. 72-1004, CAC No. L24964)," September 29, 2016 (Adams Accession Number ML16279A367).

3C-2 U.S. NRC Information Notice 2011-20, "Concrete Degradation by Alkali-Silica Reaction," Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, November 18, 2011.

3C-3 U.S. NRC Information Notice 2012-20, "Potential Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canister," U.S. Nuclear Regulatory Commission, November 14, 2012.

3C-4 U.S. NRC Information Notice 2013-07, "Premature Degradation of Spent Fuel Storage Cask Structures and Components from Environmental Moisture," U.S. Nuclear Regulatory Commission, April 16, 2013.

3C-5 U.S. NRC Bulletin 96-04, "Chemical, Galvanic or Other Reactions in Spent Fuel Storage and Transportation Casks," U.S. Nuclear Regulatory Commission, July 5, 1996.

3C-6 SMUD Ltr DPG 18-051 to Director, Division of Spent Fuel Management, "Submittal of Application for the Renewal of 10 CFR Part 72 Special Nuclear Materials License No. SNM-2510 for the Rancho Seco Independent Spent Fuel Storage Installation," Enclosure E, March 19, 2018 (Adams Accession Number ML1810A024).

3C-7 Electric Power Research Institute, "High Burnup Dry Storage Cask Research and Development Project: Final Test Plan," Rev. 0, DE-NE-0000593, February 27, 2014.

3C-8 NUREG-2214, "Managing Aging Process in Storage (MAPS) Report," Draft Report for Comment, U.S. Nuclear Regulatory Commission, October 2017 (Adams Accession Number ML17289A237).

3C-9 Electric Power Research Institute, "Susceptibility Assessment Criteria for Chloride-Induced Stress Corrosion Cracking (CISCC) of Welded Stainless Steel Canisters for Dry Storage Systems," EPRI Report 3002005371, September 2015.

3C-10 Electric Power Research Institute, "Dry Cask Storage Welded Stainless Steel Canister Breach Consequence Analysis Scoping Study," EPRI Report 3002008192, November 2017.

3C-11 Electric Power Research Institute, "Aging Management Guidance to Address Potential Chloride-Induced Stress Corrosion Cracking of Welded Stainless Steel Canisters," EPRI Report 3002008193, March 2017.

3C-12 Presentation from Jack DeSando, Exelon, "Calvert Cliffs – ISFSI AMP Update & Lessons Learned," October 31, 2017 (Adams Accession Number ML17297A414).

Proprietary Information on Pages 3C-15 through 3C-19
Withheld Pursuant to 10 CFR 2.390

CHAPTER 4
AGING MANAGEMENT PROGRAMS

CONTENTS

LIST OF TABLES

4.1 Introduction

The purpose of an aging management program (AMP) is to monitor and control the degradation of structures, systems, and components (SSCs) to ensure that no aging effects result in a loss of intended safety function of the in-scope SSCs for the period of extended operations (PEO). An effective AMP prevents, mitigates, or detects aging effects and provides for the prediction of the extent of the effects of aging and timely implementation of corrective actions before there is a loss of intended safety function. AMPs are based on the results of the aging management review (AMR) for the dry shielded canisters (DSCs), horizontal storage modules (HSMs), basemat, and spent fuel assemblies (SFAs) presented in Chapter 3. The tables in Chapter 3 summarize the results of the AMR and identify the aging management activity (AMA) credited for managing each aging effect and aging mechanism for each component or subcomponent evaluated in the AMR.

The AMPs will apply under extended Certificate of Compliance (CoC) 1029 terms, that is, implementation of the AMPs will be a CoC condition for the Standardized Advanced NUHOMS® storage system components in service after the initial 20-year period at an Independent Spent Fuel Storage Installation (ISFSI). The requirement for implementation of the proposed AMPs will be set forth under the terms and conditions of the proposed renewed certificate as described in Attachment B.

The AMPs developed to manage aging effects for the PEO are:

- DSC Aging Management Program
- HSM Aging Management Program
- ISFSI Basemat Aging Management Program
- High Burnup Fuel Aging Management Program

As discussed in Section 2.3.3, the transfer casks (TCs) approved for use under CoC 1029 are certified in CoC 1004. As such, the AMPs developed to manage the aging effects for the TCs are per CoC 1004. In this Chapter, the terms DSC and HSM are used in a generic sense, and are intended to apply to the various types of DSCs and HSMs licensed in accordance with CoC 1029.

4.2 Aging Management Program Elements

The structure of the AMPs is consistent with the 10 program elements described in NUREG-1927, as follows:

1. Scope of the program: The scope of the program includes the specific SSCs and subcomponents subject to the AMP and the intended safety functions to be maintained. In addition, the element states the specific materials, environments, and aging mechanisms and effects to be managed.
2. Preventive actions: Preventive actions used to prevent aging or mitigate the rates of aging for SSCs.
3. Parameters monitored or inspected: This element identifies the specific parameters that will be monitored or inspected and describes how those parameters will be capable of identifying degradation or potential degradation before there is a loss of intended safety function.
4. Detection of aging effects: This element includes inspection and monitoring details, including method or technique (i.e., visual, volumetric, surface inspection), frequency, sample size, data collection, and timing of inspections to ensure timely detection of aging effects. In general, the information in this element describes the "when," "where," and "how" of the AMP (i.e., the specific aspects of the activities to collect data as part of the inspection or monitoring activities).

   "Accessible areas" are defined as surfaces of in-scope SSCs and subcomponents that can be visually inspected by direct means without disassembly.

   "Normally non-accessible areas" are defined as surfaces (or portions of surfaces) of in-scope SSCs and subcomponents that can be visually inspected by remote means without significant disassembly (such as removal of HSM door).

   "Inaccessible areas" are defined as surfaces of in-scope SSCs and subcomponents that cannot be visually inspected by direct or remote means without additional actions (e.g., removal of DSC from HSM).
5. Monitoring and trending: This element describes how the data collected will be evaluated. This includes an evaluation of the results against the acceptance criteria and an evaluation regarding the rate of degradation to ensure that the timing of the next scheduled inspection will occur before there is a loss of intended safety function.
6. Acceptance criteria: Acceptance criteria, against which the need for corrective action will be evaluated, ensure that the SSC's intended safety functions and the approved design bases are maintained during the PEO.
7. Corrective actions: Corrective actions are the measures taken when the acceptance criteria are not met. Timely corrective actions, including root cause determination and prevention of recurrence for significant conditions adverse to

quality, are critical for maintaining the intended safety functions of the SSCs during the PEO.

8. Confirmation process: This element verifies that preventive actions are adequate and that effective appropriate corrective actions have been completed. The confirmation process is commensurate with the general licensee Quality Assurance (QA) Program approved under 10 CFR Part 50, Appendix B. The QA Program ensures that the confirmation process includes provisions to preclude repetition of significant conditions adverse to quality.
9. Administrative controls: Administrative controls provide a formal review and approval process in accordance with an approved QA program.
10. Operating experience: The operating experience element of the program supports a determination that the effects of aging will be adequately managed so that the SSC's intended safety functions will be maintained during the PEO. Operating experience provides justification for the effectiveness of each AMP program element and critical feedback for enhancement.

4.3 DSC Aging Management Program

4.3.1 DSC AMP – Scope of Program

This program visually inspects and monitors the external surfaces of the DSC (the term DSC applies to the 24PT1, 24PT4, and 32PTH2 DSC types) subcomponents listed in Table 4-3. The table also lists the material and environments for each subcomponent along with the aging mechanisms and aging effects to be managed. The following aging effects and mechanism will be managed via this AMP:

- Stainless Steel
  - Loss of material due to pitting, crevice, and galvanic corrosion
  - Cracking due to stress corrosion cracking

4.3.2 DSC AMP – Preventive Actions

The program is a condition-monitoring program that does not include preventive actions.

4.3.3 DSC AMP – Parameters Monitored or Inspected

The DSC AMP consists of visual inspections to monitor for material degradation. There are no accessible areas of the DSC available for direct visual inspection since it is sheltered inside the HSM.

The following normally non-accessible areas will undergo remote visual inspection for loss of material and cracking:

- Portions of the DSC surfaces, welds and heat affected zones (HAZs), and crevice locations near the DSC support rails are inspected for discontinuities and imperfections. Localized corrosion (e.g., pitting and crevice corrosion), cracking, or discolorations, if any, are documented. Appearance and location of atmospheric deposits on the DSC surfaces are recorded.
- Portions of the outer top cover plate, closure welds, and HAZ.
- Portions of the outer bottom cover plate, grapple ring assembly, and their welds and HAZ.
- Portions of the DSC shell bottom surface (including edge of DSC support rails and HAZ).

The inaccessible areas of the DSC include:

- The upper surface of the DSC Shell (i.e., where atmospheric particulates may settle).
- Majority of outer top cover plate, welds, and HAZ.
- Majority of outer bottom cover plate, grapple ring assembly, and their welds and HAZ.

All changes on this page are as a result of OBS 4-1

- The DSC shell crevice locations (i.e., where shell rests on DSC support rail).

The inspections of the HAZ will extend to a distance of at least two inches on either side of the welds.

4.3.4 DSC AMP – Detection of Aging Effects

This program manages the DSC aging effects using visual inspection. Visual examinations follow procedures consistent with the ASME B&PV Code, Section XI [4-3], Subarticle IWA-2210.

4.3.4.1 DSC AMP – Selection of DSC(s) for Inspection

A minimum of one DSC will be selected for the baseline and subsequent inspections. The selection is to be based on the following considerations/criteria:

A. Time in service: Storage duration (time in service) is related to surface temperature and deposition of contaminants. The DSC selected for inspection is to be from the group of DSCs with longest time in service.

B. Initial heat load: The DSC selected for inspection is to be from a group of DSCs with low initial heat loading that result in low DSC shell surface temperatures, thus increasing relative humidity inside the HSM and promoting incubation of ambient contaminants.

C. DSC fabrication and design considerations: A review of the design drawings and DSC fabrication package is to be performed to further "screen-in" the DSC from the pool of candidates selected based on (A) and (B). Fabrication weld maps are to be reviewed to identity locations of the circumferential and longitudinal welds, location and disposition of welded attachments, and external configurations of the inner bottom cover-to-shell weld.

D. HSM array configuration relative to climatological and geographical features: DSCs inside HSMs oriented such that the vent openings face the prevalent wind direction are to be considered for inspection, particularly if the wind direction is in the path of potential sources of contaminants (e.g., industrial plant, co-located coal power plant, if present).

4.3.4.2 DSC AMP – Inspection Methods

Standard Visual Exams

Visual examinations follow procedures consistent with the ASME B&PV Code, Section XI [4-3], Subarticle IWA-2210. ASME B&PV Code, Section XI NDE standard is chosen since the DSC is designed to ASME B&PV Code, Section III, Division 1, Subsection NB [4-4 and 4-5] criteria. ASME B&PV Code, Section XI [4-3], Subarticle IWA-2213 VT-3 visual examinations detect discontinuities and imperfections on the surface of components, including corrosion. A general visual exam will be performed on normally non-accessible portions of the DSC surface that do not receive the VT-3 exam. VT-3 visual examinations are initially performed on normally non-accessible portions of the DSC surfaces within two inches of a weld. Additional VT-1 visual examinations are performed as described in the acceptance criteria when indicated by the assessment of the VT-3 results, subject to the following provisions. For areas where the access and available technology preclude the execution of a qualified VT-3 or VT-1 inspection, a technique equivalency test will be conducted in a mockup. The equivalency test is intended to show how capable the equipment and procedures are in being able to read an approved VT-3 or VT-1 acuity card in the general lighting conditions and at the approximate distance and angle expected on the actual DSC.

Within the HSM cavity, certain surface areas of the DSC may be inaccessible for remote inspection. This AMP addresses detection of aging effects for inaccessible areas indirectly by monitoring the inspection findings in normally non-accessible areas.

Therefore, inaccessible area inspections are only performed if the licensee's corrective action program determines it is necessary to ensure that the component's intended safety function is maintained during the PEO.

Augmented Examination

An augmented examination is performed on a DSC when the visual exams indicate the presence of major corrosion (see Section 4.3.6 below for what constitutes a major corrosion indication) within two inches of a weld. These examinations will be performed using qualified personnel and, if available, qualified examination procedures.

- A volumetric examination is performed of cracking indications and the surrounding volume within one inch of the indication.
- A surface examination (a volumetric exam may be performed in lieu of the surface exam) is performed of the regions (plus one inch of the extent of the indication) of major corrosion.
- Locations inspected using surface or volumetric examination do not need to receive a VT-3 inspection.

4.3.4.3 DSC AMP – Inspection Timing and Frequency

The baseline AMP visual inspection is to be conducted within two years prior to 20 years of the first loaded DSC being placed in storage. Subsequent inspections are to be conducted every 5 years ± 1 year or when an engineering evaluation predicts an identified crack will reach 75% through-wall, whichever is less, following the baseline inspection.

4.3.5 DSC AMP – Monitoring and Trending

The inspections and monitoring activities in this AMP are performed periodically in order to identify areas of degradation. Conditions adverse to quality that are noted during the inspection and monitoring activities, such as non-conformances, failures, malfunctions, deficiencies, and deviations, are entered into the licensee's corrective action program. Visual inspections appropriately consider cumulative operating experience (OE) from previous inspections and assessments in order to monitor and trend the progression of aging effects over time. Data taken for these inspections is to be monitored by comparison to past site data taken, as well as comparison to industry OE, including data gathered by the Aging Management Institute of Nuclear Power Operations (INPO) Database (AMID) as discussed in Nuclear Energy Institute (NEI) 14-03 [4-2].

As described in Section 4.3.4.1, a minimum of one DSC is to be selected for the baseline inspection and subsequent inspections. If the baseline DSC is not available for subsequent inspections (e.g., has been shipped off-site), another DSC is to be selected for a new baseline inspection following the considerations/criteria in Section 4.3.4.1.

4.3.6 DSC AMP – Acceptance Criteria

The acceptance criteria for this AMP follows the guidance provided in Electric Power Research Institute (EPRI) Report 3002008193 [4-6], which focuses on chloride-induced stress corrosion cracking (CISCC). This report states that CISCC has been identified as the most likely and limiting degradation mechanism that could lead to through-wall penetration of the austenitic stainless steel canister during storage. Thus, other atmospheric corrosion mechanisms (e.g., pitting) are conservatively addressed by these acceptance criteria. There are three tiers of acceptance criteria:

- Visual examination criteria – visual examination results are evaluated using this criteria
- Augmented examination criteria – surface or volumetric examinations are evaluated using this criteria
- Flaw evaluation criteria – used if cracking is detected

All changes on this page are as a result of RSI 4-1

4.3.6.1 DSC AMP – Visual Examination Criteria

Criteria are provided below to classify the indication as a major corrosion indication, a minor corrosion indication, or an insignificant corrosion indication.

The presence of a major corrosion indication within two inches of a weld, will receive an augmented surface or volumetric examination for the presence of cracking and will be entered into the licensee's corrective action program. The presence of a major corrosion indication more than two inches from a weld will be entered into the licensee's corrective action program.

A minor corrosion indication within two inches from a weld will receive a supplemental VT-1 exam (a surface or volumetric exam may be performed in lieu of the VT-1 exam) to demonstrate that there is no attack of the metal under the corrosion indication. Note that the area does not need to be cleaned if there is confidence that the VT-1 exam will be able to detect pitting, cracking, under-deposit corrosion, or general attack. If it is determined there is an attack of the metal under the corrosion indication, then the condition will be entered into the licensee's corrective action program. A minor corrosion indication more than two inches from a weld is acceptable without further action other than noting the indication.

Major corrosion indications:

If a corrosion indication meets any of the following, it will be considered a major corrosion indication:

- Cracking of any size
- Corrosion products having a linear appearance, except light corrosion indicative of iron contamination
- Corrosion products having a branching appearance
- Evidence of pitting corrosion, under-deposit corrosion, or etching with measurable depth (removal/attack of material by corrosion)
- In a 10 cm by 10 cm region, corrosion product is present in 25% or more of the surface with evidence of attack into the DSC
- Evidence of water intrusion that runs into a crevice location with rust staining at the edge of the crevice
- Corrosion product deposit present at the mouth of an occluded region that includes a portion of the DSC shell weld

Minor corrosion indications:

If a corrosion indication is not a major corrosion indication and it meets any of the following, it will be considered a minor corrosion indication:

- Evidence of water intrusion stained the color of corrosion products

- Areas of light corrosion that follow a fabrication feature or anomaly (e.g., scratch or gouge) – such indications are indicative of iron contamination
- In a 10 cm by 10 cm region, corrosion product is present in 10% to 25% of the canister surface
- Corrosion product greater than 2 mm in diameter

Insignificant corrosion indications:

Corrosion indications that do not meet the criteria for being a major corrosion indication or the criteria for being a minor corrosion indication are considered insignificant corrosion indications. Insignificant corrosion indications are acceptable without further action other than noting the indications.

4.3.6.2 DSC AMP – Augmented Examination

If a surface examination is performed, no further actions are required if any of the following apply:

- If a surface examination confirms the absence of flaws
- If the detected flaw is a rounded indication, and if no corrosion products or masking deposits are present
- If the detected flaw is a linear indication, if no corrosion products or masking deposits are present, and if the linear indication is determined not to have a crack-like morphology

If none of the above surface examination bullets apply, then a volumetric exam is to be performed.

If a volumetric examination is performed, no further actions are required if any of the following apply:

- If a volumetric examination confirms the absence of planar flaws
- If the detected indication is determined to not be connected to the exterior of the DSC (i.e., not associated with the outside surface)
- If the entirety of the detected flaw is in an area that is confirmed to have no corrosion products present, and if the indication is determined to not have a crack-like morphology
- If the detected indication was recorded prior to being mitigated or remediated, and there has been no measurable increase in the flaw size after being remediated

If none of the above volumetric examination bullets apply, the detected indication is an outside surface-connected planar flaw and is considered material cracking. In this case, an engineering evaluation is performed to demonstrate the acceptability of the cracking using flaw evaluation.

4.3.6.3 DSC AMP – Flaw Evaluation

If a crack is identified, an engineering evaluation will be performed to determine when the flaw will reach 75% of the through-wall thickness [4-6]. This engineering evaluation should use the original design and licensing basis calculations, which are maintained by the CoC holder, and drawings for inputs.

If the flaw is measured to be greater than 75% through-wall, or if it is not feasible to perform an additional inspection prior to when the engineering evaluation determined the flaw will reach 75% through-wall, the condition will be addressed in accordance with the licensee's corrective action program. Industry OE will be reviewed to identify any relevant OE, repair experience, or generic industry analyses related to the consequences of through-wall CISCC.

4.3.7 DSC AMP – Corrective Actions

Site QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. The licensee's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determination and prevention of recurrence. Deficiencies are either corrected or are evaluated to be acceptable for continued service through engineering analysis, which provides reasonable assurance that the intended safety function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging should utilize the same methodology used in the licensing and design basis calculations, which are maintained by the CoC holder, as much as practical to ensure intended safety functions are maintained through the PEO. Extent of condition investigation per the licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

4.3.8 DSC AMP – Confirmation Process

The confirmation process will be commensurate with the general licensee QA program approved under 10 CFR Part 50, Appendix B. The QA program ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. It also contains provisions to preclude repetition of significant conditions adverse to quality.

4.3.9 DSC AMP – Administrative Controls

Administrative controls under the CoC holder or licensee's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue for the PEO. Licensees and CoC holder use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the U.S. Nuclear Regulatory Commission (NRC). Individual events and conditions not rising to the level of NRC reportability based on the criteria in 10 CFR Part 72 are communicated to the CoC holder as outlined in NEI 14-03 [4-2].

4.3.10 DSC AMP – Operating Experience

Appendix 3C documents the review of various sources of OE relevant to the Standardized Advanced NUHOMS® System. This review included inspections of NUHOMS® System SSCs that have been in service for several years. While the review identified several conditions that were age-related, no incidents were identified where aging effects led to the loss of intended safety functions of a NUHOMS® System SSC. This OE review supports the conclusion that the effects of aging will be managed adequately so that the SSC's intended safety functions will be maintained during the PEO.

This AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. Future plant-specific and industry aging management and age-related OE are captured through the licensee's OE review process. The ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects.

In addition to the ongoing OE review, this AMP requires periodic written evaluations (as described in Table 4-1) of the aggregate impact of aging-related DSCs OE, research, monitoring, and inspections on the intended safety functions of the in-scope DSC's subcomponents (i.e., tollgates). While licensees and TN Americas LLC assess new information relevant to aging management in accordance with normal corrective action and OE programs, tollgates are an opportunity to seek other information that may be available and to perform an aggregate assessment. Tollgate assessments are not stopping points. No action, other than performing an assessment and addressing relevant findings in the licensee's corrective action program, is required to continue Standardized Advanced NUHOMS® dry storage system operation. Tollgate assessment reports are not required to be submitted to the NRC, but are available for inspection. Appendix A of NEI 14-03 [4-2] provides guidance on the performance criteria for the tollgate assessments.

4.4 HSM Aging Management Program

4.4.1 HSM AMP – Scope of Program

This program visually inspects the surfaces of the HSM (the term HSM applies to the Advanced Horizontal Storage Modules (AHSM) and AHSM-HS designs) subcomponents listed in Table 4-4. The table also lists the material and environments for each subcomponent along with the aging mechanisms and aging effects to be managed. The following aging effects/mechanisms will be managed via this AMP:

- Steel
  - Loss of material due to general, pitting, crevice, and galvanic corrosion
- Stainless Steel
  - Loss of material due to pitting, and crevice corrosion
  - Cracking due to stress corrosion cracking
- Concrete
  - Loss of material due to freeze-thaw, aggressive chemical attack, corrosion of reinforcing steel, and salt scaling
  - Cracking due to freeze-thaw, reaction with aggregates, differential settlement, aggressive chemical attack, and corrosion of reinforcing steel
  - Loss of strength due to reaction with aggregates, aggressive chemical attack, corrosion of reinforcing steel, and leaching of calcium hydroxide
  - Reduction of concrete pH due to aggressive chemical attack and leaching of calcium hydroxide
  - Loss of concrete/steel bond due to corrosion of reinforcing steel
  - Increase in porosity and permeability due to leaching of calcium hydroxide

4.4.2 HSM AMP – Preventive Actions

The program is a condition-monitoring program that does not include preventive actions.

4.4.3 HSM AMP – Parameters Monitored or Inspected

The HSM AMP consists of visual inspections to monitor for material degradation.

The following accessible areas of the HSMs will undergo direct visual inspection for the aging effects listed in Table 4-4:

- The external concrete surfaces of the HSM roof and walls
- External surfaces of the HSM access door
- External attachment hardware

The following normally non-accessible areas of HSM will undergo remote visual inspection for the aging effects listed in Table 4-4:

- Portions of the concrete front, back, and sides of the base unit
- Portions of the DSC support structure and attachment hardware

The inaccessible areas of the HSM include:

- The internal surface of the HSM blocked from view due to the heat shields
- Heat shields at internal surface of the roof and side walls
- Portions of the concrete front, back, and sides of the base unit
- Portions of the DSC support structure and attachment hardware
- External surfaces of the base unit's side and rear walls
- Components embedded in concrete

4.4.4 HSM AMP – Detection of Aging Effects

A minimum of one HSM will be selected for the baseline and subsequent inspections. The selection is to be based on the time in service or the DSC selected for aging management inspections.

As appropriate, direct or remote visual inspections utilizing ACI 349.3R [4-9], Section 3.6.1 are conducted for HSM concrete in both outdoor and sheltered environments, allowing for detection of aging effects from Table 4-4. Direct or remote visual inspections are utilized for general inspections for HSM steel components depending on whether these components are accessible or normally non-accessible, respectively. Visual examinations are performed for steel surfaces, detecting aging effects from Table 4-4 while identifying and assessing discontinuities and imperfections on the surface of components. As much of the HSM steel surfaces as can be reasonably accessed is examined to ascertain their general condition.

Inspection of the normally, non-accessible internal surfaces of the HSM concrete may be performed using a video camera, fiber-optic scope, or other remote inspection technology via existing access points of the HSM. The remote inspection system is qualified and demonstrated to have sufficient resolution capability and enhanced lighting to resolve the acceptance criteria identified in Section 4.4.6.

For HSM concrete, crack maps are developed. Dimensioning is documented in photographic records by inclusion of a tape measure/crack gauge, a comparator, or both.

Within the HSM cavity, certain surface areas may be inaccessible for direct visual and remote inspection. This AMP addresses detection of aging effects for inaccessible areas indirectly by monitoring the inspection findings within accessible and normally non-accessible areas. Therefore, inaccessible area inspections may only be necessitated because of the licensee's corrective action program to ensure the aging effect is adequately managed and that the component's intended safety function is maintained during the PEO.

The baseline AMP visual inspection is to be conducted within two years prior to 20 years of the first loaded DSC being placed in storage. Subsequent inspections are to be conducted every 5 years ± 1 year following the baseline inspection.

4.4.5 HSM AMP – Monitoring and Trending

The inspections and monitoring activities in this AMP are performed periodically in order to identify areas of degradation. Conditions adverse to quality that are noted during the inspection and monitoring activities, such as non-conformances, failures, malfunctions, deficiencies, and deviations, are entered into the licensee's corrective action program. Visual inspections appropriately consider cumulative OE from previous inspections and assessments in order to monitor and trend the progression of aging effects over time. Data taken for these inspections is to be monitored by comparison to past site data taken, as well as comparison to industry OE, including data gathered by the AMID as discussed in NEI 14-03 [4-2].

For HSM concrete, crack maps are monitored and trended as a means of identifying progressive growth of defects that may indicate degradation due to specific aging effects, such as rebar corrosion. Crack maps and photographic records are compared with those from previous inspections to identify accelerated degradation of the concrete during the PEO.

As described in Section 4.4.4, a minimum of one HSM is to be selected for the baseline inspection and subsequent inspections. If the baseline HSM is not available for subsequent inspections or is no longer in service (e.g., the stored DSC has been shipped off-site), another HSM is to be selected for a new baseline inspection.

4.4.6 HSM AMP – Acceptance Criteria

The criteria below are derived from design basis codes and standards that include ACI 349.3R [4-9]. The criteria are directed at the identification and evaluation of degradation that may affect the ability of the HSM to perform its intended safety function. Licensees who are not committed to ACI 349.3R, and elect to use site-specific criteria for concrete structures, should describe the criteria and provide a technical basis for deviations from those acceptance criteria in ACI 349.3R. Should the inspection acceptance criteria be exceeded, the identified issue requires further evaluation and is entered into the licensee's corrective action program.

- Steel
  - Loss of material due to general, pitting, crevice, and galvanic corrosion
- Stainless Steel
  - Loss of material due to pitting and crevice corrosion
  - Cracking due to stress corrosion cracking

Metallic Components

Visual inspections are utilized for general inspections for HSM steel components. For metallic surfaces, any of the following indications of relevant degradation detected are evaluated:

- General, pitting, crevice, and galvanic corrosion (loss of material)
- Corrosion stains on adjacent components and structures (indicating loss of material)
- Surface cracks (cracking)

If any of the above items are identified by the inspection, further evaluation is required through the licensee's corrective action program.

Concrete HSM structure:

Concrete acceptance criteria from ACI 349.3R [4-9] represent acceptable conditions for observed degradation that has been determined to be inactive. These criteria are termed second-tier for structures possessing a concrete cover in excess of the minimum requirements of ACI 349. Inactive degradation can be determined by the quantitative comparison of current observed conditions with that of prior inspections. If there is a high potential for progressive degradation or propagation to occur at its present or an accelerated rate, the disposition should consider more frequent evaluations of the specific structure or initiation of repair planning.

The following findings from a visual inspection are considered acceptable:

- Absence of leaching and chemical attack
- Absence of signs of corrosion in the steel reinforcement
- Drummy areas that cannot exceed the cover concrete thickness in depth
- Popouts and voids less than 50 mm (2 in.) in diameter or equivalent surface area
- Scaling less than 30 mm (1.125 in.) in depth
- Spalling less than 20 mm (0.75 in.) in depth and 200 mm (8 in.) in any dimension
- Absence of corrosion staining of undefined source on concrete surfaces
- Passive cracks less than 1 mm (0.04 in.) in maximum width

- Passive settlement or deflections within the design basis (serviceability limits)
- Absence of visible signs of deterioration from alkali-aggregate reaction such as excessive out-of-plane expansion or other cement/aggregate reaction

If any of the above acceptance criteria are not met, further evaluation is required through the licensee's corrective action program.

4.4.7 HSM AMP – Corrective Actions

Site QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. The licensee's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determination and prevention of recurrence. Deficiencies are either corrected or are evaluated to be acceptable for continued service through engineering analysis, which provides reasonable assurance that the intended safety function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging should utilize the same methodology used in the licensing and design basis calculations as much as practical to ensure intended safety functions are maintained through the PEO. Extent of condition investigation per the licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

4.4.8 HSM AMP – Confirmation Process

The confirmation process will be commensurate with the general licensee QA program approved under 10 CFR Part 50, Appendix B. The QA program ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. It also contains provisions to preclude repetition of significant conditions adverse to quality.

4.4.9 HSM AMP – Administrative Controls

Administrative controls under the CoC holder or licensee's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue for the PEO. Licensees and CoC holder use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC. Individual events and conditions not rising to the level of NRC reportability based on the criteria in 10 CFR Part 72 are communicated to the CoC holder as outlined in NEI 14-03 [4-2].

4.4.10 HSM AMP – Operating Experience

Appendix 3C documents the review of various sources of OE relevant to the Standardized Advanced NUHOMS® System. This review included inspections of NUHOMS® System SSCs that have been in service for several years. While the review identified several conditions that were age-related, no incidents were identified where aging effects led to the loss of intended safety functions of a NUHOMS® System SSC. This OE review supports the conclusion that the effects of aging will be managed adequately so that the SSC's intended safety functions will be maintained during the PEO.

This AMP will be updated as necessary to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. Future plant-specific and industry aging management and age-related OE are captured through the licensee's OE review process. The ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects.

4.5 Basemat Aging Management Program

4.5.1 Basemat AMP – Scope of Program

This program visually inspects the surfaces of the basemat subcomponents listed in Table 4-5. The table also lists the material and environments for each subcomponent along with the aging mechanisms and aging effects to be managed. The following aging effects/mechanisms will be managed via this AMP:

- Steel
  - Loss of material due to general, pitting, and crevice corrosion
- Concrete
  - Loss of material due to freeze-thaw, aggressive chemical attack, corrosion of reinforcing steel, delayed ettringite formation [1], salt scaling, and microbiological degradation
  - Cracking due to freeze-thaw, reaction with aggregates, differential settlement, aggressive chemical attack, corrosion of reinforcing steel, and delayed ettringite formation [1]
  - Loss of strength due to reaction with aggregates, aggressive chemical attack, corrosion of reinforcing steel, leaching of calcium hydroxide, delayed ettringite formation [1], and microbiological degradation
  - Reduction of concrete pH due to aggressive chemical attack, leaching of calcium hydroxide, and microbiological degradation
  - Loss of concrete/steel bond due to corrosion of reinforcing steel
  - Increase in porosity and permeability due to leaching of calcium hydroxide and microbiological degradation

4.5.2 Basemat AMP – Preventive Actions

The program is a condition-monitoring program that does not include preventive actions.

4.5.3 Basemat AMP – Parameters Monitored or Inspected

The Basemat AMP consists of visual inspections to monitor for material degradation.

The following accessible areas of the basemat will undergo direct visual inspection for the aging effects listed in Table 4-5:

- The aboveground exposed surface of the basemat

[1] Delayed ettringite formation may be ruled out as a credible aging mechanism by the general licensee based on an ISFSI-specific evaluation.

The inaccessible areas of the basemat include:

- Below-grade surfaces off the basemat
- External surfaces of the basemat under the HSM base unit walls
- Components embedded in concrete

4.5.4 Basemat AMP – Detection of Aging Effects

Direct visual inspections utilizing ACI-349.3R [4-9], Section 3.5.1 are to be conducted of the above-grade portions of the concrete basemat, allowing for detection of aging effects from Table 4-5.

For basemat concrete, crack maps are developed. Dimensioning is documented in photographic records by inclusion of a tape measure/crack gauge, a comparator, or both.

Potential degradation of the below-grade portion of the concrete pad is assessed by results of groundwater sampling at a minimum of three locations in the area of the ISFSI.

The baseline AMP visual inspection and groundwater sampling is to be conducted within two years prior to 20 years of the first loaded DSC being placed in storage. Subsequent inspections are to be conducted every 5 years ± 1 year following the baseline inspection.

4.5.5 Basemat AMP – Monitoring and Trending

The inspections and monitoring activities in this AMP are performed periodically in order to identify areas of degradation. Conditions adverse to quality that are noted during the inspection and monitoring activities, such as non-conformances, failures, malfunctions, deficiencies, and deviations are entered into the licensee's corrective action program. Visual inspections appropriately consider cumulative OE from previous inspections and assessments in order to monitor and trend the progression of aging effects over time. Data taken for these inspections is to be monitored by comparison to past site data taken, as well as comparison to industry OE, including data gathered by the AMID as discussed in NEI 14-03 [4-2].

For basemat concrete, crack maps are monitored and trended as a means of identifying progressive growth of defects that may indicate degradation due to specific aging effects, such as rebar corrosion. Crack maps and photographic records are compared with those from previous inspections to identify accelerated degradation of the concrete during the PEO.

4.5.6 Basemat AMP – Acceptance Criteria

Concrete acceptance criteria from ACI 349.3R [4-9] represent acceptable conditions for observed degradation that has been determined to be inactive. These criteria are termed second-tier for structures possessing a concrete cover in excess of the minimum requirements of ACI 349. Inactive degradation can be determined by the quantitative comparison of current observed conditions with that of prior inspections. If there is a high potential for progressive degradation or propagation to occur at its present or an accelerated rate, the disposition should consider more frequent evaluations of the specific structure or initiation of repair planning.

The following findings from a visual inspection are considered acceptable:

- Absence of leaching and chemical attack, including microbiological chemical attack
- Absence of signs of corrosion in the steel reinforcement
- Drummy areas that cannot exceed the cover concrete thickness in depth
- Popouts and voids less than 50 mm (2 in.) in diameter or equivalent surface area
- Scaling less than 30 mm (1.125 in.) in depth
- Spalling less than 20 mm (0.75 in.) in depth and 200 mm (8 in.) in any dimension
- Absence of corrosion staining of undefined source on concrete surfaces
- Passive cracks less than 1 mm (0.04 in.) in maximum width
- Passive settlement or deflections within the design basis (serviceability limits)
- Absence of visible signs of deterioration from alkali-aggregate reaction such as excessive out-of-plane expansion, delayed ettringite formation, or other cement/aggregate reaction

If any of the above acceptance criteria are not met, further evaluation is required through the licensee's corrective action program.

The acceptance criteria for the groundwater chemistry-sampling program are:

- pH ≥ 5.5
- Chlorides ≤ 500 ppm
- Sulfates ≤ 1500 ppm

If any of the above acceptance criteria are not met, further evaluation is required through the licensee's corrective action program.

4.5.7 Basemat AMP – Corrective Actions

Site QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. The licensee's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determination and prevention of recurrence. Deficiencies are either corrected or are evaluated to be acceptable for continued service through engineering analysis, which provides reasonable assurance that the intended safety function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging should utilize the same methodology used in the licensing and design basis calculations as much as practical to ensure intended safety functions are maintained through the PEO. Extent of condition investigation per the licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

4.5.8 Basemat AMP – Confirmation Process

The confirmation process will be commensurate with the general licensee QA program approved under 10 CFR Part 50, Appendix B. The QA program ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. It also contains provisions to preclude repetition of significant conditions adverse to quality.

4.5.9 Basemat AMP – Administrative Controls

Administrative controls under the CoC holder or licensee's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue for the PEO. Licensees and CoC holder use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC. Individual events and conditions not rising to the level of NRC reportability based on the criteria in 10 CFR Part 72 are communicated to the CoC holder as outlined in NEI 14-03 [4-2].

4.5.10 Basemat AMP – Operating Experience

Appendix 3C documents the review of various sources of OE relevant to the Standardized Advanced NUHOMS® System. This review included inspections of NUHOMS® System SSCs that have been in service for several years. While the review identified several conditions that were age-related, no incidents were identified where aging effects led to the loss of intended safety functions of a NUHOMS® System SSC. This OE review supports the conclusion that the effects of aging will be managed adequately so that the SSC's intended safety functions will be maintained during the PEO.

This AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. Future plant-specific and industry aging management and aging-related OE are captured through the licensee's OE review process. The ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects.

4.6 High Burnup Fuel Aging Management Program

4.6.1 HBU AMP – Scope of Program

Fuel stored in a 24PT4 DSC is limited to an assembly average burnup of 60 GWd/MTU and fuel stored in a 32PTH2 DSC is limited to 62.5 GWd/MTU. The 24PT1 DSC is not authorized to store high burnup fuel. The cladding materials for the high burnup (HBU) fuel are zirconium-based, and the fuel is stored in a dry helium environment. The program relies on the joint EPRI and Department of Energy (DOE) HBU Dry Storage Cask Research and Development Project (HDRP) [4-11], conducted in accordance with the guidance in Appendix D of NUREG–1927, Revision 1 [4-1] as a surrogate demonstration program for monitoring the performance of HBU fuel in dry storage. The HDRP is a program designed to collect data from a spent nuclear fuel (SNF) storage system containing HBU fuel in a dry helium environment. The program entails loading and storing an AREVA TN-32B bolted lid cask (the "Research Project Cask") at Dominion Virginia Power's North Anna Power Station with intact HBU fuel (of nominal burnups ranging between 53 GWd/MTU and 58 GWd/MTU). The fuel to be used in the program includes four kinds of cladding (Zircaloy-4, low-tin Zircaloy-4, ZIRLO™, and M5™). The research project cask is licensed to the temperature limits contained in Interim Staff Guidance (ISG) 11, Revision 3 [4-12], and loaded in such a way that the fuel cladding temperature is as close to the limit as practicable.

The parameters of the surrogate demonstration program are applicable to the design-bases HBU fuel, as;

- maximum allowed burnup of the design-bases HBU fuel (i.e., 62.5 GWd/MTU) is on the order of the nominal burnup of the fuel in the surrogate demonstration program (i.e., 58 GWd/MTUtu),
- the cladding type of the design-bases HBU fuel (i.e., zirconium-based) is the same as the surrogate demonstration program, and
- the cladding temperature of the HBU fuel is limited to the values in ISG-11 and the cladding temperature in the surrogate demonstration program is as close to the ISG-11 limits as practicable.

4.6.2 HBU AMP – Preventive Actions

During the initial loading operations of the cask/canister, the design and CoC 1029 Technical Specifications (TS) require that the fuel be stored in a dry inert environment. TS 3.1.1 demonstrates that the cask/canister cavity is dry by maintaining a cavity absolute pressure less than or equal to 3 Torr for at least 30 minutes with the cask/canister isolated from the vacuum pump. TS 3.1.2 requires that the DSC then be backfilled with helium. These two TS requirements ensure that the HBU fuel is stored in an inert environment, thus preventing cladding degradation due to oxidation mechanisms. The cask/canister is loaded in accordance with the criteria of ISG 11, Revision 3 [4-12].

4.6.3 HBU AMP – Parameters Monitored or Inspected

The parameters monitored or inspected are as described in the HDRP [4-11].

While the research project cask is on the storage pad, these parameters include temperature measurements at various locations within the cask. Temperature is the key driver for hydride-induced embrittlement and thermal creep.

It is anticipated that eventually the research project cask will be transported to an off-site fuel examination facility, where the cask will be reopened and the fuel visually examined for changes that occurred during drying and storage.

4.6.4 HBU AMP – Detection of Aging Effects

This AMP relies on the HDRP [4-11] as a surrogate demonstration program for monitoring the performance of HBU fuel in dry storage. The program calls for monitoring cask internal temperatures during the drying process and while the cask is in storage on the ISFSI pad. Temperature is the key driver for hydride-induced embrittlement and thermal creep.

After approximately 10 years of storage at the ISFSI site, it is anticipated that the research project cask will be transported to an off-site fuel examination facility. At the fuel examination facility, the cask will be reopened and the fuel visually examined for changes that occurred during drying and storage. Rods will be extracted from the HBU assemblies and nondestructive and destructive examinations will be performed. It is anticipated that these nondestructive and destructive exams will include cladding profilometry (for creep evaluation), rod internal gas pressure, hydride content and orientation, and cladding mechanical testing (i.e., ductility testing). These examinations will be a direct indication of the susceptibility of high burnup fuel to hydride-induced embrittlement and thermal creep.

4.6.5 HBU AMP – Monitoring and Trending

As information/data from a surrogate demonstration program or from other sources (such as testing or research results and scientific analyses) become available, the licensee will monitor, evaluate, and trend the information via its operating experience program and/or its corrective action program to determine what actions should be taken.

Formal evaluations of the aggregate information from a surrogate demonstration program and other available domestic or international operating experience (including data from monitoring and inspection programs, NRC-generated communications, and other information) will be performed at specific points in time during the PEO, as delineated in Section 4.6.10.

4.6.6 HBU AMP – Acceptance Criteria

The following acceptance criteria are to be applied to the data obtained from the HDRP [4-11]. If any of the following fuel performance criteria are not met, the condition will be addressed in accordance with licensee's corrective action program:

- Cladding Temperature: The maximum cladding temperature measured is less than or equal to that predicted by the thermal analysis. A benchmarked thermal model against the demonstration test data may be used for the as-loaded configuration to show that calculated maximum cladding temperature is greater than the demonstration's measured maximum cladding temperature.
- Cladding Creep: Total creep strain extrapolated to the total approved storage duration based on the best fit to the data, accounting for initial condition uncertainty, shall be less than 1%.
- Confirmation that hydride reorientation has not compromised the ability to retrieve the spent fuel on a single-assembly basis.

4.6.7 HBU AMP – Corrective Actions

Site QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. The licensee's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determination and prevention of recurrence. Deficiencies are either corrected or are evaluated to be acceptable for continued service through engineering analysis, which provides reasonable assurance that the intended safety function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging should utilize the same methodology used in the licensing and design basis calculations as much as practical to ensure intended safety functions are maintained through the PEO. Extent of condition investigation per the licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

4.6.8 HBU AMP – Confirmation Process

The confirmation process will be commensurate with the general licensee QA program approved under 10 CFR Part 50, Appendix B. The QA program ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. It also contains provisions to preclude repetition of significant conditions adverse to quality.

4.6.9 HBU AMP – Administrative Controls

Administrative controls under the CoC holder or licensee's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue for the PEO. Licensees and CoC holder use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC. Individual events and conditions not rising to the level of NRC reportability based on the criteria in 10 CFR Part 72 are communicated to the CoC holder as outlined in NEI 14-03 [4-2].

4.6.10 HBU AMP – Operating Experience

Short-term testing (i.e., laboratory scale testing up to a few months) and scientific analyses examining the performance of HBU fuel have provided a foundation for the technical basis that storage of HBU fuel in the PEO may be performed safely and in compliance with regulations. However, there has been relatively little OE to date with dry storage of HBU fuel. Therefore, the HDRP is used as a surrogate program to monitor and assess data regarding HBU fuel performance to confirm there is no degradation of HBU fuel that would result in an unanalyzed configuration during the PEO.

This AMP will be updated as necessary to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. Future plant-specific and industry aging management and age-related OE are captured through the licensee's OE review process. The ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects.

In addition to the ongoing OE review, this AMP requires periodic written evaluations as described in Table 4-2 of the aggregate impact of aging-related HBU fuel OE, research, monitoring, and inspections on the intended safety functions of the in-scope HBU fuel subcomponents (i.e., tollgates). While licensees and TN Americas LLC assess new information relevant to aging management in accordance with normal corrective action and OE programs, tollgates are an opportunity to seek out other information that may be available and to perform an aggregate assessment. Tollgate assessments are not stopping points. No action, other than performing an assessment and addressing relevant findings in the licensee's corrective action program, is required to continue Standardized Advanced NUHOMS® dry storage system operation. Tollgate assessment reports are not required to be submitted to the NRC, but are available for inspection. Appendix A of NEI 14-03 [4-2] provides guidance on the performance criteria for the tollgate assessments.

4.7 References

4-1 NUREG-1927, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel," Revision 1, U.S. Nuclear Regulatory Commission, June 2016 (Adams Accession Number ML16179A148).

4-2 NEI 14-03, "Format, Content, and Implementation Guidance for Cask Storage Operations-Based Aging Management," Revision 2, Nuclear Energy Institute, December 2016.

4-3 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section XI, "Rules for Inservice Inspection of Nuclear Power Plants and Fuel Processing Plants," 2017 Edition.

4-4 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section III, Division 1, 1992 Edition, with 1994 Addenda, including exceptions allowed by Code Case N-595-1.

4-5 American Society of Mechanical Engineers, "ASME Boiler and Pressure Vessel Code," Section III, Division 1, 2010 Edition.

4-6 Electric Power Research Institute, "Aging Management Guidance to Address Potential Chloride-Induced Stress Corrosion Cracking of Welded Stainless Steel Canisters," EPRI-TR-3002008193, March 2017.

4-7 ACI-201.1R, "Guide for Conducting a Visual Inspection of Concrete in Service," American Concrete Institute, 2008.

4-8 Not Used.

4-9 ACI-349.3R, "Evaluation of Existing Nuclear Safety Related Concrete Structures," American Concrete Institute, 2018.

4-10 Not Used.

4-11 Electric Power Research Institute, "High Burnup Dry Storage Cask Research and Development Project: Final Test Plan," Revision 0, DE-NE-0000593, February 27, 2014.

4-12 NRC Spent Fuel Project Office, Interim Staff Guidance 11, "Cladding Considerations for the Transportation and Storage of Spent Fuel," Revision 3, November 17, 2003.

Proprietary Information on Pages 4-28 and 4-29
Withheld Pursuant to 10 CFR 2.390

Table 4-3
Subcomponents Within Scope of DSC AMP
(3 Pages)

Subcomponent Parts		Intended Safety Function(s) [(1)]	Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect
Cylindrical Shell		CO, SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Outer Bottom Cover Plate		SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Grapple Ring and Support		SR, RT	Stainless Steel	Sheltered	Pitting & Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-3
Subcomponents Within Scope of DSC AMP
(3 Pages)

Subcomponent Parts		Intended Safety Function(s) [(1)]	Material Group	Environment [(2)]	Credible Aging Mechanism	Aging Effect
Shear Key		SR	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Outer Top Cover Plate and Test Port plug		CO, SH, SR, TH, RT	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Bottom Shield Plug		SH, SR, TH	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-3
Subcomponents Within Scope of DSC AMP
(3 Pages)

Subcomponent Parts	[ ]	Intended Safety Function(s) (1)	Material Group	Environment (2)	Credible Aging Mechanism	Aging Effect
Inner Bottom Cover Plate		CO, SH, SR, TH	Stainless Steel	(E) Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Notes:

1. The Intended Safety Functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT). Note that not all of the subcomponents in a group have all of the listed intended safety functions for that group.
2. (I) refers to an internal (or towards the interior of the DSC) environment and (E) refers to an external (or towards the exterior of the DSC) environment.

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
Base Walls, Roof, Door Concrete Core		SH, SR, TH, RT	Steel	Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
			Concrete	Air-Outdoor Sheltered	Freeze-Thaw	Cracking
						Loss of Material
					Reaction with Aggregates	Cracking
						Loss of Strength
					Differential Settlement	Cracking
					Aggressive Chemical Attack	Cracking
						Loss of Strength
						Loss of Material
						Reduction of Concrete pH
					Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond
						Loss of Material
						Cracking
						Loss of Strength
					Leaching of Calcium Hydroxide	Loss of Strength
						Increase in Porosity and Permeability

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
						Reduction of Concrete pH
					Salt Scaling	Loss of Material
					Reaction with Aggregates	Cracking
						Loss of Strength
					Differential Settlement	Cracking
					Leaching of Calcium Hydroxide	Loss of Strength
						Increase in Porosity and Permeability
						Reduction of Concrete pH
Outlet Vent Cover, End Walls, Rear Walls, Lower Vent Cover, Transition Roof, Transition Walls		SH, SR, TH	Steel	Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
			Concrete	Air-outdoor	Freeze-Thaw	Cracking
						Loss of Material
					Reaction with Aggregates	Cracking
						Loss of Strength
					Differential Settlement	Cracking
					Aggressive Chemical Attack	Cracking
						Loss of Strength
						Loss of Material

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
						Reduction of Concrete pH
					Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond
						Loss of Material
						Cracking
						Loss of Strength
					Leaching of Calcium Hydroxide	Loss of Strength
						Increase in Porosity and Permeability
						Reduction of Concrete pH
					Salt Scaling	Loss of Material
DSC Support Structure Assembly Hardware		SR	Steel	Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
				Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
DSC Support Structure Assembly		SR, TH, RT	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Adjustable DSC Axial Retainer		SR	Steel	Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Heat Shield Assemblies Attachment Hardware		SR	Steel	Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
				Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
Heat Shields		SH, TH	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Rear Wall and Shield Door Attachment Embedment Hardware		SR	Steel	Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
				Air-Outdoor	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Shield Door Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
				Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
				Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
Shield Door backing Plate		SH, SR	Steel	Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
Deformed Bar Anchors, Mechanical Splice, Rebar		SR	Steel	Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
Upper and Lower Vent Cover Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
				Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
Module-to Module-Wall Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
				Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
				Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
AHSM Roof Attachment Hardware		SR	Steel	Air-Outdoor	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
			Stainless Steel	Air-Outdoor	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
AHSM-HS Roof Connection Hardware		SR	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking
AHSM Liner Plates		SH, TH	Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Table 4-4
Subcomponents Within Scope of HSM AMP
(8 Pages)

Subcomponent Parts		Intended Safety Functions (3)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
Transition Wall Attachment Hardware		SR	Steel	Embedded in Concrete	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
				Sheltered	General Corrosion	Loss of Material
					Pitting and Crevice Corrosion	Loss of Material
					Galvanic Corrosion	Loss of Material
			Stainless Steel	Sheltered	Pitting and Crevice Corrosion	Loss of Material
					Stress Corrosion Cracking	Cracking

Notes:

1. UFSAR Drawing NUH-03-4011 does not assign a part number to these subcomponents; however, the drawing does call them out and specifies the design and construction standards (i.e., Note 1 on Drawing NUH-03-4011).
2. UFSAR Drawings NUH-03-4012 and NUH 03-4013 do not assign a part number to these subcomponents; however, the drawings do show them.
3. The Intended Safety Functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT). Note that not all of the subcomponents in a group have all of the listed intended safety functions for that group.

Table 4-5
Subcomponents Within Scope of Basemat AMP
(3 Pages)

Subcomponent Parts	Intended Safety Function(s) (2)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
Basemat	SR, RT	Steel	Embedded in Concrete	General Corrosion	Loss of Material
				Pitting and Crevice Corrosion	Loss of Material
		Concrete	Air-Outdoor	Freeze-Thaw	Cracking
					Loss of Material
				Reaction with Aggregates	Cracking
					Loss of Strength
				Differential Settlement	Cracking
				Aggressive Chemical Attack	Cracking
					Loss of Strength
					Loss of Material
					Reduction of Concrete pH
				Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond
					Loss of Material
					Cracking
					Loss of Strength
				Leaching of Calcium Hydroxide	Loss of Strength
					Increase in Porosity and Permeability
					Reduction of Concrete pH
				Delayed Ettringite Formation (1)	Loss of Material
					Loss of Strength
					Cracking
				Salt Scaling	Loss of Material

Table 4-5
Subcomponents Within Scope of Basemat AMP
(3 Pages)

Subcomponent Parts	Intended Safety Function(s) (2)	Material Group	Environment	Credible Aging Mechanism	Aging Effect
			Sheltered	Reaction with Aggregates	Cracking
					Loss of Strength
				Differential Settlement	Cracking
				Leaching of Calcium Hydroxide	Loss of Strength
					Increase in Porosity and Permeability
					Reduction of Concrete pH
				Delayed Ettringite Formation (1)	Loss of Material
					Loss of Strength
					Cracking
			Groundwater/ Soil	Freeze-Thaw	Cracking
					Loss of Material
				Reaction with Aggregates	Cracking
					Loss of Strength
				Differential Settlement	Cracking
				Aggressive Chemical Attack	Cracking
					Loss of Strength
					Loss of Material
					Reduction of Concrete pH
				Corrosion of Reinforcing Steel	Loss of Concrete/Steel Bond
					Loss of Material
					Cracking
					Loss of Strength
				Leaching of Calcium Hydroxide	Loss of Strength
					Increase in Porosity and Permeability
					Reduction of Concrete pH

Table 4-5
Subcomponents Within Scope of Basemat AMP
(3 Pages)

Subcomponent Parts	Intended Safety Function(s) [2]	Material Group	Environment	Credible Aging Mechanism	Aging Effect
				Microbiological Degradation	Loss of Strength
					Loss of Material
					Increase in Porosity and Permeability
					Reduction of Concrete pH
				Delayed Ettringite Formation [1]	Loss of Material
					Loss of Strength
					Cracking
				Salt Scaling	Loss of Material

Notes:

1. Delayed ettringite formation may be ruled out as a credible aging mechanism by the general licensee based on an ISFSI-specific evaluation.
2. The Intended Safety Functions are: Confinement (CO), Radiation Shielding (SH), Sub-Criticality Control (CR), Structural Integrity (SR), Heat Removal Capability (TH), Retrievability (RT).

ATTACHMENT A
CHANGES TO THE COC 1029 UPDATED FINAL SAFETY ANALYSIS REPORT

CONTENTS

LIST OF TABLES

A.1 Introduction

The proposed changes to the Certificate of Compliance (CoC) No. 1029, Updated Final Safety Analysis Report (UFSAR) for the Standardized Advanced NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, to support the CoC 1029 renewal are discussed and described in this attachment.

Table A-1 provides a list of UFSAR pages that require changes, a description of each change, and the basis for the change. UFSAR Revision 9 is referenced in the table for the location of the changed UFSAR text. Table A-2 through Table A-7 provide the format and referenced content for new UFSAR Chapter 15 tables.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
1.1	1-1a	Following the third paragraph (end of Section 1.1), add the following new note: "**NOTE: CoC 1029 was originally licensed for 20 years. On [mm/dd/yy], the NRC approved renewal of CoC 1029 for an additional 40 years. The aging management activities (AMA) associated with this renewal apply to the previously approved amendments, and future amendments will include an aging management review (AMR) and any resultant, required AMA. The current aging management results are detailed in Chapter 15.**"	CoC renewal discussion provided in this historical introductory UFSAR section, with a pointer to AMR results.
1.2	1.2-8	At the end of Section 1.2.3, add heading: "**1.2.4 Aging Management Program Requirements**" with only "Aging Management Program Requirements" underlined. Add text: "**Aging management program (AMP) requirements for use of the 24PT1 DSC and AHSM during the period of extended storage operations are contained in Section 15.3.**"	Add CoC renewal AMP requirements, with pointers to location of AMP requirements.
3.3.1.1	3.3-1	Change the second sentence to read: The effect of fast neutron irradiation of metals is a function of the integrated fast neutron fluence, which is on the order of ~~1x10^{15}~~ **5.2*10^{15}** neutrons/cm^2 inside the 24PT1 DSC after ~~50~~ **100** years **[3.41]**.	Bounds extended storage period.
3.3.2.1	3.3-2	Change the two paragraphs to read: The accumulated neutron flux **and gamma dose** over a ~~40~~ **100-**year service life of the AHSM is estimated to be ~~1.5E14~~ **1.8*10^{15}** neutrons/cm^2 **and 2.9*10^{9} Rad respectively [3.41]**. ~~From the study by Hilsdorf, Kropp, and Koch [3.23], the compressive strength and modulus of elasticity of concrete is not affected by a neutron flux of this magnitude.~~ **These values are less than the 1*10^{19} n/cm^2 neutron fluence and 1*10^{10} Rad value used in NUREG-2214 [3.42] as the fluence below which concrete structures are regarded as being sound.** ~~The gamma energy flux deposited in the AHSM concrete is 1.7E9 MeV/cm2-sec. or 3.0E-4 watt/cm^2. According to ANSI/ANS-6.4-1977 [3.24], the temperature rise in concrete due to this level of radiation is negligible. Thus, radiation effects on concrete strength are not evaluated further for the AHSM design.~~	Bounds extended storage period.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
3.5.1.1.1	3.5-1	Add the following sentences to the end of the third paragraph: "**While these clad temperature limits were based on a 50-year storage design life, the methodology used pre-dates the current accepted limit for low burnup fuel in ISG-11 [3.44], i.e., 752 °F. Since the fuel clad temperature limits applied to the fuel stored in the 24PT1 DSC are less than, i.e., more restrictive than, the limit in ISG-11, they remain valid for the period of extended operation and demonstrate that the cladding will continue to perform its intended safety function through the end of the period of extended operation (PEO).**"	Bounds extended storage period.
3.5.1.2.1	3.5-2	Add the following sentences to the end of the first paragraph: "**While these clad temperature limits were based on a 50-year storage design life, the methodology used pre-dates the current accepted limit for low burnup fuel in ISG-11 [3.44], i.e., 752°F. Since the fuel clad temperature limits applied to the fuel stored in the 24PT1 DSC are less than, i.e., more restrictive than, the limit in ISG-11, they remain valid for the period of extended operation and demonstrate that the cladding will continue to perform its intended safety function through the end of the PEO.**"	Bounds extended storage period.
3.6.1.3	3.6-11	Change the paragraph to read: The 24PT1 DSC shell has been evaluated for fatigue in accordance with the rules of NB-3222.4 to show that a detailed fatigue evaluation is not required **[3.43]**.	Added reference that evaluated fatigue for the period of extended operations.
3.6.3	3.6-59	Change reference [3.23] as follows: [3.23] ~~H. K. Hilsdorf, J. Kropp, and H. J. Koch, "The Effects of Nuclear Radiation on the Mechanical Properties of Concrete," Paper 55-10, Douglas McHenry International Symposium on Concrete and Concrete Structures, American Concrete Institute, Detroit, MI (1978)~~ **Not Used**.	Reference no longer used.
3.6.3	3.6-59	Change reference [3.24] as follows: [3.24] ~~American Nuclear Society, "American National Standard Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants," ANSI/ANS-6.4-1977, American National Standards Institute, Inc., (1977)~~ **Not Used**.	Reference no longer used.
3.6.3	3.6-60	Add the following reference: "**[3.41]Time-Limited Aging Analysis for Boron Depletion and Radiation Fluence for CoC 1029 License Renewal, Calculation Number 503821-TLAA03, Revision 0.**"	New reference for Sections 3.3.1.1 and 3.3.2.1.
3.6.3	3.6-60	Add the following reference: "**[3.42]** NRC **NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report"** ***Final Report, July 2019 (ML19214A111).***"	New reference for Section 3.3.2.1.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
3.6.3	3.6-60	Add the following reference: "**[3.43] Fatigue Evaluation of Dry Shielded Canisters for CoC 1029, Calculation Number 503821-TLAA02, Revision 0.**"	New reference for Section 3.6.1.3.
3.6.3	3.6-60	Add the following reference: "**[3.44] NRC Interim Staff Guidance No. 11, ISG-11, Rev. 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel", November 2003.**"	New reference for Section 3.5.1.1.1.
4.4.2	4.4-1	Change the first paragraph to read: For normal condition of storage, the Advanced NUHOMS® System components are evaluated for a range of design basis ambient temperatures. The system components are evaluated for the average ambient temperatures given in Table 4.1-1. Ambient temperatures within this range are assumed to occur for a sufficient duration to cause a steady-state temperature distribution in the Advanced NUHOMS® System components. The lifetime average ambient temperature ~~for the 40 year service life~~ is taken as 70 °F. The "stress-free" temperature for material properties is also 70 °F.	Lifetime average ambient temperature is not dependent upon the length of the service life.
6.3.2	6.3-7	Change the fourth paragraph on the page to read: Depletion of the B-10 in the neutron poison plates is evaluated below. Although the license period of the cask is ~~20~~ **60** years, actual storage time could be much longer. Using the total calculated scalar flux of $5.0x10^5$ n/cm^2-s at the center of the basket, and the thermal neutron cross section for B-10 of 3837 barn [6.9], the fraction of the original B-10 depleted after 1000 years would be.	Extended storage period.
7.2.2	7.2-1	Change the paragraph to read: The design provides for drying and evacuation of the 24PT1-DSC interior as part of the loading operations. The design is acceptable for the pressures that may be experienced during these operations as discussed in Chapter 4. On completion of fuel loading, the gas fill of the 24PT1 DSC interior is at a pressure level that will maintain a non-reactive environment for ~~at least the 40 year~~ the storage life of the 24PT1 DSC interior under normal, off-normal, and accident conditions.	The maintenance of the non-reactive environment is not dependent upon the storage life of the DSC.
15 (new)	new	Add centered heading: "**15. AGING MANAGEMENT**".	New UFSAR chapter.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
15.1 (new)	new	Add heading: "**15.1 Aging Management Review**" with only "Aging Management Review" underlined. Add text: "**The aging management review (AMR) of the Standardized Advanced NUHOMS® System contained in the application for initial Certificate of Compliance (CoC) renewal [15.1] provides an assessment of aging effects that could adversely affect the ability of in-scope structures, systems, and components (SSCs) to perform their intended safety functions during the extended storage period. Aging effects, and the mechanisms that cause them, were evaluated for the combinations of materials and environments identified for the subcomponent of the in-scope SSCs based on a review of the Managing Aging Processes in Storage (MAPS) Report [15.2]. Aging effects that could adversely affect the ability of the in-scope SSCs to perform their safety function(s) require an aging management activity (AMA) to address potential degradation that may occur during the extended storage period. The AMA may consist of a time-limited-aging-analysis (TLAA) or an aging management program (AMP). TLAAs and AMPs that are credited with managing aging effects during the extended storage period are discussed in Sections 15.2 and 15.3, respectively.**"	New section describing AMR.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
15.2 (new)	new	Add heading: "**<u>15.2 Time-Limited Aging Analyses</u>**" with only "Time-Limited Aging Analyses" underlined. Add text: "**<u>A comprehensive review to identify the TLAAs for the in-scope SSCs of the Standardized Advanced NUHOMS® System was performed to determine the analyses that could be credited with managing aging effects over the extended storage period. The TLAAs identified involved the in-scope SSCs, considered the effects of aging, involved explicit time-limited assumptions, are relevant in making a safety determination, provided conclusions regarding the capability of an SSC to perform its intended safety function through the operating term, and were contained or incorporated in the design basis. The identified TLAAs were dispositioned by demonstrating that the pre-renewal analysis remains valid for the PEO or the analysis was updated. The identified TLAAs were:</u>** – **<u>Boron depletion in the BORAL® plates in the 24PT1 and 24PT4 dry shielded canisters (DSCs) – the pre-renewal analysis in Sections 6.3.2 and A.6.3.2 remain valid for the PEO</u>** – **<u>Creep analysis for aluminum components in the 32PTH2 basket – the pre-renewal analysis in Section B.3.6.1.2.8 remains valid for the PEO</u>** – **<u>Fatigue analyses for the 24PT1, 24PT4, and 32PTH2 DSC shells – the pre-renewal evaluation in Section B.3.6.1.1.8 for the 32PTH2 remains valid for the PEO, the evaluations in Sections 3.6.1.3and A.3.6.1.3 for the 24PT1 and 24PT4 were updated</u>** – **<u>Irradiation embrittlement of metals in the 24PT1, 24PT4, and 32PTH2 DSCs – the pre-renewal analysis in Section B.3.3.1.1 for the 32PTH2 remains valid for the PEO, the analyses in Sections 3.3.1.1 and A.3.3.1.1 for the 24PT1 and 24PT4 were updated</u>** – **<u>Irradiation effects on the concrete in the AHSM and AHSM-HS – the pre-renewal analysis in Section B.3.3.3.1 for the AHSM-HS remains valid for the PEO, the analysis in Sections 3.3.2.1 and A.3.3.2.1 for the AHSM was updated</u>** – **<u>Establishment of cladding temperature limits for fuel stored in the 24PT1 DSC – the pre-renewal fuel cladding limits in Sections 3.5.1.1.1 and 3.5.1.2.1 remain valid for the PEO</u>**"	New section discusses TLAAs that are credited with managing aging effect during the extended storage period.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	**UFSAR Revision 9 Page**	**Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)**	**Basis for Change**
15.3 (new)	new	Add heading: "**<u>15.3 Aging Management Program</u>**" with only "Aging Management Program" underlined. Add text: "**<u>Aging effects that could result in the loss of in-scope SSCs' intended safety function(s) are managed during the extended storage period. Many aging effects are adequately managed for the extended storage period using TLAA, as discussed in Section 15.2. An AMP is used to manage those aging effects that are not managed by TLAA. The AMPs that manage each of the identified aging effects for all in-scope SSCs include the following:</u>** – **<u>DSC Aging Management Program</u>** – **<u>HSM Aging Management Program</u>** – **<u>Basemat Aging Management Program</u>** – **<u>High Burnup Fuel Aging Management Program</u>** **<u>The AMPs are summarized in Tables 15-1 through 15-4. Additional details are available in the CoC 1029 renewal application [15.1].</u>**"	New section summarizing the aging management program credited with managing aging during the extended storage period. New tables below provide the summary discussion and requirements of each individual aging management program.
15.3 (new)	new	Add table heading: "**<u>Table 15-1 DSC Aging Management Program</u>**" with only "DSC Aging Management Program" underlined. Add the information from Table A-2.	New table to summarize this AMP.
15.3 (new)	new	Add table heading: "**<u>Table 15-2 HSM Aging Management Program</u>**" with only "HSM Aging Management Program" underlined. Add the information from Table A-3.	New table to summarize this AMP.
15.3 (new)	new	Add table heading: "**<u>Table 15-3 Basemat Aging Management Program</u>**" with only "Basemat Aging Management Program" underlined. Add the information from Table A-4.	New table to summarize this AMP.
15.3 (new)	new	Add table heading: "**<u>Table 15-4 High Burnup Fuel Aging Management Program</u>**" with only "High Burnup Fuel Aging Management Program" underlined. Add the information from Table A-5.	New table to summarize this AMP.
15.3 (new)	new	Add table heading: "**<u>Table 15-5 DSC AMP Tollgate</u>**" with only "DSC AMP Tollgate" underlined. Add the information from Table A-6.	New table to summarize this DSC AMP Tollgate.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
15.3 (new)	new	Add table heading: "**<u>Table 15-6 High Burnup Fuel AMP Tollgate</u>**" with only "High Burnup Fuel AMP Tollgate" underlined. Add the information from Table A-7.	New table to summarize this HBU AMP Tollgate.
15.4 (new)	new	Add heading: "**<u>15.4 Supplemental Information</u>**" with only "Supplemental Information" underlined.	New section for Chapter 15 References.
15.4.1 (new)	New	Add heading: "**<u>15.4.1 References</u>**" with only "References" underlined.	New section for Chapter 15 References.
15.4.1 (new)	New	Add the following references: "**<u>[15.1] (This renewal application)</u>** **<u>[15.2] NRC NUREG-2214, "Managing Aging Process in Storage (MAPS) Report" (draft report for comment, October 2017) (ML17289A237)</u>** **<u>[15.3] Electric Power Research Institute, "High Burnup Dry Storage Cask Research and Development Project: Final Test Plan," Revision 0, DE-NE-0000593, February 27, 2014.</u>** **<u>[15.4] NRC Interim Staff Guidance No. 11, ISG-11, Rev. 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," U.S. NRC, November 2003.</u>**"	New section for Chapter 15 References.
A.1.2	A.1.2-3	At the end of Section A.1.2.3: Add heading: "**<u>A.1.2.4 Aging Management Program Requirements</u>**" with only "Aging Management Program Requirements" underlined. Add text: "**<u>Aging management program (AMP) requirements for use of the 24PT4 DSC during the period of extended storage operations are contained in Section 15.3.</u>**"	Add CoC renewal AMP requirements with pointers to location of AMP requirements.
A.6.3.2	A.6.3-6	Change the second paragraph on the page to read: Depletion of the B-10 in the neutron poison plates is evaluated below. Although the license period of the cask is ~~20~~ **<u>60</u>** years, actual storage time could be much longer. Using an estimated scalar flux of $5.0x10^5$ n/cm^2-s at the center of the basket, and the thermal neutron cross section for B-10 of 3837 barn [A6.9], the fraction of the original B-10 depleted after 1000 years would be:	Extended storage period.

Table A-1
List of UFSAR Changes Associated with CoC 1029 Renewal
(8 Pages)

UFSAR Revision 9 Section #	UFSAR Revision 9 Page	Description of Change (Newly inserted text is shown as bold and underlined; deleted text is shown by a single strike-through.)	Basis for Change
B.1.2	B.1.2-5	At the end of Section B.1.2.3: Add heading: "<u>**B.1.2.4 Aging Management Program Requirements**</u>" with only "Aging Management Program Requirements" underlined. Add text: "<u>**Aging management program (AMP) requirements for use of the 32PTH2 DSC and AHSM-HS during the period of extended storage operations are contained in Section 15.3.**</u>"	Add CoC renewal AMP requirements with pointers to location of AMP requirements.

Table A-2
DSC Aging Management Program
(3 Pages)

AMP Element	AMP Activity
Scope of Program	The program visually inspects the external surfaces of the dry shielded canister (DSC) subcomponents.
Preventative Actions	The program is a condition-monitoring program that does not include preventive actions.
Parameters Monitored or Inspected	The following normally non-accessible areas will undergo remote visual inspections for loss of material and cracking: – Portions of the DSC surfaces, welds, and heat affected zones (HAZs) and crevice locations near the DSC support rails are inspected for discontinuities and imperfections. Localized corrosion (e.g., pitting and crevice corrosion), cracking, or discolorations, if any, are documented. Appearance and location of atmospheric deposits on the DSC surfaces are recorded. – Portions of the outer top cover plate, closure welds, and HAZ. – Portions of the outer bottom cover plate, grapple ring assembly, and their welds and HAZ. – Portions of the DSC shell bottom surface (including edge of DSC support rails and HAZ).
Detection of Aging Effects	
Selection of DSC(s) for Inspection:	One DSC is selected for baseline and subsequent inspections based on time in service, initial heat load, fabrication/design considerations, and HSM array configuration relative to climatological/geographical features.
Inspection Methods:	<u>Standard Visual Exams</u> VT-3 visual examinations within two inches of a weld are initially performed for the DSC surfaces. Additional VT-1 visual examinations are performed as described in the acceptance criteria when indicated by the assessment of the VT-3 results. A general visual exam will be performed on normally non-accessible portions of the DSC surface that do not receive the VT-3 exam. <u>Augmented Exams</u> Augmented examination is performed on a DSC when the visual exams indicate the presence of major corrosion within two inches of a weld. – A volumetric examination is performed of cracking indications and the surrounding volume within 1” of the indication. – A surface examination (a volumetric exam may be performed in lieu of the surface exam) is performed of the regions (plus one inch of the extent of the indication) of major corrosion. – Locations inspected using surface or volumetric examinations do not need to receive a VT-3 inspection.
Inspection Timing and Frequency:	Baseline AMP visual inspection is to be conducted within two years prior to 20 years of the first loaded DSC being placed in storage. Subsequent inspections at least once every 5 years ± 1 year or when an engineering evaluation predicts an identified crack will reach 75% through-wall, whichever is less.
Monitoring and Trending	Data taken for these inspections is to be monitored by comparison to past site data taken as well as comparison to industry operating experience (OE), including data gathered by the Aging Management INPO Database (AMID).

Table A-2
DSC Aging Management Program
(3 Pages)

<table>
<tr><th>AMP Element</th><th>AMP Activity</th></tr>
<tr><td>Acceptance Criteria</td><td><u>Visual Examination Criteria</u>
Major corrosion indication within 2 inches of a weld will receive an augmented surface or volumetric examination for the presence of cracking. Major corrosion indications more than two inches from a weld will be entered into the licensee's corrective action program.

A minor corrosion indication within two inches of a weld will receive a supplemental VT-1 exam. If it is determined that there is an attack of the metal under the corrosion indication, then the condition will be entered into the licensee's corrective action program. A minor corrosion indication more than 2 inches from a weld is acceptable without further action other than noting the indication.

Major corrosion indication if any of the following exist:
– Cracking of any size.
– Corrosion products having a linear appearance, except light corrosion indicative of iron contamination.
– Corrosion products having a branching appearance.
– Evidence of pitting corrosion, under deposit corrosion, or etching with measurable depth (removal/attack of material by corrosion).
– In a 10 cm by 10 cm region, corrosion product is present in 25% or more of the surface with evidence of attack into the DSC.
– Evidence of water intrusion that runs into a crevice location with rust staining at the edge of the crevice.
– Corrosion product deposit present at the mouth of an occluded region that includes a portion of the DSC shell weld.
If a corrosion indication is not a major corrosion indication and it meets any of the following, it will be considered a minor corrosion indication:
– Evidence of water intrusion stained the color of corrosion products.
– Areas of light corrosion that follow a fabrication feature or anomaly (e.g., scratch or gouge). Such indications are indicative of iron contamination.
– In a 10 cm by 10 cm region, corrosion product is present in 10% to 25% of the canister surface.
– Corrosion product greater than 2 mm in diameter.
<u>Augmented Examination</u>
If a surface examination is performed, no further actions are required if any of the following apply:
– If a surface examination confirms the absence of flaws.
– If the detected flaw is a rounded indication, and if no corrosion products or masking deposits are present.
– If the detected flaw is a linear indication, if no corrosion products or masking deposits are present, and if the linear indication is determined not to have a crack-like morphology.
If none of the above surface examination bullets apply, then a volumetric exam is to be performed.
If a volumetric examination is performed, no further actions are required if any of the following apply:</td></tr>
</table>

Table A-2
DSC Aging Management Program
(3 Pages)

AMP Element	AMP Activity
	– If a volumetric examination confirms the absence of planar flaws. – If the detected indication is determined to not be connected to the exterior of the DSC (i.e., not associated with the outside surface). – If the entirety of the detected flaw is in an area that is confirmed to have no corrosion products present, and if the indication is determined to not have a crack-like morphology. – If the detected indication was recorded prior to being mitigated or was remediated and there has been no measurable increase in the flaw size after the remediation. If none of the above volumetric examination bullets apply, an engineering evaluation is to be performed. Flaw Evaluation If a crack is identified, an engineering evaluation will be performed to determine when the flaw will reach 75% of the through-wall thickness.
Corrective Actions	Per the licensee's corrective action program.
Confirmation Process	Per the licensee's quality assurance program.
Administrative Controls	Per the CoC holder or licensee's quality assurance program. The 10 CFR Part 72 regulatory requirements are used to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.
Operating Experience	This AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. In addition to the ongoing OE review, this AMP requires periodic written evaluations as described in Table 15-5, of the aggregate impact of aging-related DSC OE, research, monitoring, and inspections on the intended safety functions of the in-scope DSC subcomponents (i.e., tollgates).

Table A-3
HSM Aging Management Program
(2 Pages)

AMP Element	AMP Activity
Scope of Program	The program visually inspects the surfaces of the horizontal storage module (HSM) subcomponents.
Preventative Actions	The program is a condition-monitoring program that does not include preventive actions.
Parameters Monitored or Inspected	The following accessible areas of the HSMs will undergo direct visual inspection for aging effects: – The external concrete surfaces of the HSM roof and walls. – External surfaces of the HSM access door. – External attachment hardware. The following normally non-accessible areas of HSM will undergo remote visual inspection for aging effects: – Portions of the concrete front, back, and sides of the base unit. – Portions of the DSC support structure and attachment hardware.
Detection of Aging Effects	
Selection of HSM for Inspection:	One HSM is selected for baseline and subsequent inspections.
Inspection Methods:	Direct or remote visual inspections.
Inspection Timing and Frequency:	The baseline AMP visual inspection is to be conducted within two years prior to 20 years of service of the HSM. Subsequent inspections are to be conducted every 5 years ± 1 year following the baseline inspection.
Monitoring and Trending	Data taken for these inspections is to be monitored by comparison to past site data taken, as well as comparison to industry OE, including data gathered by the AMID.
Acceptance Criteria	For metallic surfaces, any of the following indications of relevant degradation detected are evaluated: – General, pitting, crevice, and galvanic corrosion (loss of material). – Corrosion stains on adjacent components and structures (indicating loss of material). – Surface cracks (cracking). For concrete, the following findings from a visual inspection are considered acceptable without requiring any further evaluation: – Absence of leaching and chemical attack, including microbiological chemical attack. – Absence of signs of corrosion in the steel reinforcement. – Drummy areas that cannot exceed the cover concrete thickness depth. – Popouts and voids less than 50 mm (2 in.) in diameter or equivalent surface area. – Scaling less than 30 mm (1.125 in.) in depth. – Spalling less than 20 mm (0.75 in.) in depth and 200 mm (8 in.) in any dimension. – Absence of corrosion staining of undefined source on concrete surfaces. – Passive cracks less than 1 mm (0.04 in.) in maximum width. – Passive settlement or deflections within the design basis (serviceability limits). – Absence of visible signs of deterioration from alkali-aggregate reaction such as excessive out-of-plane expansion or other cement/aggregate reaction.

Table A-3
HSM Aging Management Program
(2 Pages)

AMP Element	AMP Activity
Corrective Actions	Per the licensee's corrective action program.
Confirmation Process	Per the licensee's quality assurance program.
Administrative Controls	Per the CoC holder or licensee's quality assurance program. The 10 CFR Part 72 regulatory requirements are used to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.
Operating Experience	This AMP will be updated as necessary to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research.

Table A-4
Basemat Aging Management Program
(2 Pages)

AMP Element	AMP Activity
Scope of Program	The program visually inspects the surfaces of the basemat.
Preventative Actions	The program is a condition-monitoring program that does not include preventive actions.
Parameters Monitored or Inspected	The aboveground, exposed surface of the basemat will undergo direct visual inspection for aging effects.
Detection of Aging Effects	
Areas for Inspection:	Above-grade portions of the concrete basemat.
Inspection Methods:	Direct visual inspections of the above-grade portions of the basemat. Groundwater sampling is performed at a minimum of three locations in the area of the independent spent fuel storage installation (ISFSI).
Inspection Timing and Frequency:	The baseline AMP visual inspection and groundwater sampling is to be conducted within two years prior to 20 years of the first loaded DSC being placed in storage. Subsequent inspections are to be conducted every 5 years ± 1 year following the baseline inspection.
Monitoring and Trending	Data taken for these inspections is to be monitored by comparison to past site data taken as well as comparison to industry OE, including data gathered by the AMID.
Acceptance Criteria	For concrete, the following findings from a visual inspection are considered acceptable without requiring any further evaluation: – Absence of leaching and chemical attack, including microbiological chemical attack. – Absence of signs of corrosion in the steel reinforcement. – Drummy areas that cannot exceed the cover concrete thickness in depth. – Popouts and voids less than 50 mm (2 in.) in diameter or equivalent surface area. – Scaling less than 30 mm (1.125 in.) in depth. – Spalling less than 20 mm (0.75 in.) in depth and 200 mm (8 in.) in any dimension. – Absence of corrosion staining of undefined source on concrete surfaces. – Passive cracks less than 1 mm (0.04 in.) in maximum width. – Passive settlement or deflections within the design basis (serviceability limits). – Absences of visible signs of deterioration from alkali-aggregate reaction such as excessive out-of-plane expansion, delayed ettringite formation, or other cement/aggregate reaction. For the groundwater samples: – pH $\geq$ 5.5. – Chlorides $\leq$ 500 ppm. – Sulfates $\leq$ 1500 ppm.
Corrective Actions	Per the licensee's corrective action program.
Confirmation Process	Per the licensee's quality assurance program.
Administrative Controls	Per the CoC holder or licensee's quality assurance program. The 10 CFR Part 72 regulatory requirements are used to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.

Table A-4
Basemat Aging Management Program
(2 Pages)

AMP Element	AMP Activity
Operating Experience	This AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research.

Table A-5
High Burnup Fuel Aging Management Program
(2 Pages)

AMP Element	AMP Activity
Scope of Program	The program relies on the joint Electric Power Research Institute (EPRI) and Department of Energy (DOE) High Burnup (HBU) Dry Storage Cask Research and Development Project (HDRP) [15.3] as a surrogate demonstration program that monitors the performance of HBU fuel in dry storage.
Preventative Actions	During the initial loading operations of the canister, the Technical Specifications (TS) require that the fuel be stored in a dry inert environment. These TS requirements ensure that the HBU fuel is stored in an inert environment, thus preventing cladding degradation due to oxidation mechanisms. The canister is also loaded in accordance with the criteria of ISG 11, Revision 3 [15.4].
Parameters Monitored or Inspected	– While the Research Project Cask is on the storage pad, parameters monitored include temperature measurements at various locations within the cask. – After several years in storage, it is anticipated that fuel rods will be extracted from the Research Project Cask and exams, including cladding profilometry (for creep evaluation), rod internal gas pressure, hydride content and orientation, and cladding mechanical testing (e.g., ductility testing), will be performed.
Detection of Aging Effects	This AMP relies on the HDRP [15.3] as a surrogate demonstration program for monitoring the performance of HBU fuel in dry storage. After approximately 10 years of storage at the ISFSI site, it is anticipated that the Research Project Cask will be transported to an off-site fuel examination facility. At the fuel examination facility, the cask will be reopened and the fuel visually examined for changes that occurred during drying and storage. Rods will be extracted from the HBU fuel assemblies and nondestructive and destructive examinations will be performed. It is anticipated that these nondestructive and destructive exams will include cladding profilometry (for creep evaluation), rod internal gas pressure, hydride content and orientation, and cladding mechanical testing (i.e., ductility testing). These examinations will be a direct indication of the susceptibility of HBU fuel to hydride-induced embrittlement and thermal creep.
Monitoring and Trending	As information/data from a surrogate demonstration program or from other sources (such as testing or research results and scientific analyses) become available, the licensee will monitor, evaluate, and trend the information via its operating experience program and/or its corrective action program to determine what actions should be taken.
Acceptance Criteria	The following acceptance criteria are to be applied to the data obtained from the HDRP [15.3]: – Cladding Temperature – The maximum cladding temperature measured is less than or equal to that predicted by the thermal analysis. – Cladding Creep – total creep strain extrapolated to the total approved storage duration based on the best fit to the data, accounting for initial condition uncertainty, shall be less than 1%. – Confirmation that hydride reorientation has not compromised the ability to retrieve the spent fuel on a single-assembly basis.
Corrective Actions	Per the licensee’s corrective action program.
Confirmation Process	Per the licensee’s quality assurance program.

Table A-5
High Burnup Fuel Aging Management Program
(2 Pages)

AMP Element	AMP Activity
Administrative Controls	Per the CoC holder or licensee's quality assurance program. The 10 CFR Part 72 regulatory requirements are used to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.
Operating Experience	This AMP will be updated as necessary to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. In addition to the ongoing OE review, this AMP requires periodic written evaluations, as described in Table 15-6, of the aggregate impact of aging-related DSC OE, research, monitoring, and inspections on the intended safety functions of the in-scope DSC subcomponents (i.e., tollgates).

Proprietary Information on Pages A-19 and A-20
Withheld Pursuant to 10 CFR 2.390

ATTACHMENT B
CHANGES TO COC 1029 AND TECHNICAL SPECIFICATIONS

CONTENTS

B.1 Details of Proposed CoC Changes

The following changes are proposed to the Certificate of Compliance (CoC) No. 1029, initial Amendment 0, Amendment 1, Amendment 3, and Amendment 4 (an Amendment 2 application was submitted, but was subsequently withdrawn) to support the CoC 1029 renewal:

Amendments 0 and 1

Add the following conditions to the CoC:

10. UFSAR UPDATE FOR RENEWED COC

    The CoC holder shall submit an updated final safety analysis report (UFSAR) to the Commission, in accordance with 10 CFR 72.4, within 90 days of the effective date of the CoC renewal. The UFSAR shall reflect the changes and CoC holder commitments resulting from the review and approval of the CoC renewal. The CoC holder shall continue to update the UFSAR pursuant to the requirements of 10 CFR 72.248.

11. 72.212 EVALUATIONS FOR RENEWED COC USE

    Any general licensee that initiates spent fuel dry storage operations with the Standardized Advanced NUHOMS® Horizontal Modular Storage System after the effective date of the CoC renewal, and any general licensee operating a Standardized Advanced NUHOMS® Horizontal Modular Storage System as of the effective date of the CoC renewal, including those that put additional storage systems into service after that date, shall:

    a. as part of the evaluations required by 10 CFR 72.212(b)(5), include evaluations related to the terms, conditions, and specifications of this CoC amendment as modified (i.e., changed or added) as a result of the CoC renewal;

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

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

12. AMENDMENTS AND REVISIONS FOR RENEWED COC

All future amendments and revisions to this CoC shall include evaluations of the impacts to aging management activities (i.e., time-limited aging analyses and aging management programs) to ensure that they remain adequate for any changes to SSCs within the scope of the CoC renewal.

13. USE OF COC 1004 TRANSFER CASKS

General licensees shall not use the OS197, OS197H, and the OS200FC TCs aged 20 years or more to perform the TC functions described in the Standardized Advanced NUHOMS® System UFSAR after the PEO for CoC 1004 ends.

Amendments 3 and 4

Add the following conditions to the CoC:

11. UFSAR UPDATE FOR RENEWED COC

The CoC holder shall submit an updated UFSAR to the Commission, in accordance with 10 CFR 72.4, within 90 days of the effective date of the CoC renewal. The updated UFSAR shall reflect the changes and CoC holder commitments resulting from the review and approval of the CoC renewal. The CoC holder shall continue to update the UFSAR pursuant to the requirements of 10 CFR 72.248.

12. 72.212 EVALUATIONS FOR RENEWED COC USE

Any general licensee that initiates spent fuel dry storage operations with the Standardized Advanced NUHOMS® Horizontal Modular Storage System after the effective date of the CoC renewal, and any general licensee operating a Standardized Advanced NUHOMS® Horizontal Modular Storage System as of the effective date of the renewal of the CoC, including those that put additional storage systems into service after that date, shall:

a. as part of the evaluations required by 10 CFR 72.212(b)(5), include evaluations related to the terms, conditions, and specifications of this CoC amendment as modified (i.e., changed or added) as a result of the CoC renewal;

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

All changes on this page are as a result of OBS 2-3

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

13. AMENDMENTS AND REVISIONS FOR RENEWED COC

All future amendments and revisions to this CoC shall include evaluations of the impacts to aging management activities (i.e., time-limited aging analyses and aging management programs) to ensure that they remain adequate for any changes to SSCs within the scope of the CoC renewal.

14. USE OF COC 1004 TRANSFER CASKS

General licensees shall not use the OS197, OS197H, and the OS200FC TCs aged 20 years or more to perform the TC functions described in the Standardized Advanced NUHOMS® System UFSAR after the PEO for CoC 1004 ends.

All changes on this page are as a result of OBS 2-3

B.2 Details of Proposed Technical Specifications Changes

The following changes are proposed to the Technical Specifications (TS) associated with CoC 1029, initial Amendment 0, Amendment 1, Amendment 3, and Amendment 4 (an Amendment 2 application was submitted, but was subsequently withdrawn) to support the CoC 1029 renewal:

Amendment 0

Revise TS Section 4.3.3, "Transfer Cask," first paragraph, as indicated:

- The Transfer Cask shall meet the codes and standards that are applicable to its design under **Renewed** Certificate of Compliance ~~C of C~~ **(CoC)** ~~72-~~1004, OS-197 Transfer Cask. **The general licensee shall ensure that the requirements of the applicable TRANSFER CASK aging management program (AMP) under The Renewed CoC 1004 have been satisfied.**

Revise TS Section 5.2, "Programs," as follows:

- Add a bullet entitled "Aging Management Program" to the end of the bulleted list.
- Add the following new section after Section 5.2.5:

  5.2.6 Aging Management Program

  Each general licensee shall have a program to establish, implement, and maintain written procedures for each aging management program (AMP) described in the updated final safety analysis report (UFSAR). The program shall include provisions for changing AMP elements, as necessary, and, within the limitations of the approved licensing bases, to address new information on aging effects based on inspection findings and/or industry operating experience provided to the general licensee during the renewal period. Each procedure shall contain a reference to the specific aspect of the AMP element implemented by that procedure, and that reference shall be maintained even if the procedure is modified.

  The general licensee shall establish and implement these written procedures within 180 days after the effective date of the CoC renewal or 180 days after the 20th anniversary of the loading of the first dry storage system at its site, whichever is later. The general licensee shall maintain these written procedures for as long as the general licensee continues to operate Standardized Advanced NUHOMS® Horizontal Modular Storage Systems in service for longer than 20 years.

Amendment 1

Revise TS Section 4.3.3, “Transfer Cask,” first paragraph, as indicated:

- The TRANSFER CASK (OS197 or OS197H) shall meet the codes and standards that are applicable to its design under **Renewed** ~~Certificate of Compliance C of C~~ **CoC** 1004. **The general licensee shall ensure that the requirements of the applicable TRANSFER CASK aging management program (AMP) under The Renewed CoC 1004 have been satisfied.**

Revise TS Section 5.2, “Programs,” as follows:

- Add a bullet entitled “Aging Management Program” to the end of the bulleted list.
- Add the following new section after Section 5.2.5:

  5.2.6 Aging Management Program

  Each general licensee shall have a program to establish, implement, and maintain written procedures for each AMP described in the UFSAR. The program shall include provisions for changing AMP elements, as necessary, and within the limitations of the approved licensing bases, to address new information on aging effects based on inspection findings and/or industry operating experience provided to the general licensee during the CoC renewal period. Each procedure shall contain a reference to the specific aspect of the AMP element implemented by that procedure, and that reference shall be maintained even if the procedure is modified.

  The general licensee shall establish and implement these written procedures within 180 days after the effective date of the CoC renewal, or 180 days after the 20th anniversary of the loading of the first dry storage system at its site, whichever is later. The general licensee shall maintain these written procedures for as long as the general licensee continues to operate Standardized Advanced NUHOMS® Horizontal Modular Storage Systems in service for longer than 20 years.

Amendments 3 and 4

Revise TS Section 4.3.3, “Transfer Cask,” first paragraph, as indicated:

- The TRANSFER CASK (OS197, OS197H, or OS200FC) shall meet the codes and standards that are applicable to its design under **Renewed CoC** ~~Certificate of Compliance C of C~~ 1004. **The general licensee shall ensure that the requirements of the applicable TRANSFER CASK aging management program (AMP) under the Renewed CoC 1004 have been satisfied.**

Revise TS Section 5.2, "Programs," as follows:

- Add a bullet entitled "Aging Management Program" to the end of the bulleted list.
- Add the following new section after Section 5.2.6:

5.2.7 Aging Management Program

Each general licensee shall have a program to establish, implement, and maintain written procedures for each AMP described in the UFSAR. The program shall include provisions for changing AMP elements, as necessary, and within the limitations of the approved licensing bases, to address new information on aging effects based on inspection findings and/or industry operating experience provided to the general licensee during the CoC renewal period. Each procedure shall contain a reference to the specific aspect of the AMP element implemented by that procedure, and that reference shall be maintained even if the procedure is modified.

The general licensee shall establish and implement these written procedures within 180 days after the effective date of the CoC renewal, or 180 days after the 20th anniversary of the loading of the first dry storage system at its site, whichever is later. The general licensee shall maintain these written procedures for as long as the general licensee continues to operate Standardized Advanced NUHOMS® Horizontal Modular Storage Systems in service for longer than 20 years.

Enclosure 6 to E-55203

Calculation 503821-TLAA03, Revision 0, Time-Limited Aging Analysis for Boron Depletion and Radiation Fluence for CoC 1029 License Renewal, Associated with the Response to RSI A-2

(Proprietary)

Withheld Pursuant to 10 CFR 2.390

Enclosure 7 to E-55203

Calculation 503821-TLAA02, Revision 0, Fatigue Evaluation of 24PT1 and 24PT4 Dry Shielded Canisters for CoC 1029, Associated with the Response to RSI A-2

(Proprietary)

Withheld Pursuant to 10 CFR 2.390

Enclosure 8 to E-55203

AREVA Final Report 1001060 R000, "Calvert Cliffs Nuclear Power Plant Horizontal Storage Module (HSM) and Dry Shielded Canister (DSC) Examination" Revision 0, September 29, 2017, Associated with the Response to RSI A-1

(Public)

AREVA

Final Report

Calvert Cliffs Nuclear Power Plant Horizontal Storage Module (HSM) and Dry Shielded Canister (DSC) Examination

Document Number: 1001060

Revision 000, September 29, 2017

Name	Signature/Date	Role
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1.0 Background/Introduction

1.1 The Calvert Cliffs Nuclear Power Plant (CCNPP) Aging Management Program (AMP) required visual inspection and surface chemical sampling of the dry shielded canister (DSC) and horizontal storage module (HSM) visual inspection. As required by (Ref - 8.5) visual inspection was performed in accordance with ASME Section XI Article IWA-2201 VT-3 standards. Chemical sampling is performed using a remotely operated system equipped with a Scotch-Brite® pad to collect samples and the SaltSmart® system for sample analyses. The scope of the DSC AMP for this inspection involved monitoring the DSC shell exterior and cover plates surfaces for the effects of aging associated with stress corrosion cracking (SCC). Aging effects due to loss of material from crevice and pitting corrosion, and cracking due to SCC of stainless steel are managed using visual inspection in accordance with American Society of Mechanical Engineers (ASME) Section Xl and performed by qualified individuals.

1.2 The DSC population for each inspection campaign always includes the DSCs examined in previous inspections for trending purposes. Two DSC/HSMs were inspected in the previous June 2012 campaign (Ref 8.7, 8.11 and 8.8). The first DSC examined was DSC-6 stored in HSM-15. This DSC was loaded in November 1996 and contained the "lead canister" identified to have the highest integrated neutron, gamma, and thermal exposure at the time of the inspection as required by the draft NUREG-1927 Appendix E requirements.

1.3 The second DSC inspected was DSC-11 stored in HSM-1. This DSC was loaded in November 1993 and represents one of the lowest heat load canisters ever loaded.

1.4 Surface deposit samples were collected from DSC-11 (Table 1) and analyzed in this campaign consisting of six SaltSmart® samples and six dry dust samples, each consisting of a Scotch-Brite® pad and a paper filter that were analyzed separately. Sandia National Laboratories analyzed the SaltSmart® and dust samples and submitted a report (Ref - 8.9) of its chemical and mineralogical analyses. The report includes a description of the sample preparation and handling techniques, and all quantitative and semi-quantitative results generated.

1.4.1 It is noted that the Scotch-Brite® pad samples were contaminated by moisture in the sample package, and resulted in molded samples that could not be analyzed. (see Section - 7.2)

1.5 The purpose of the HSM AMP is to ensure that the HSM structures and components maintain their ability to perform their design function throughout the period of extended operation. Only inspection of the internal HSM is included in this report.

1.6 The inspection was contracted to TN Americas (TNA) LLC using Exelon Contract 00406540, release 22 (Ref - 8.5) and has been completed under the TNA QA Program on the same DSCs and HSMs first inspected in June 2012 (DSC-6 in HSM-15 and DSC-11 in HSM-1), herein referred to as the baseline inspection. The canisters encompass a lead canister based on integral dose per NUREG 1927 and a canister with low anticipated surface temperature. The canisters remained stored in the HSM for the inspection.

1.7 TNA provided labor and supervision necessary to complete the work scope using procedures developed with Exelon and TNA Inspection Equipment. The team completed Dry Run Training with the crew on the full scale mockup at TNA's facility at Aiken, SC.

1.8 TNA procedure PTIP F.503919-1, Calvert Cliffs Nuclear Power Plant (CCNPP) Aging Management Inspection Procedure (Ref - 8.6), was used to control the inspection activities.

2.0 HSM Inspection

2.1 Requirements

2.1.1 The inspection requirement for HSMs is a VT-3 level visual inspection of the inside of the Calvert Cliff HSM over pack for used nuclear fuel dry storage subject to the following:

- Perform visual inspection of the interior surfaces of HSM-1 and HSM-15. These inspections were focused on the interior concrete and steel subcomponents, including steel support structure.
- Visual inspections were conducted by remote and direct methods using a high resolution remote PTZ camera (Ref-8.3) capable of detecting age-related degradation such as loss of material due to corrosion, and cracking of metallic components.
- Remote inspections were conducted using an Everest Ca-Zoom, Model PTZ 100 through the HSM rear outlet vent on the HSM interior concrete and steel subcomponents, including the DSC support structure and were evaluated for loss of intended function for inspection results meeting Tier 2 or Tier 3 acceptance criteria in ACI 349.3R-02.

2.2 Acceptance Criteria

2.2.1 Inspection acceptance criteria for the HSM are per inspection results meeting Tier 2 and Tier 3 acceptance criteria in ACI 349.3R-02.

2.2.2 For DSC Support Structure, loss of material due to age-related corrosion of DSC Support Structure shall be evaluated by a Structural Engineer. Acceptance Criteria for the DSC Support Structure for both stainless and carbon steel components shall be based on the design methodologies defined in Calvert Cliffs Nuclear Power Plant ISFSI Updated Safety Analysis Report (USAR) Section 4.2.1.1. "American Institute of Steel Construction (AISC), "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings"' 8th Edition.

3.0 DSC Inspection

3.1 Requirements

3.1.1 The inspection requirement for the DSC is a VT 3 inspection performed in accordance with Ref 8.4 which is qualified in accordance with ASME Code Section XI IWA 2300. Areas to inspect are the easily accessible surfaces of the SS304 canister. The inspections of the DSC surfaces will include the following areas with the High Definition PTZ camera.

- As much as practicable of the bottom end of the DSC visible from the HSM doorway opening including the grapple ring , and excluding areas obstructed by the seismic restraint and the sides of the bottom shield plug where access is restricted by the small HSM doorway gap.
- As much as practicable of the top cover including the closure weld and excluding areas obstructed by the HSM rail back stops.
- As much as practicable of the DSC shell from and including the center circumferential weld (WJ-3) to the top end of the DSC (near the back wall of the HSM), including the longitudinal weld in this region (WJ-2) and excluding the portion of the shell obstructed by the HSM rails. The condition of the DSC shell at the support rail contact region shall be evaluated based on the appearance of the visible regions immediately adjacent to the crevice location.

3.2 The HSM access door was removed for direct inspection of the DSC bottom end for signs of aging degradation.

3.3 As much as practicable of the portion of the DSC shell from the center circumferential weld to the bottom end of the DSC (near the HSM doorway), including the longitudinal weld in this region (WJ-1) and excluding the portion of the shell obstructed by the HSM rails, will be imaged. Inspection to VT-3 standards in this region will be performed to the extent allowed by the inspection equipment. The condition of areas outside of the range capable of being inspected to VT-3 standards will be documented to the best of the ability of the inspector.

3.4 Inspection Criteria

3.4.1 Inspection acceptance criteria for the Dry Shielded Canister (DSC) External Surfaces Aging Management Program are as follows:

- Indications of crevice corrosion or heavy pitting corrosion are absent, or have not increased in extent or density from the previously evaluated baseline.
- Discoloration or stains identified in baseline inspections have not increased in extent and new areas of discoloration or staining have not appeared since the prior inspection.

- Cracks are absent within the material.

3.4.2 Based on the inspection, the DSC is determined to be either Acceptable, Acceptable with Defects, or Unacceptable. The following describes conditions that could lead to each determination and the appropriate response:

- Acceptable signifies that a component is free of significant deficiencies or degradation that could lead to the loss of intended function.
- Acceptable with Defects signifies that a component contains deficiencies or degradation new or increased areas of pitting, crevice corrosion, or staining, compared to the baseline but will remain able to perform its design basis function until the next inspection.
- Unacceptable signifies a component contains deficiencies or degradation that either prevents (or could prevent prior to the next inspection the ability to perform their intended function such as a positive identification of the presence of cracks on the DSC surface with length exceeding the requirements of ASME Section XI Table IWB-3514-2 acceptance criteria for surface examination of in-service austenitic steel components.

In the event of an inspection finding other than acceptable as described in (i) above, the contractor will notify the licensee to perform further evaluation, characterization, and other actions might be needed to preserve the DSC intended functions. The cask may not develop through wall cracking or any other through wall breach that places the licensee out of compliance with 72.122(h)(5), and which the licensee is unable to, through corrective actions, return the DSC to its approved design basis. If the licensee identifies such through wall cracking or other through wall breach and is unable, through corrective actions, to return the DSC to its approved design basis, the licensee shall cease use of such cask or submit a license amendment request to modify this license condition.

3.5 Surface Sampling

3.5.1 SaltSmart® wet samples and Scotchbrite® dry samples were collected from the canister surfaces. Handling, shipping, and analyses protocols, as well as sampling substrates and sample collection, were provided by Sandia National Laboratory. Each sample was labeled for tracking purposes.

3.5.2 A total of six SaltSmart® samples were collected at the locations identified in Figure 1, SaltSmart® Sample Location Map and Table 1, SaltSmart(r) Sample Locations.

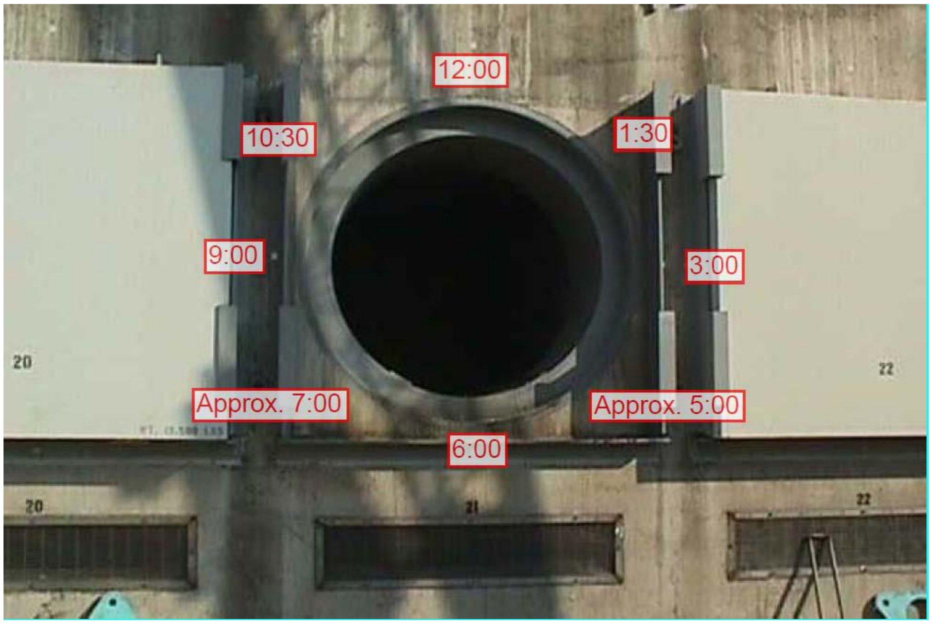

Figure 1, SaltSmart® Sample Location Map

Table 1, SaltSmart(r) Sample Locations

DSC-11		
Axial Location	Sample Location	Sample ID#
Within 6" from the Bottom Cover Plate	11:00	1
Within 6" from the Bottom Cover Plate	10:00	4
Within 6" from the Bottom Cover Plate	11:00	2
3 - 4 feet from Bottom Cover plate	10:30	5
3 - 4 feet from Bottom Cover plate	10:00	3
3 - 4 feet from Bottom Cover plate	10:30	6

4.0

5.0 Inspection Results

5.1 Visual

Reference 8.7 provides a detailed summary of the visual inspections of the two HSMs and DSCs addressed in the 2017 campaign. The results identify no new areas of concern, and also document no degradation in either the HSM or DSC components over the results of the previous campaign.

5.2 Chemical Analysis

The salt compositions from the 2017 Sandia Report (Ref - 8.9) sampled locations suggest that the soluble salts are a combination of both sea-salts (rich in Na, Cl, and Mg), and salts derived from continental sources, rich in NH_4, K, Ca, NO_3, and SO_4, although NH_4 was not observed here. It is reasonable to assume that most of the chloride was deposited as sea-salts; however, chloride is deficient relative to Na. If the chloride was deposited as sea-salts, then the salt particles partially underwent particle-gas conversion reactions prior to or after deposition. Such reactions have been discussed before (Bryan and Enos, 2015), and convert chloride-rich sea-salts to nitrate and sulfate minerals. By reducing the chloride load on the canister surface, these reactions reduce the risk of canister SCC.

Because the SaltSmart® test strips sample a known surface area (3 cm^2), the measured salt compositions can be used to calculate salt surface loads on the metal surface. The measured surface loads in mg/m^2 are given in Table 2. Total soluble salt loads vary from 500 mg/m^2 to nearly 1500 mg/m^2 and this does not include carbonate, which was not measured. Including carbonate would push the values above 2000 mg/m^2. However, chloride concentrations were 50 mg/m^2 or less, and represent only a tiny fraction of the total solutes present.

From letter, Mark D. Flaherty to USNRC, Material License No. SNM-2505, Docket No. 72-8, Response to Request for Additional Information, RE: Calvert Cliffs Independent Spent Fuel Storage Installation License Renewal Application (TAC No. L24475) (Ref - 8.10) see pdf "ML13170A574"). "The results of the June 2012 inspections and the analyses discussed in the response to RAI E-l suggest that chloride concentrations on the oldest Calvert Cliffs DSCs still appear to be well below the proposed 100 mg/m^2 initiation threshold for CISCC indicated by laboratory results, and that they would be expected to remain so for many years."

Table 2, SaltSmart® Sample Results

Sample ID	Na^+	NH_4^+	K^+	Mg^{+2}	Ca^{+2}	F^-	Cl^-	NO_3^-	PO_4^{-3}	SO_4^{-2}
#1 6-8-17/11:30	138	12.0	56	28	279	2.0	44	294	31	251
#2 6-8-17/11:45	119	8.4	70	31	376	n.a.	25	70	46	378
#3 6-8-17/12:00	43	7.2	29	12	135	n.a.	14	104	17	122
#4 6-8-17/12:10	142	11.5	99	39	468	1.3	50	115	52	495
#5 6-8-17/13:20	35	5.0	26	12	217	n.a.	12	82	11	129
#6 6-8-17/13:36	66	12.5	60	31	509	1.4	21	89	47	287
500 mg NaCl/m2 (A)	178	n.a.	n.a.	n.a.	n.a.	n.a.	273	n.a.	n.a.	n.a.
500 mg NaCl/m2 (B)	194	n.a.	n.a.	n.a.	4.5	n.a.	292	8.4	n.a.	10.1

6.0 Conclusion

6.1 HSM interior surfaces are considered to be ACCEPTABLE.

6.2 DSC accessible surfaces are considered to be ACCEPTABLE.

6.3 There has been no change from the conditions reported from the 2012 inspections (Ref - 8.11).

6.4 The chloride concentrations remain well below the SCC 100 mg/m2 initiation threshold. There is no deleterious increase in the chloride concentration identified in the 2017 inspection over the 2012 inspection.

6.5 It is concluded based on the results documented in Sections 5.1 and 5.2 that there has been no degradation of either the HSM interior surfaces, DSC support structure or the accessible portions of the DSC shell that require any further action.

7.0 Lessons Learned

7.1 Improving efficiency of the DOE report

- Get contract with Sandia Lab in place well before the start of the project.
- Clearly define deliverable schedule within contract with DOE.

7.2 Dust Sample Contamination

- The weather the day before the day that the surface dust samples were collected was a driving rain storm. When the dust samples were collected they were controlled as directed by Sandia National Labs (i.e., the samples were wrapped and refrigerated after collection and during shipment).

- Apparently the samples contained excessive moisture from the high humidity resulting from the previous day's driving rain storm that condensed onto the sample pads in the refrigerated environment and molded the samples.
- In the future, these samples should be packaged with desiccant in the shipping container to prevent this condensation from occurring.

8.0 References

8.1 Transnuclear Letter E-31068-"EPRI program for evaluation of stress corrosion cracking (SCC) of dry storage canisters at coastal and near-coastal ISFSIs"

8.2 Site-Specific Independent Spent Fuel Storage Installation (ISFSI) Material License No. SNM-2505, Docket No. 72-8

8.3 Everest Ca-Zoom, Model PTZ 100, Operating Manual

8.4 AREVA 54-ISI-366, VT-1 and VT-3 Visual Examinations

8.5 Exelon Contract 406540 Release 22 (Includes Amendment-1) Commercial Information REDACTED

8.6 PTIP F.503919 Calvert Cliffs Nuclear Plant (CCNP) Aging Management Inspection Procedure

8.7 EG-26-F01 (Rev. 000, 05/28/2014), AREVA Document Number: 180-9273125-000, Calvert Cliffs Nuclear Power Station Horizontal Storage Module (HSM) and Dry Shielded Cask (DSC) Visual Examination (VE)

8.8 AMBD-ISFSI Rev 0001, Calvert Cliffs Independent Spent Fuel Storage Installation

8.9 SAND2017-10555, Analysis of Samples Collected from the Surface of Interim Storage Canisters at Calvert Cliffs in June, 2017

8.10 Letter from Mark D. Flaherty, CENG 2013, Response to Request for Additional Information, RE: Calvert Cliffs Independent Spent Fuel Storage Installation License Renewal Application (TAC No. L24475)

8.11 2014 EPRI Technical Report, Calvert Cliffs Stainless Steel Dry Storage Canister Inspection

Enclosure 9 to E-55203

Exelon Generation Report R000, "Aging Management Program Inspections for Spent Fuel Horizontal Storage Modules" dated July 2017, Associated with the Response to RSI A-1

(Public)

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REPORT COVER SHEET

Exelon®

Exelon Generation

Calvert Cliffs Nuclear Power Plant

Lusby, Maryland

Aging Management Program Inspections for Spent Fuel Horizontal Storage Modules

REPORT

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STRUCTURAL Project Number 100470

July 2017

000	Client Comments Incorporated	81	Appendix D, Sht. D7	[signature]	[signature]	[signature]	July 21, 2017
00A	Issued for Review	78	Appendix D, Sht. D7	JSD	DGR	OSA	July 12, 2017
REV. NO.	REASON FOR REVISION	TOTAL NO. OF SHEETS	LAST SHEET NO.	ORIGINATOR	CHECKER	APPROVER	DATE

RECORD OF REVISIONS

4.0 Acceptance Criteria

The acceptance criteria for the HSM AMP walkdowns are based on the criteria established in ACI 349.3R-02 (Ref. 5.2), which is required per Section 2.3.6 of AMBD-ISFSI (Ref. 5.5). They are split into three tiers with applicable limits as follows:

- **Tier 1 – Acceptance without further evaluation:**
  - Absence of leaching and chemical attack
  - Absence of abrasion, erosion, and cavitation
  - Absence of drummy areas (see ACI 201.1R, Ref. 5.3)
  - Popouts and voids less than 20 mm (3/4 in.) in diameter or equivalent surface area
  - Scaling less than 5 mm (3/16 in.) in depth
  - Spalling less than 10 mm (3/8 in.) in depth and 100 mm (4 in.) in any dimension
  - Absence of any signs of corrosion in the steel reinforcement or anchorage components
  - Passive cracks less than 0.4 mm (0.015 in.) in maximum width
- **Tier 2 – Acceptance after review:**
  - Appearance of leaching or chemical attack;
  - Areas of abrasion, erosion, and cavitation degradation;
  - Drummy areas that can exceed the cover concrete thickness in depth;
  - Popouts and voids less than 50 mm (2 in.) in diameter or equivalent surface area;
  - Scaling less than 30 mm (1-1/8 in.) in depth;
  - Spalling less than 20 mm (3/4 in.) in depth and 200 mm (8 in.) in any dimension;
  - Corrosion staining of undefined source on concrete surfaces;
  - Passive cracks less than 1 mm (0.04 in.) in maximum width; and
  - Passive settlements or deflections within the original design limits.
- **Tier 3 – Conditions requiring further evaluation – Any condition in excess of the above criteria**

Any degradation exceeding Tier 1 criteria must be entered into CCNPP's Corrective Action Program according to Section 2.3.6 of AMBD-ISFSI (Ref. 5.5). Section 6.0 of this report notes whether each observation meets or exceeds Tier 1 Criteria, and if an observation exceeds the Tier 1 Criteria whether the observation has already been entered into the Corrective Action Program or not.

6.0 Observations

In this section, a description is provided for each type of degradation observed during the inspections, and on which HSMs they were noted. Sample photographs and diagrams are included within the body of this report. For further details, see the attached appendices.

6.1 Map Cracking on Roofs

Cracking consistent with the ACI201.1R (Ref. 5.3) definition of map cracking or crazing appears on the roofs of all of the units designated for inspection. For all of the HSM structures inspected the cracks all appear to be very shallow in depth.. In addition, there was no evidence of exuded gel associated with alkali-silica reaction (ASR) degradation. Note that specialized testing would be required to confirm the absence of ASR, which is not within the scope of this inspection. The areas with the observed map cracking were hammer sounded and no delamination was detected. A schematic view of map cracking for HSM-31 is shown in Figure 6, and a photograph of the observed map cracking is shown in Figure 7. The photograph shown in Figure 7 is representative of all of the map cracking observed on the HSM roof slabs.

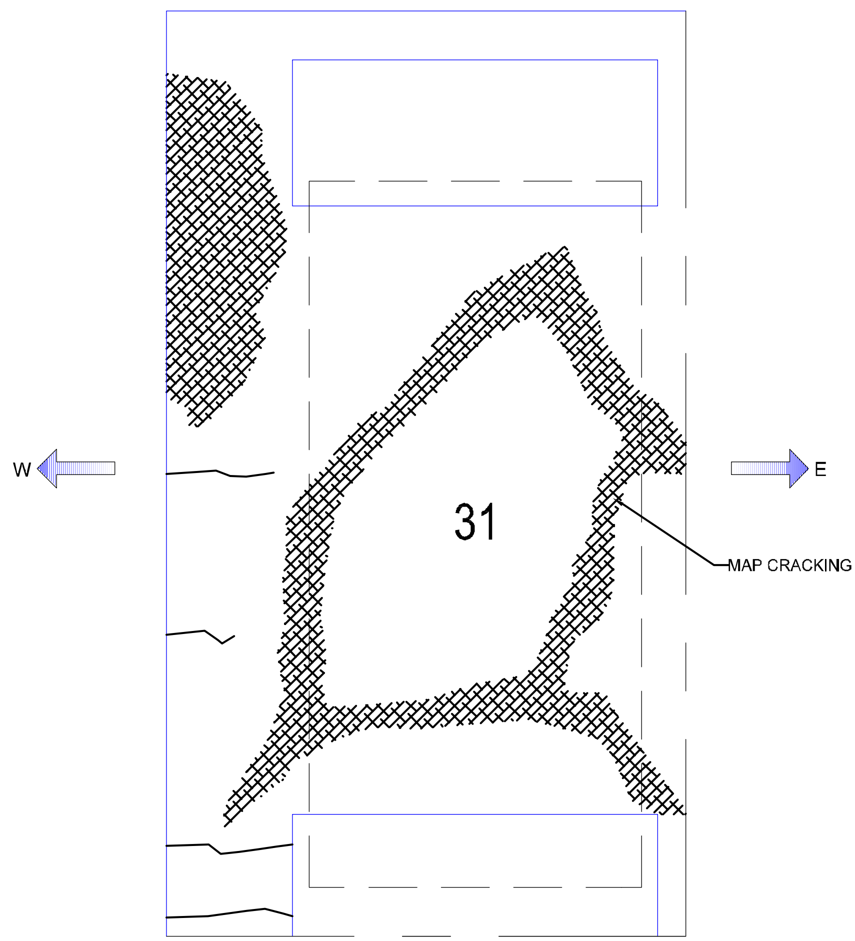


Figure 6 – Diagram of Map Cracking On HSM-31

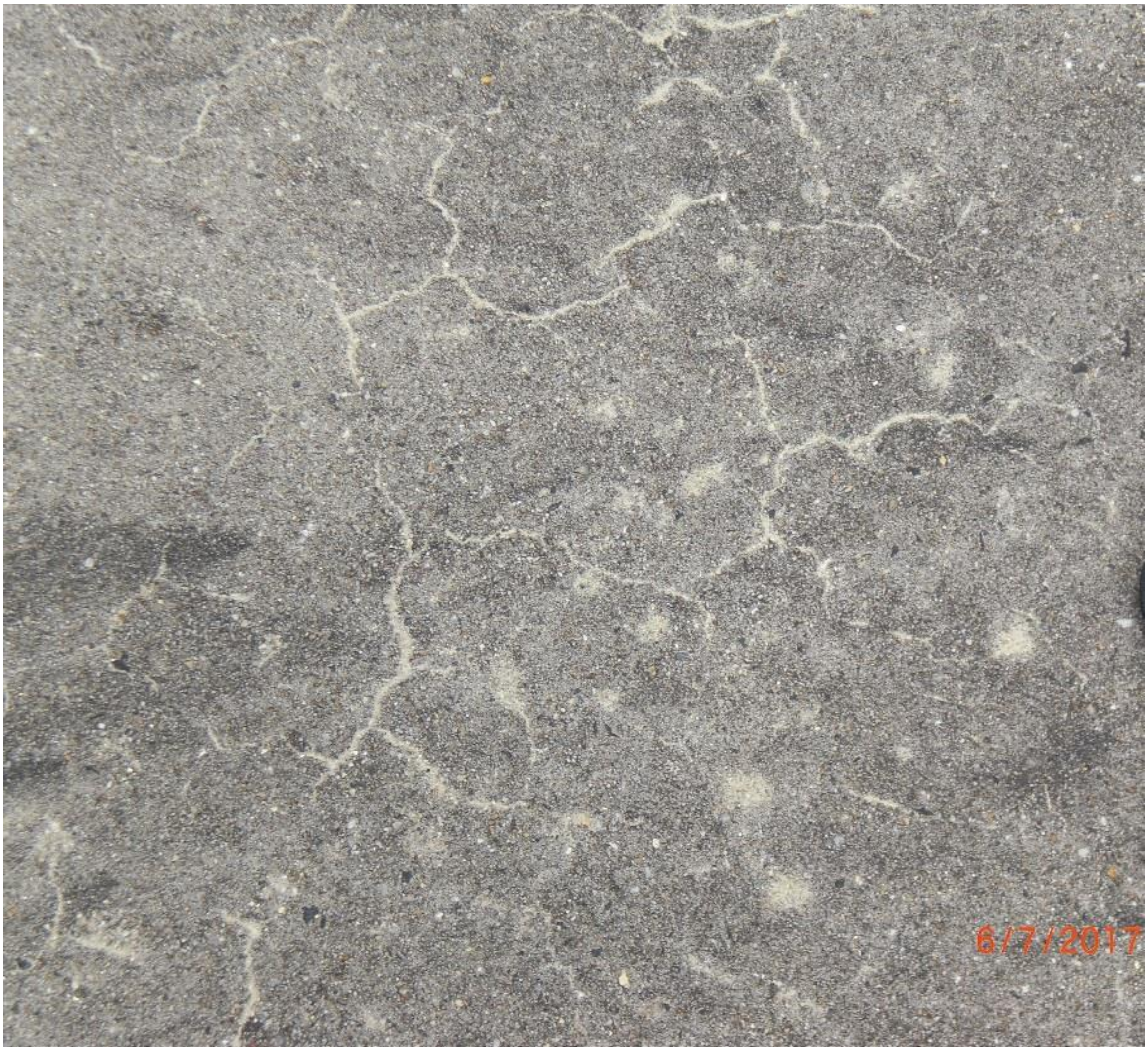


Figure 7 – Map Cracking on HSM-7

These surface cracks may be the result of plastic or drying shrinkage after placement of the concrete. All cracks observed were less than 0.015 in. (0.4 mm) in width, which places them within the ACI 349.3R-02 Tier 1 acceptance criteria, "acceptance without further evaluation" (Ref. 5.2). These findings are consistent with the findings of the previous third party inspection report (Ref. 5.4), which is summarized in Item No. 1 of Table 1 of this report. It does not appear that this map cracking condition has worsened since the previous report was authored in 2012 (Ref. 5.4), and are thus considered as passive cracks. However, these instances of map cracking on the roof slabs should continue to be monitored.

HSMs Affected: HSM-1, HSM-7, HSM-13, HSM-15, HSM-31, and HSM-46

6.2 Cracking at Roofs and Walls

6.2.1 Roof Slab Cracks and Efflorescence on Walls

Cracking was observed on the roof slab at the edge where the roof slab meets the walls, and the cracking continues around the roof corner and down the walls on all of the end units that were inspected. Figure 8 shows a schematic elevation view of the cracking propagating down from the top of the wall to approximately the location of the bottom of the roof slab. Figure 9 shows a photograph illustrating typical roof cracks and corresponding wall cracks with efflorescence, with the efflorescence stopping at approximately the location of the bottom of the roof slab. Note that since the roof slab is 3'-0" thick, as shown in Section A-A of CCNPP Dwg. 84081 (Ref. 5.9.3), it appears that these cracks and corresponding efflorescence are within the thickness of the roof slab. UPV testing was performed and all cracks were measured to be less than 3 in. (76 mm) in depth (within the depth of the concrete cover over embedded reinforcing steel) at the roof portion of the crack. The efflorescence visible on the top of the walls (see Figure 9) is likely caused by water intruding from the top of roof slab cracks and subsequently exiting through cracks on the walls.

This observation is consistent with the findings of CCNPP Condition Report# IR3-033-810 (see Table 2 of this report), which found cracking in the roof slabs of HSM-1. These cracks were also identified in the previous third party inspection report that was authored in 2012 (Ref. 5.4), which is summarized in Item No. 3 of Table 1 in this report. The areas with cracking were hammer sounded and no delamination was detected. Crack widths were measured to be less than 0.015 in. (0.4 mm) in width, which places them within the ACI 349.3R-02 Tier 1 acceptance criteria, "acceptance without further evaluation" (Ref. 5.2). Based on the description provided in CCNPP Condition Report# IR3-033-810 and the previous third party inspection report that was authored in 2012 (Ref. 5.4), it does not appear this cracking issue has worsened, and are thus considered as passive cracks. A photograph provided by CCNPP from a prior site annual inspection dated April 24, 2015 is shown in Figure 10. Making a visual comparison of the condition in 2015 shown in Figure 10 with the current condition shown in Figure 9 it is observed that there is no visual change from 2015 to the current condition. However, these instances of cracking on the roof slabs and efflorescence in the walls should continue to be monitored.

6.2.2 Wall Cracking Not Extending to Roof and Without Efflorescence

Some cracks that did not extend up to the roof were also observed on the end walls of some of the units, but these cracks did not have efflorescence (see Figure 11). These areas with cracking were also hammer sounded and no delamination was detected. All cracks observed were less than 0.015 in. (0.4 mm) in width, which places them within the ACI 349.3R-02 Tier 1 acceptance criteria, "acceptance without further evaluation" (Ref. 5.2).

6.2.3 Isolated Areas of Map Cracking on Walls

Some isolated areas of map cracking was also observed near the top of some of the HSM walls on the corners (see Figure 12 and Figure 13). These isolated areas were observed mostly on the older corner HSMs, such as HSM-7 and HSM-1. These areas were not easily accessible, and so no direct crack measurements were possible. However, from visible inspection, the cracking appears to be purely superficial, and appear to be within the ACI 349.3R-02 Tier 1 acceptance criteria, "acceptance without further evaluation" (Ref. 5.2). Note that these isolated areas of map cracking are not new conditions, and have been previously identified by site annual inspections. A photograph of HSM-1 provided by CCNPP from a prior site annual inspection dated April 24, 2015 is shown in Figure 14. Making a visual comparison of the condition in 2015 shown in Figure 14 with the existing condition shown in Figure 13 it is observed that there is no visual change from 2015 to the current condition. However, it is recommended that these areas be monitored in the future.

6.2.4 Efflorescence in Previous Repair Areas of Walls

Some efflorescence was observed in previous repair areas on the side of HSM-1 (see Figure 15). Note that the observed efflorescence in the repair areas of HSM-1 are not new conditions, and have been previously identified by site annual inspections. A photograph of HSM-1 provided by CCNPP from a prior site annual inspection dated April 24, 2015 showing the condition of the repair areas of HSM-1 is provided in Figure 16. Making a visual comparison of the condition in 2015 shown in Figure 16 with the current condition shown in Figure 15 it is observed that there is no visual change from 2015 to the current condition. Thus, this is not considered a cause for concern or for being reportable, but something that should be monitored in the future.

HSMs Affected: HSM-1, HSM-7, HSM-13, HSM-15, HSM-31, and HSM-46

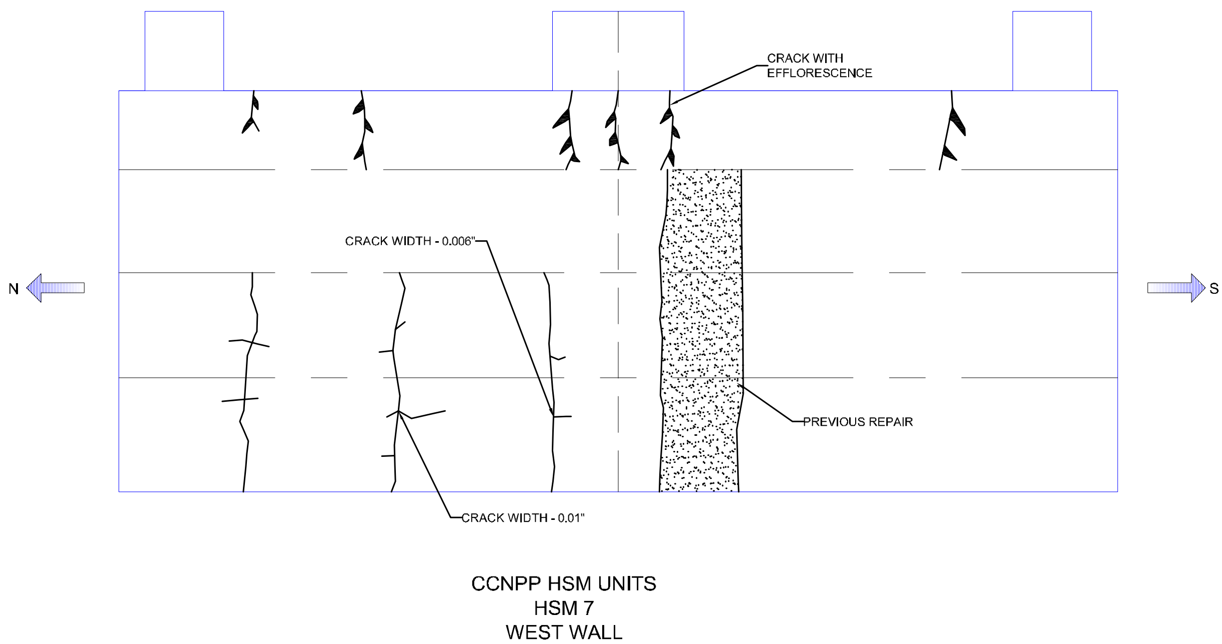


Figure 8 – Diagram of Cracking on HSM-7

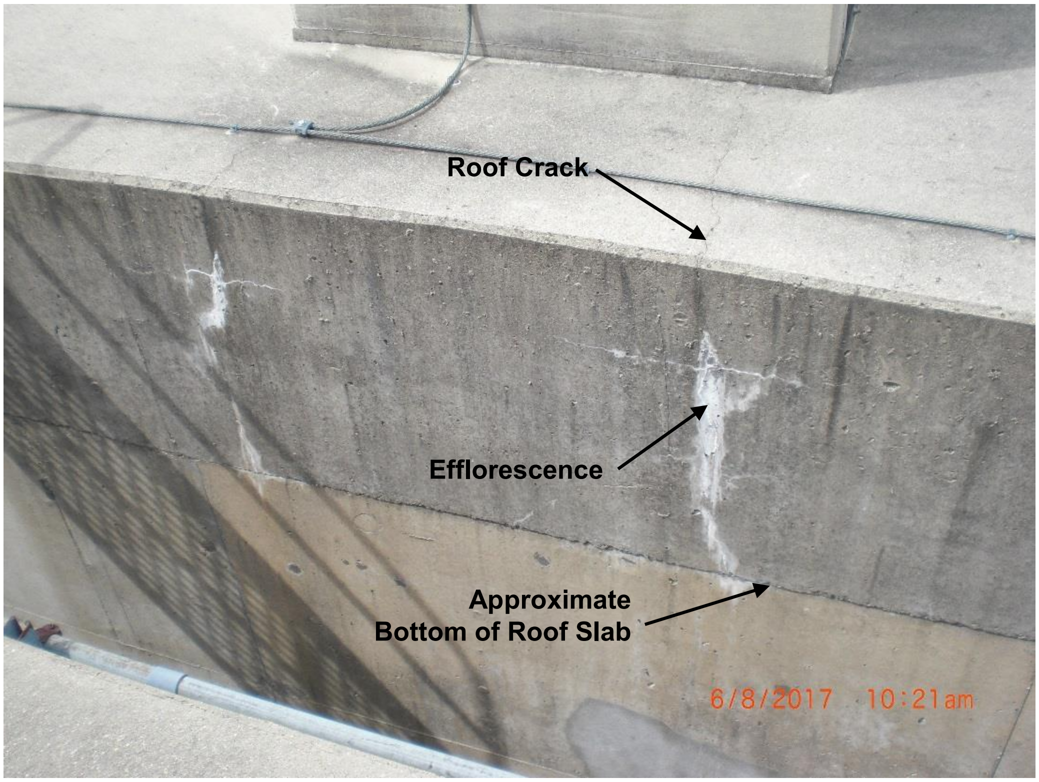


Figure 9 – Roof Cracking Extending to Efflorescence on Walls

Figure 10 – Prior 2015 Site Annual Inspection Showing Similar Cracking and Efflorescence as in Figure 9

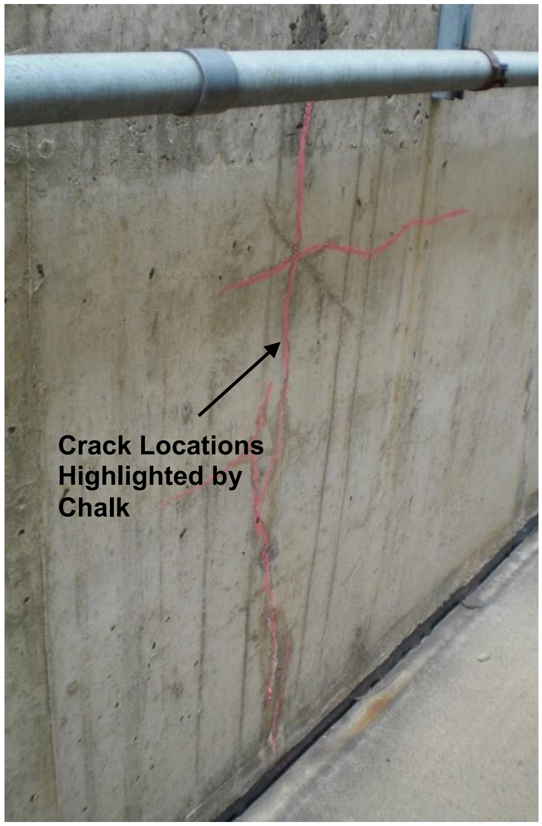


Figure 11 – Cracking on Side of HSM Not Extending to Roof

Figure 12 – Map Cracking on the Wall Corner of HSM-7

Figure 13 – Map Cracking on Wall of HSM-1

Figure 14 – Prior 2015 Site Annual Inspection Showing Prior Condition of HSM-1 Walls

Figure 15 – Efflorescence Observed in Previous Repair Areas on the Side of HSM-1

Figure 16 – Prior 2015 Site Annual Inspection Showing Condition of HSM-1 Repair Areas

6.3 Cracking on Rooftop Vents

Cracking was observed at the roof vents of the oldest of the units designated for inspection, specifically HSM-1 and HSM-15. UPV testing was performed and the cracks were measured to be less than 1.0 inch in depth (within the concrete cover), and ground penetrating radar (GPR) revealed that the cracks occurred at the location of the East-West oriented rebar. All cracks observed were measured to be less than 0.015 in. (0.4 mm) in width, which places within the ACI349.3-02 Tier 1 acceptance criteria, “acceptance without further evaluation” (Ref. 5.2). These findings are consistent with the findings of the previous third party inspection report (Ref. 5.4), which is summarized in Item No. 3 in Table 1 of this report. It does not appear that this condition has worsened since the previous report was authored, and is thus considered a passive condition. However, it is recommended that these cracks continue to be monitored.

HSMs Affected: HSM-1, HSM-15 (similar degradation appears on HSM-3, though that HSM was not designated for survey)

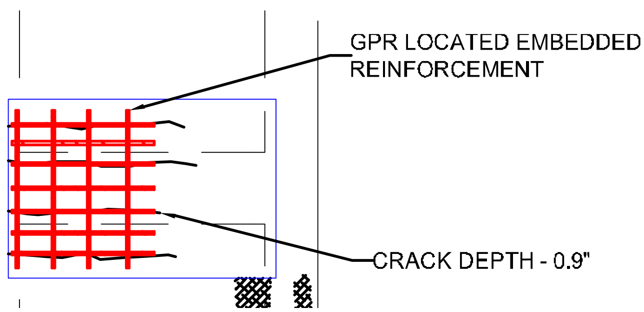


Figure 17 – Diagram of Cracking on Top of Vents

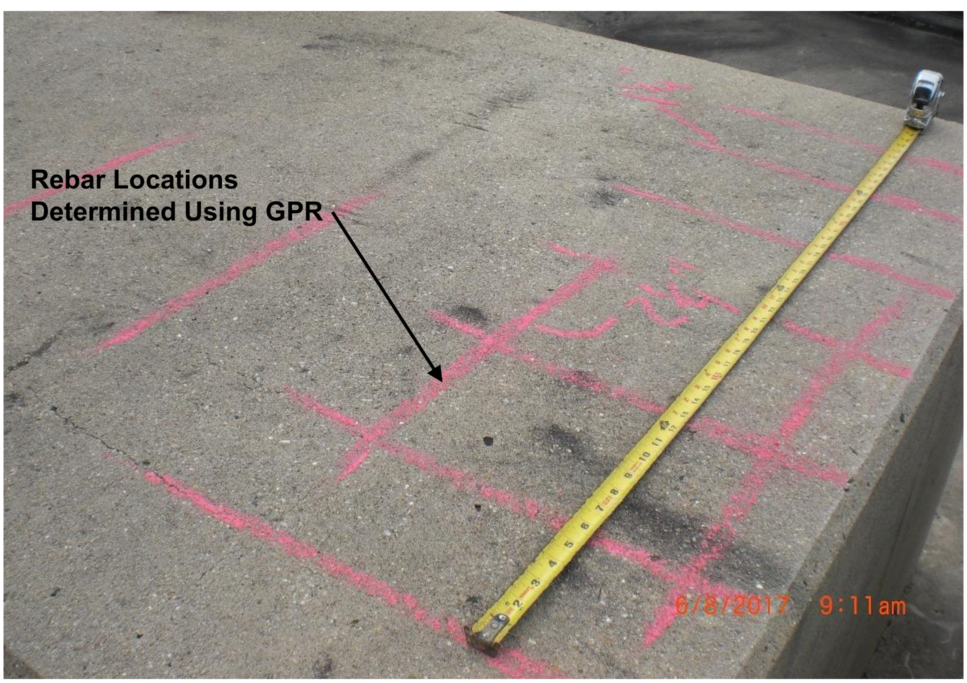


Figure 18 – Cracking Observed on Top of Vents

6.4 Spalling of Concrete

Spalling appears above the door at HSM-46 at the location of a concrete repair (see Figure 19 and Figure 20). This repair may have been necessary due to poorly formed concrete at this location. Although inaccessible for direct measurement at the time of inspection due to dose concerns, the spalling does appear to exceed the ACI349.3R-02 (Ref. 5.2) threshold for a Tier 1 finding, being larger than 4 in. (100 mm) in any dimension. However, this spalling has already been captured by Condition Report # IRE-00-318 (see Table 2 of this report), and matches the description of the previous third party inspection report made in 2012 (Ref. 5.4), which is summarized in Item # 4 of Table 1 in this report. Furthermore, it does not appear that this condition has worsened since the previous report (Ref. 5.4) was authored, and is thus considered a passive condition.

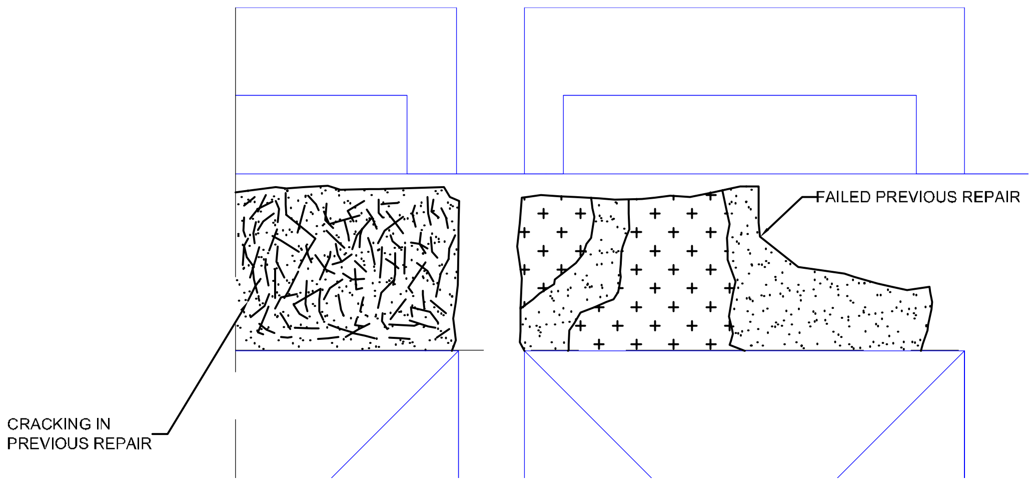


Figure 19 – Cracking and Spalling Above Shield Doors at HSM-45 and HSM-46

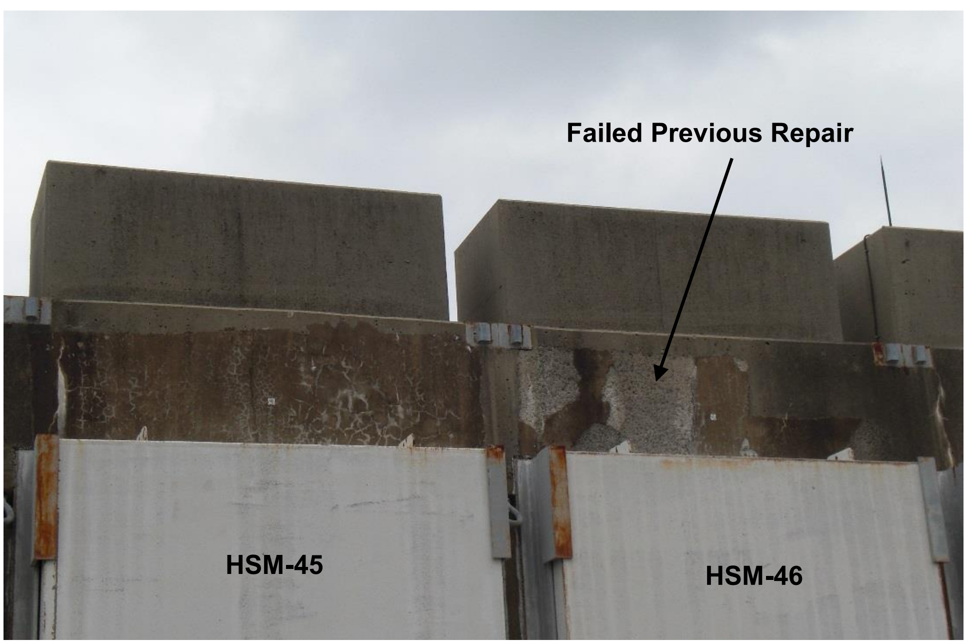


Figure 20 – Spalling Above Shield Door at HSM-46

HSMs Affected: HSM-46 (similar degradation appears on HSM-45, though that HSM was not designated for inspection)

6.5 Possible Delaminated Concrete at Cask Restraint Turnbuckle Eyes

Hammer sounding of the concrete revealed delaminated areas just below the cask restraint assembly turnbuckle eyes on the front of multiple HSMs (see Figure 21 and Figure 22). There was no extensive corrosion, and the areas have not yet spalled. These cask restraint turnbuckle eyes do not appear to serve any structural purpose for the continued functionality of the HSMs. However, the continued cask restraint functionality is important in case there is a future need to unload the dry storage canister. The cask restraint assembly shown in Figure 23(a) (Ref. 5.9.4) provides a connection between the transfer cask and the HSM during transfer of the dry storage canister to or from the HSM. The hollow sound observed from hammer sounding during the site inspection appeared to be concentrated around the area near the insert of the turnbuckle where concrete cover is shallow. It is believed this may be caused by a lack of complete concrete consolidation in that area during concrete placement. However, because of the deep embedment depth of the cask restraint anchorage (see Figure 23(b)) and the high concrete pull-out capacity (see Ref. 5.10), it is considered by engineering judgment that this does not hinder the function of the cask restraint. However, it is recommended that the area around the anchors be monitored and observed during future inspections for possible water intrusion that could lead to future problems.

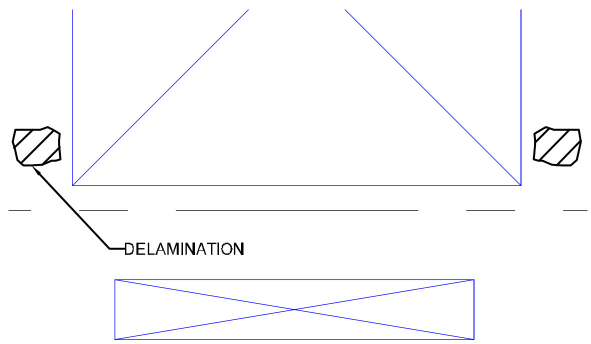


Figure 21 – Delamination

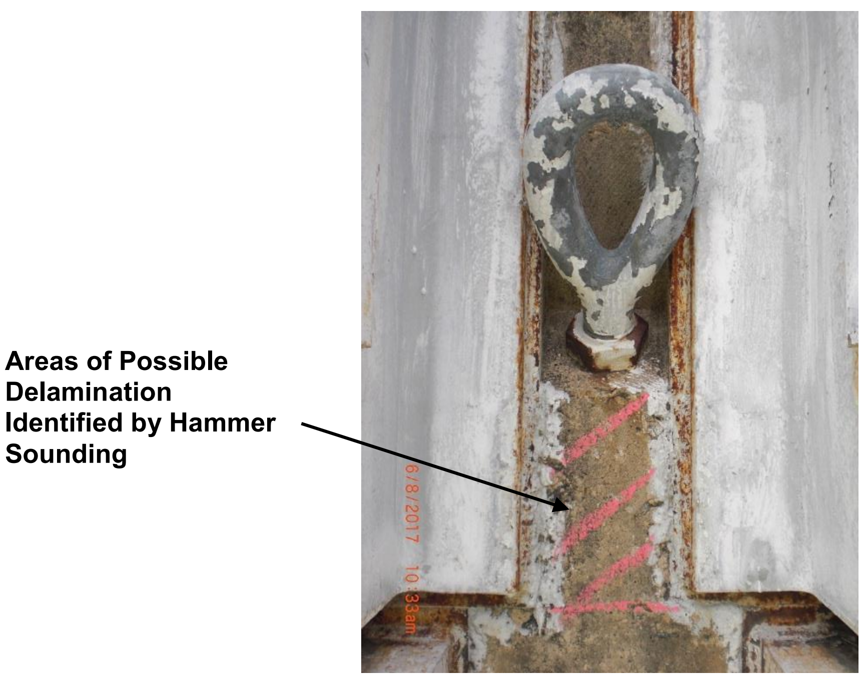
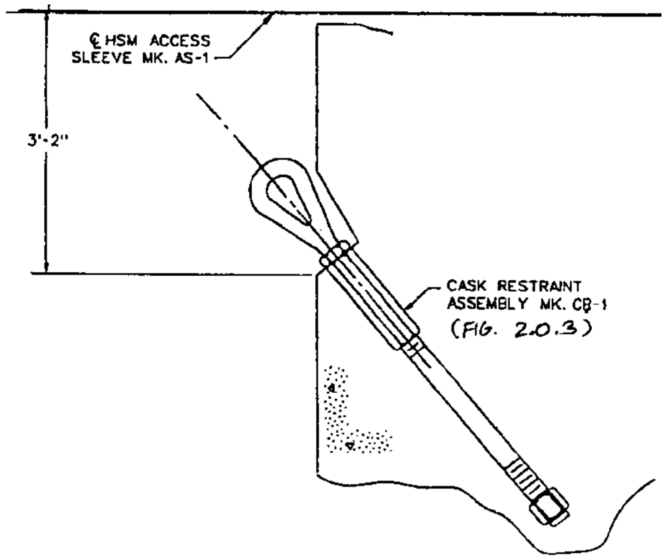
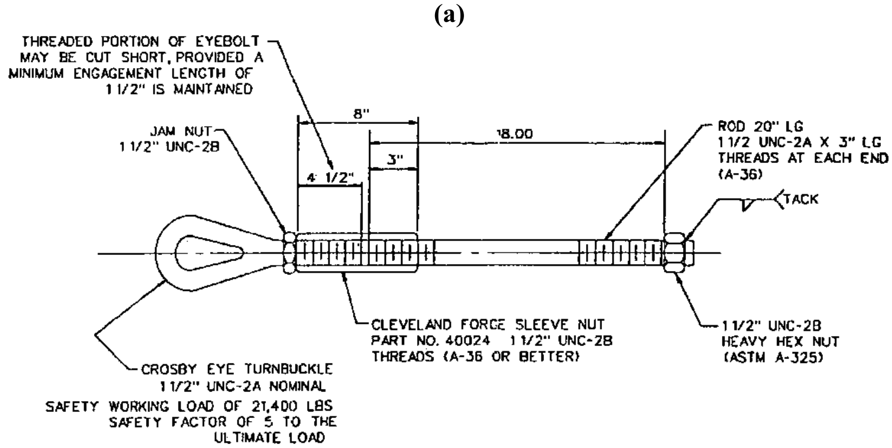


Figure 22 – Possible Delamination Below Cask Restraint Assembly Turnbuckle Eyes



(a)



(b)

Figure 23 – Cask Restraint Assembly: (a) Section View (Ref. 5.9.4, Section B-B) and (b) Detail of Cask Restraint Anchor (Ref. 5.10)

HSMs Affected: HSM-15, HSM-46 (similar degradation appears on other HSMs that were not designated for inspection)

6.6 Grade Slab Damage

In numerous areas around the HSMs, cracking in the grade slabs due to soil settlement and heaving was noted (see Figure 24, Figure 25, Figure 26, and Figure 27). In some areas, joint sealant has detached or disintegrated due to this soil motion. This is especially apparent adjacent to the HSMs where there is differential displacement between the HSMs and the grade slab. The grade slab degradation is consistent with the description of concrete slab cracking provided in Condition Report # IRE-022-449 (Ref. 5.4) describing concrete slab cracking around HSM-42 and Condition Report # IRE-00-318 describing concrete slab cracking between HSMs 30 and 31 (see Table 2 for a full description). Although the grade slabs are not connected to the HSMs (see Figure 25), the lack of joint sealant between the grade slabs and the HSMs allows water intrusion that can lead to foundation problems or general reinforcement corrosion issues in the future. Sealant repair is currently being tracked in CCNPP's Corrective Action Program (CAP), and monitoring is continued by CCNPP's annual inspection. However, it is recommended that the sealant be repaired in the near future to prevent issues with the base of the HSMs.

Figure 24 – Grade Slab Damage

Figure 25 – Indentation in HSM-37 Near Failed Grade Slab Seal

Figure 26 – Failed Seal Material at Grade Slabs

Figure 27 – Failed Seal Material at Grade Slabs

HSMs Affected: HSM-31 (similar degradation appears around other HSMs that were not designated for inspection)

7.0 Conclusions and Recommendations

All observed conditions that have been described in this report, which have not already been entered into CCNPP's Corrective Action Program, were found to be within the ACI 349.3R-02 (Ref. 5.2) Tier 1 Criteria, "acceptance without further review," and the "Acceptable" condition defined in Section 6.7 of Procedure MN-1-319 (Ref. 5.1). Continued monitoring per procedure and ACI guideline is recommended, with particular attention to the condition of the grade slabs and cracking in the HSMs displaying efflorescence. These conditions currently exhibit characteristics of passive conditions, but require proactive maintenance to prevent water intrusion from affecting the HSMs in the future. The spalling on HSM-46 is acceptable as is, but should be monitored closely and repaired if it progresses any further. The hollow sound observed from hammer sounding in the area of the cask restraint assembly during the site inspection appeared to be concentrated around the area near the insert of the turnbuckle where concrete cover is shallow. It is believed this may be caused by a lack of complete concrete consolidation in that area during original concrete placement. However, because of the deep embedment depth of the cask restraint anchorage, it is considered by engineering judgment that this does not hinder the function of the cask restraint. However, it is recommended that the area around the anchors be monitored and observed during future inspections for possible water intrusion that could lead to future problems.

8.0 List of Appendices

A. Attachment 4 to Procedure MN-1-319 (31 Sheets)
B. Condition Survey Drawings (14 Sheets)
C. Field Testing Results (2 Sheets)
D. Field Photographs (7 Sheets)

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APPENDIX D

FIELD PHOTOGRAPHS

structural TECHNOLOGIES	FIELD PHOTOGRAPHS	Project No.	100470	
		Date	06 08	17
		Sheet	FP	1

PROJECT INFORMATION

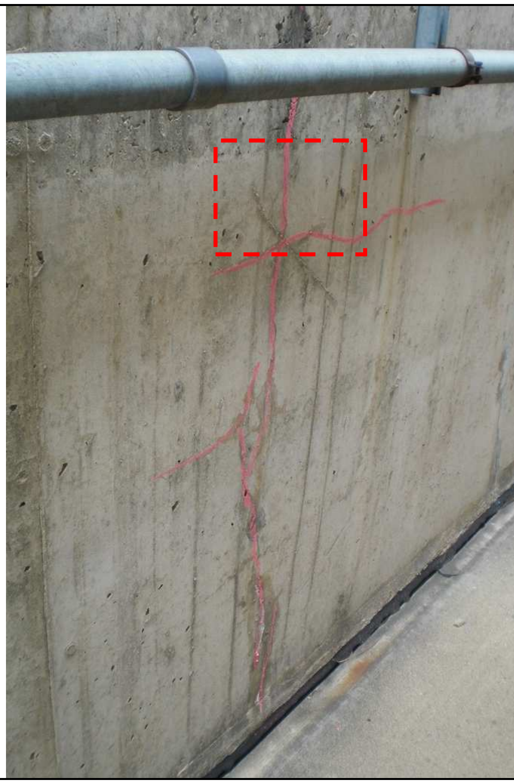
Client Name:	Calvert Cliffs Nuclear Power Plant		
Location:	Calvert Cliffs CITY	Maryland STATE/PROVINCE	US COUNTRY

Process Unit/Structure Name: HSM Structures 1, 7, 13, 15, 31, and 46

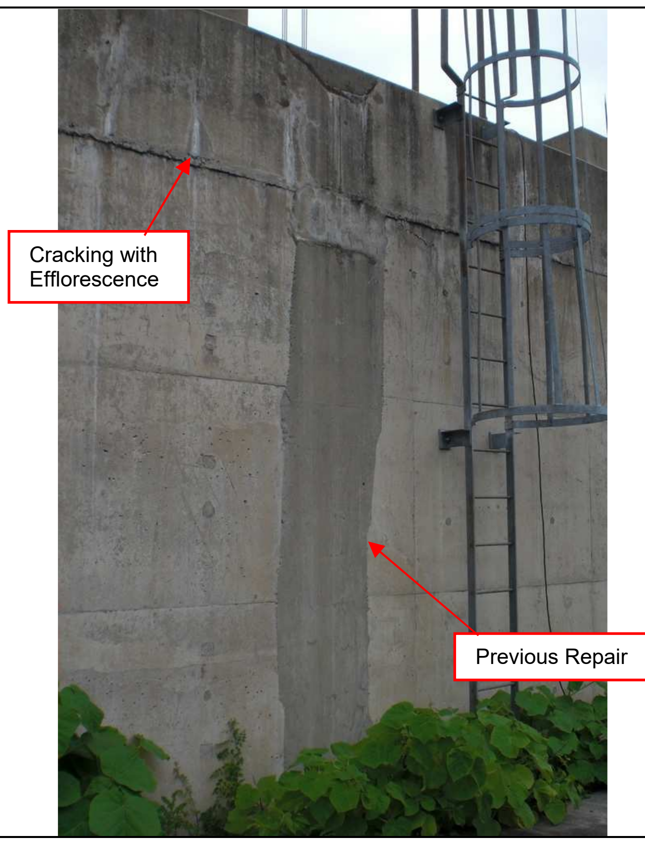
Photograph 1. HSMs 43 through 48 overall view.

Photograph 2. HSMs 45 and 46 showing failed repairs and spalling.

struc'tur'al TECHNOLOGIES	FIELD PHOTOGRAPHS	Project No.	100470	
		Date	06	08	17
		Sheet	FP	2



Photograph 3. Crack on the west face of HSM 7 showing a 0.01” crack.



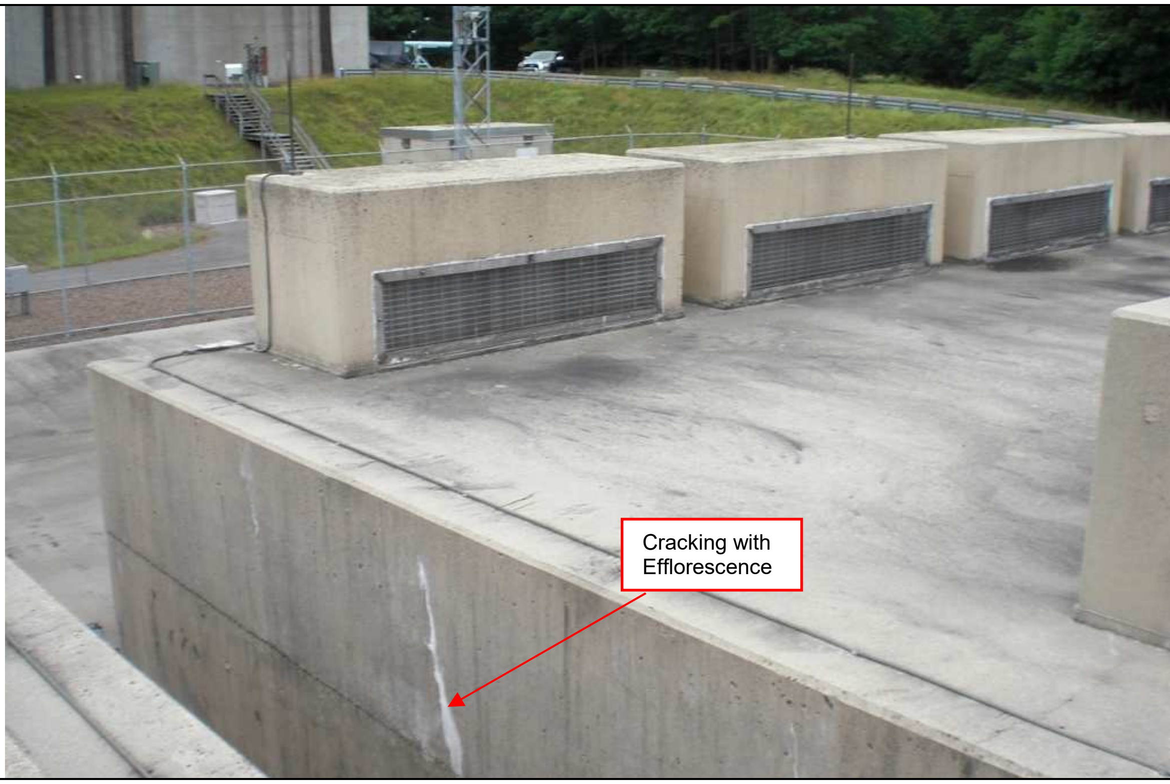
Photograph 4. West face of HSM 1 and 13 showing previous repairs and cracking with efflorescence.

structural TECHNOLOGIES	FIELD PHOTOGRAPHS	Project No.	100470		
		Date	06	08	17
		Sheet	FP		3

Photograph 5. South face of HSM 13 and 15 showing cracking with efflorescence.

Photograph 6. Top of HSM 7 showing map cracking.

structural TECHNOLOGIES	FIELD PHOTOGRAPHS	Project No.	100470	
		Date	06 08	17
		Sheet	FP	4



Photograph 7. West face and top of HSM 7 showing cracking with efflorescence.

Photograph 8. Top of HSM 31 showing map cracking.

structural TECHNOLOGIES	FIELD PHOTOGRAPHS	Project No.	100470	
		Date	06 08	17
		Sheet	FP	5

Photograph 9. Top of HSM 46 showing map cracking and shrinkage cracking.

Photograph 10. Ground slab on the northwest corner of HSM 31 showing delaminated and spalled concrete.

structural TECHNOLOGIES	FIELD PHOTOGRAPHS	Project No.	100470		
		Date	06	08	17
		Sheet	FP		6

Photograph 11. South face of HSM 46 showing delaminated concrete.

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