Enclosure 5

Non-Proprietary Draft SAR Section C.13

APPENDIX C.13
AGING MANAGEMENT PROGRAMS

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This section is newly added.

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C.13. AGING MANAGEMENT PROGRAMS

C.13.1 Purpose

This chapter describes the aging management programs *(AMPs)* credited for managing each of the identified aging effects for the in-scope structures, systems, and components (SSCs) of the NUHOMS® related dry storage systems at the Waste Control Specialists (WCS) Consolidated Interim Storage Facility (CISF). The purpose of the AMPs is to ensure that aging effects *do not* result in a loss of intended function of the SSCs. The AMPs are based on the results of the aging management reviews (AMR) for the dry shielded canisters (DSCs), horizontal storage modules (HSMs), and concrete basemat presented in [C.13-29].

The AMPs developed to manage aging effects are:

- DSC External Surfaces Aging Management Program (applicable to DSC)
- DSC Aging Management Program for the Effects of Chloride-Induced Stress Corrosion Cracking (applicable to DSC)
- Horizontal Storage Module Aging Management Program for External and Internal Surfaces (applicable to HSM and DSC support structure)

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 used in the NUHOMS® related dry storage systems.

This section is newly added.

C.13.2 Methodology

The AMPs are based on the AMPs approved for the renewal of CoC 1004 [C.13-29 and C.13-30]. The structure of the AMPs is consistent with the 10 program elements described in NUREG-1927 [C.13-1], 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 (e.g., 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, it also includes 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.

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, ensures that the SSC intended safety functions and the approved design bases are maintained during the period of extended operations.

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 period of extended operations.

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 TN Americas 10 CFR Part 72, Subpart G Program. 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 intended safety functions will be maintained during the period of extended operations. Operating experience provides justification for the effectiveness of each AMP program element and critical feedback for enhancement.

Note: For the purpose of these AMPs, the phrase "period of extended operation" is defined *as* the period starting 20 years after the component was first placed in service, (i.e., at the original Independent Spent fuel Storage Installation (ISFSI), or nuclear power site, for the DSCs or at the CISF for the HSM and basemat).

C.13.3 DSC External Surfaces Aging Management Program

C.13.3.1 Scope of Program

This AMP applies to all DSCs except those where the AMP in Section C.13.4, aging management for the effects of chloride-induced stress corrosion cracking (CISCC), applies.

This program visually inspects and monitors the external surfaces of the DSC that may be subject to loss of material and cracking. The program scope includes external surfaces of the DSC shell assembly. The areas of DSC inspection are:

- Fabrication welds of the confinement boundary and the associated heat affected zone (HAZ), i.e., longitudinal and (if any) circumferential welds on the cylindrical shell,
- Crevice locations, *e.g.*, where the shell sits on the support rail,
- The upper surface of the cylindrical shell, where atmospheric particulates would settle,
- The top and bottom ends of the cylinder, which are cooler than the center,
- Outer bottom cover plate, grapple assembly, their welds and HAZs, and
- Outer top cover plate, welds and HAZs.

The last two areas are not part of the confinement boundary, but their condition must be ascertained prior to retrieval and transport. As vertical surfaces out of the main path of air flow, they are the least susceptible to the effect of atmospheric deposits. Accessibility to the outer top cover plate may be limited during storage, but prior to transport, it can be inspected after the canister is pulled into a transport cask.

The materials, environments, and aging effects requiring management for the external surfaces of DSC shell assembly (to maintain confinement, shielding structural, heat transfer, and retrievability intended safety functions) are as follows:

Materials

DSC shell assembly components subject to AMR are constructed of the following material:

- Stainless Steel – shell assembly

Environments

DSC shell assembly components subject to AMR are exposed to the following environments:

- Sheltered

Aging Effects Requiring Management

The following aging effects associated with the DSC shell assembly components require management:

- Loss of material due to crevice and pitting corrosion for stainless steel components
- Loss of material due to galvanic corrosion for the DSC shell contacting graphite lubricant at the sliding rail surface
- Loss of material due to radiation-induced crevice corrosion, pitting corrosion, and *stress corrosion cracking (*SCC*)* for stainless steel DSC shell
- Cracking due to SCC for stainless steel components when exposed to moisture and aggressive chemicals in the environment

Interim Storage Partners (ISP) may use inspections results from other general or specific licensee inspections if it can be demonstrated that the other licensee inspections are bounding. Parameters to be considered in making a bounding determination include: similar or more benign environmental conditions, similar storage system design components, similar stored fuel parameters, heat load, and operational history. The criteria for DSC selection or the bounding determination shall be justified and documented. Justification of these bounding demonstrations needs to follow the same methodology used in the licensing and design basis calculations.

C.13.3.2 Preventive Actions

The program is a condition-monitoring program that does not include preventive actions.

C.13.3.3 Parameters Monitored or Inspected

The DSC External Surfaces AMP consists of visual inspections to monitor for material degradation of the DSC shell assembly.

- DSC surfaces, welds and HAZs, and crevice locations near the DSC support rails are inspected for discontinuities and imperfections.

Parameters Monitored or Inspected for Identified Aging Effects

Aging Effect	Aging Mechanism	Parameter(s) Monitored
Loss of Material	Crevice Corrosion	Surface Condition
Loss of Material	Pitting Corrosion	Surface Condition
Loss of Material	Galvanic Corrosion	Surface Condition
Cracking	Stress Corrosion Cracking	Surface Condition, Cracks

C.13.3.4 Detection of Aging Effects

A minimum of one DSC from each originating ISFSI, is selected for inspection. The DSC(s) selected for inspection is based on the following considerations/criteria which provide the basis for selection of a bounding DSC(s):

1. Time in service: Storage duration (time in service at originating ISFSI and WCS CISF) is related to surface temperature and deposition of contaminants. The DSC(s) selected for inspection is from the pool of DSCs with longest time in service.

2. Initial heat load: The DSC selected for inspection is from a pool of DSC(s) 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.

3. DSC Fabrication and Design Considerations: A review of the design drawings and DSC fabrication package is performed to further screen-in the DSC(s) from the pool of candidates selected based on (1) and (2). Fabrication weld maps, if available, should be reviewed to identity locations of the circumferential and longitudinal welds, and external configurations of the inner bottom cover-to-shell weld (e.g., ASME Figure NB-4243-1(c)). These features are verified against the fabrication drawings for the specific DSC(s) under consideration for inspection.

4. 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).

Visual inspections are performed at intervals of 5 years ± 1 year. The ± 1 year is provided for inspection planning and potential limited availability of vendor remote non-destructive examination (NDE) equipment. The first examination will be performed on the selected DSC(s) prior to entering their period of extended operation. The same DSC(s) are used for each subsequent examination for trending.

Visual inspection can be conducted remotely by inserting high-resolution remote pan-tilt-zoom (PTZ) cameras or fiber optics through the HSM vents or through the annular gap between the DSC and HSM front door opening. Visual examinations follow procedures consistent with the ASME Code, Section XI, IWA-2200 [C.13-3].

Within the HSM cavity, certain surface areas of the DSC may be inaccessible for remote camera. This program addresses detection of aging affects for inaccessible areas by the inspection findings in accessible areas.

As much of the DSC surface as can be accessed is examined by VT-3 to ascertain its general condition, including evidence of water stains, discoloration, and surface deposits.

This section is newly added.

Areas subject to VT-1[1] examination are:

- the confinement boundary weld seams and their HAZ,
- the confinement boundary adjacent to the sliding rail surface that it rests upon,
- the confinement boundary surfaces with water staining or with discoloration indicative of corrosion products observed by the VT-3 inspection, and
- the outer top cover plate, welds, and HAZ, if accessible, or if the DSC needs to be completely withdrawn into the transfer cask.

Less than 100% coverage is acceptable if ISP can demonstrate that the areas sampled for inspection bound or are representative of the balance of the subject area.

Localized corrosion (e.g., pitting and crevice corrosion), cracking and stains (caused by leaking rainwater) or discolorations are documented, if any. Appearance and location of atmospheric deposits on the canister surfaces are recorded.

The examination system shall be, as a minimum, capable of detecting flaws sizes meeting the allowable flaws in ASME B&PV Code Section XI IWB-3514.3 [C.13-3].

Personnel performing visual examinations shall be qualified and certified in accordance with ASME XI, IWA-2300, including the requirements of ASME XI, Appendix VI.

[1] According to ASME Section XI IWA-2211, the VT-1 visual examination is conducted to detect discontinuities and imperfections on the surface of components, including such conditions as cracks, wear, or corrosion. The VT-1 examination procedure is capable of resolving demonstration characters height of 1.1 mm in accordance with ASME Section XI Table IWA-2211-1 "Visual Examinations." Remote inspection camera resolution capability shall meet VT-1 illumination, distance, and character height requirements for examination effectiveness.

Qualification of other NDE personnel shall be in accordance with ASME XI, IWA-2300. Personnel performing ultrasonic examinations shall also meet the additional certification requirements of ASME XI Appendix VII. In addition, they shall have a current certification for ASME XI, Appendix VIII, Supplement 2, for detection, depth sizing, and length sizing of intergranular stress corrosion cracking (IGSCC) in austenitic materials.

C.13.3.5 Monitoring and Trending

A baseline inspection is performed as part of the monitoring and trending activities so that the inspection results can be used for subsequent trending. Deficiencies are documented using approved processes and procedures, such that results can be trended and corrected. This monitoring is conducted in accordance with the provisions of the TN Americas 10 CFR Part 72, Subpart G Program.

C.13.3.6 Acceptance Criteria

The acceptance criteria are defined to ensure that the need for corrective actions will be identified before loss of intended functions. Visual examination via the use of remote digital camera is based on ASME VT-3 or VT-1 examination or equivalent (ASME Section XI Table IWA-2211-1) [C.13-3]. Any indications of relevant degradation detected are evaluated for continued service in TN America's corrective action program.

Inspection acceptance criteria for the VT-3 examination are no indications of pitting, rust, discoloration, or any indication of surface degradation.

Inspection acceptance criteria for the VT-1 examination are as follows:

- No indications of pitting or crevice corrosion
- No indications of galvanic corrosion as evidenced by red-orange corrosion products emanating from crevice locations (support rail plate-to-DSC shell interface).
- No indications of stress corrosion cracking
- No indications of corrosion products near crevices
- No indications of corrosion products on or adjacent to confinement boundary welds.

If, based on the results of the inspection, the DSC is determined to be free of any indications of corrosion or other degradation that could lead to the loss of intended function, no further actions are necessary until the next inspection.

This section is newly added.

If the DSC is determined to contain confirmed or suspected indications of corrosion or degradation, additional engineering evaluations are performed to demonstrate that the DSC will remain able to perform its design bases functions until the next inspection. ASME Code Section XI provides specific rules for evaluating flaw indications that may be detected during the inspections. If flaw indications are found, the flaw geometry is determined from the inspection results in accordance with Section XI, IWA-3300 [C.13-3]. The flaw dimensions are assessed and compared with the allowable flaw dimensions in Section XI, IWB-3514 [C.13-3] acceptance standards. If the flaw size is less than the allowable flaw size in the IWB-3514.1 acceptance standards, the flaw is acceptable with no need for further evaluation. If the flaw size exceeds the allowable flaw size in the IWB-3514.1 acceptance standards, the flaw must be evaluated using the acceptance criteria in IWB-3640. The procedures in ASME Section XI Appendix C [C.13-3] may be used for these evaluations.

When visual examination detects evidence of localized corrosion, the affected areas will be further examined to determine the extent and the depth of penetration. The additional information would be that required to evaluate defects, depending on the nature of the defects observed:

- Surface-connected crack length, for example by VT-1, or eddy current examination, for evaluation in accordance with ASME Code Section XI, IWB-3514.3.
- Surface-connected crack length and depth, for example by eddy current, UT, or both, for evaluation in accordance with IWB-3514.3 or IWB-3640.
- For macroscopic corrosion conditions such as crevice corrosion or concentrated pitting, the extent and depth of the corrosion would be determined by visual examination for evaluation of minimum shell thickness in accordance with ASME Code Section III, NB-3000.

If aging effects are identified in accessible locations, further evaluation of the aging effects in inaccessible locations is conducted via TN America's corrective action program to ensure the aging effect is adequately managed and that the component's intended function is maintained during the period of extended operation.

This section is newly added.

C.13.3.7 Corrective Actions

Site quality assurance (QA) procedures, review and approval processes, and administrative controls are implemented according to the requirements of TN Americas 10 CFR Part 72, Subpart G Program. TN America's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determinations and prevention of recurrence. Deficiencies are either corrected, or are evaluated as acceptable for continued service through engineering analysis, which provides reasonable assurance that the intended function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging need to follow the same methodology used in the licensing and design basis calculations. Extent of condition investigation may trigger additional inspections via a different method, increased inspection frequency or expanded inspection sample size, as described next.

Identification of localized corrosion or stress corrosion cracking requires an expansion of the sample size to determine the extent of condition at the site. Canisters with confirmed localized corrosion or stress corrosion cracking must be evaluated for continued service. Canisters with localized corrosion or stress corrosion cracking that do not meet the prescribed evaluation criteria must be repaired or replaced.

<u>Disposition of Canisters with Aging Effects</u>

Confirmation of localized corrosion or stress corrosion cracking requires inspection of additional canisters at the same location to determine the extent of condition. Priority for additional inspections should be to canisters with similar time in service and initial thermal loading.

Extent of condition disposition is commensurate with in-service inspection results:

- Canisters with no evidence of corrosion are permitted to remain in service and will continue to be evaluated at 5-year intervals with no expansion of sampling.
  - Canisters with rust deposits that are determined to be a result of iron contamination but do not have evidence of localized corrosion or stress corrosion cracking are permitted to remain in service and will continue to be evaluated at 5-year intervals with no expansion of sampling.
- Canisters that show evidence of localized corrosion or stress corrosion cracking that does not exceed the acceptance standards in IWB-3514.1 are permitted to remain in service and will be evaluated at 5-year intervals. Sample size should be increased to assess candidate canisters with similar susceptibility assessments as determined from the selection criteria in Section C.13.3.4.

- Canisters that show evidence of localized corrosion or stress corrosion cracking that exceeds the acceptance standards in IWB-3514.1 but meet the acceptance criteria identified in IWB-3640 including the required evaluation per IWB-3641(a) using the prescribed evaluation procedures, are permitted to remain in service and should be evaluated at 3-year intervals. Sample size should be increased to assess candidate canisters with similar susceptibility assessments as determined from the selection criteria in Section C.13.3.4.
- Canisters that show evidence of localized corrosion or stress corrosion cracking that exceeds acceptance criteria identified in IWB-3640 are not permitted to remain in service. Sample size should be increased to assess candidate canisters with similar susceptibility assessments as determined from the selection criteria in Section C.13.3.4.

C.13.3.8 Confirmation Process

Confirmatory actions, as needed, are implemented as part of TN America's corrective action program. *See also* Section C.13.3.7.

C.13.3.9 Administrative Controls

Administrative controls under TN America's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of TN Americas 10 CFR Part 72, Subpart G Program, and will continue for the period of extended operation. 10 CFR Part 72 [C.13-26] 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. 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 industry as outlined in NEI 14-03 [C.13-2]. *See also* Section C.13.3.7.

C.13.3.10 Operating Experience

Calvert Cliffs Nuclear Power Plant Experience

The following discussion is extracted from Calvert Cliffs' response to NRC request for supplemental information letter (ML12212A216) [C.13-4].

In 2012, Calvert Cliffs performed an inspection of the interior of two NUHOMS® HSMs, and the exterior of the DSCs as part of their license renewal application. The first module examined was HSM-15, which was loaded in November 1996 and contained the "lead canister" to meet NUREG-1927 [C.13-28] Appendix E guidance. The second module inspected was HSM-1, which was loaded in November 1993 (the first loading) and represents one of the lowest heat load canisters ever loaded (estimated at 4.2 kW (as of the time of inspection)). The latter supplemental canister was added as part of the Electric Power Research Institute (EPRI) research efforts on evaluating stress corrosion cracking of stainless steel canisters used for dry storage. The EPRI research effort included salt concentration measurements on the upper shell of the DSC, collection of samples of the deposits on the upper shell of the DSC for offsite analysis, and surface temperature measurements via contact thermocouples for benchmarking best-estimate thermal models.

The visual inspection was conducted by remote and direct means with a remote controlled high definition PTZ camera system. The remote inspection was performed by lowering the camera through the rear outlet vent, which allowed for viewing of the majority portion of the DSC. The direct inspection was performed through the partially open door by mounting the camera on a pole.

On both DSCs selected for inspection (DSC-6 inside HSM-15 and DSC-11 inside HSM-1), the entire surface of the top cover plate and the top cover plate weld were examined and found to be in good condition with no signs of corrosion.

The shell of DSC-6 was observed to be in good general condition. The center circumferential weld and longitudinal welds were examined and no rust spots or signs of cracking were noted. The bottom shield plug circumferential weld could not be observed because it was obscured by the steel sleeve of the HSM doorway opening. A few small surface rust spots were noted on the DSC shell base metal. Calvert Cliffs believes that the few small spots of light rust on the shell were the result of contamination of the shell with free iron during fabrication or handling prior to being placed in service. Free iron contamination can occur when carbon or low-alloy steel tools come into contact with the surface or particles that are transferred to the stainless steel surface from grinding, welding, or cutting of carbon or low-alloy steel. Rusting of such free iron would be expected to have occurred fairly quickly once the outside surface of the DSC was exposed to water, which happens during the normal course of loading when the TC annulus is filled with demineralized water. The resulting light coating of surface rust would be cosmetic in nature, and would not result in degradation to the stainless steel shell of the DSC in the sheltered environment of the HSM, and is, therefore, not believed to be a current challenge to the confinement function of DSC-6. Calvert Cliffs has initiated a condition report to evaluate these locations in further detail to determine if additional and/or more frequent monitoring is required to conclusively ascertain their nature, and then take appropriate corrective action if their presence is determined to represent a potential challenge to the confinement function of the DSC.

The shell of DSC-11 (the lower heat load canister) was observed to be in good condition, and no signs of the rust were noted on the base metal or welds. A linear wear mark was noted running the length of the lower shell of DSC-11 near the inner side of the west rail. This mark is believed to be from the demonstration Independent Spent Fuel Storage Installation loading campaign that was conducted prior to the start of formal loading operations in 1993. During that demonstration, DSC-11 was loaded with dummy fuel assemblies (FAs) and inserted into an HSM, and then withdrawn. Verbal discussions with individuals who worked on the first loading campaign indicated that when the DSC-11 was used for an actual loading, it was rotated from the position used for the demonstration not to slide it along the rails in the same location twice. No signs of corrosion were noted on this wear mark. Since the wear occurred from sliding on the Nitronic 60 stainless steel surface of the rail, the lack of corrosion on this wear mark compared with that of the scratch on DSC-6, lends additional credence to the idea that the rust on the latter occurred through contact with carbon or low-alloy steel. The bottom end of both DSCs appeared polished, free of corrosion and in very good condition. Both grapple rings were examined and appeared to be in good condition.

Learning AMP

The "DSC External Surfaces Aging Management Program" is a "learning" AMP. This means that this AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from site-specific inspection findings, related industry OE, and related industry research. Site-specific and industry OE is captured through ISP's OE review process.

The ongoing review of both site-specific and industry OE will continue through the period of extended operation to ensure that this AMP continues to be effective in managing the identified aging effects. Reviews of OE in the future may identify areas where this AMPs should be enhanced, updated, or if a new program should be developed.

ISP to maintain the effectiveness of this AMP under its QA program used to meet the criteria of 10 CFR Part 72, Subpart G [C.13-5 and C.13-26].

This section is newly added.

C.13.4 DSC Aging Management Program for the Effects of CISCC (Coastal Locations, Near Salted Roads, or in the Path of Effluent Downwind from the Cooling Tower(s))

C.13.4.1 Scope of Program

This AMP is applicable to DSCs from ISFSIs that may have sufficient atmospheric chlorides to initiate CISCC.

First, a site-specific applicability evaluation is performed to determine if this AMP is applicable to the DSC. This applicability evaluation is to be performed prior to entering the period of extended operation. The applicability evaluation determines if the site-specific environmental conditions could expose the DSCs to a chloride-containing atmosphere. This includes ISFSI sites located: (1) in a coastal environment, (2) near salted roads, and (3) in the path of effluent downwind from the cooling tower(s). The site-specific applicability evaluation shall be justified and documented.

This AMP is applicable to DSCs from ISFSIs that may have sufficient atmospheric chlorides to initiate CISCC within the period of extended operation. ISP may demonstrate that this AMP is not applicable by one of two methods:

Air monitoring can be accomplished by using airborne particulate monitors or other monitoring stations specific to airborne chloride measurement. The airborne chloride concentration data should follow Environmental Protection Agency Clean Air Status and Trends Network (CASTNET) protocol. CASTNET measures weekly concentrations of chloride using a three-stage filter pack with a controlled flow rate, and chloride results are presented in $\mu g/m^3$.

The DSC AMP for the Effects of CISCC comprises three distinct processes:

- ISFSI specific applicability evaluation to determine if this AMP is applicable to the DSC
- DSC surface monitoring for chlorides, and

- Remote visual inspection for aging effects

This program visually inspects and monitors the external surfaces of the DSC shell assemblies that may be subject to loss of material or CISCC. The program scope includes the external surfaces of the DSC. The areas of DSC inspection are:

- Fabrication welds of the confinement boundary and the associated heat affected zone (HAZ), i.e., longitudinal and (if any) circumferential welds on the cylindrical shell,
- Crevice locations, e.g., where the shell sits on the support rail,
- The upper surface of the cylindrical shell, where atmospheric particulates would settle,
- The top and bottom ends of the cylinder, which are cooler than the center,
- Outer bottom cover plate, grapple assembly, their welds and HAZs, and
- Outer top cover plate, welds and HAZs.

The last two areas are not part of the confinement boundary, but their condition must be ascertained prior to retrieval and transport. As vertical surfaces out of the main path of air flow, they are the least susceptible to the effect of atmospheric deposits. Accessibility to the outer top cover plate may be limited during storage, but prior to transport, it can be inspected after the canister is pulled into a transport cask.

The materials, environments, and aging effects requiring management for the DSC shell stainless steel components in a coastal location, near salted roads, or in the path of effluent downwind from the cooling tower(s) (to maintain confinement, shielding, structural, heat transfer, and retrievability intended safety functions) are as follows:

<u>Materials</u>

DSC shell assembly components subject to AMR are constructed of the following material:

- Stainless steel – shell assembly

<u>Environments</u>

DSC shell assembly components subject to AMR are exposed to the following environments:

- Sheltered

This section is newly added.

Aging Effects Requiring Management

The following aging effects associated with the DSC shell assembly components require management:

- Loss of material due to crevice and pitting corrosion for stainless steel components,
- Loss of material due to galvanic corrosion for the DSC shell contacting graphite lubricant at the sliding rail surface,
- Cracking due to CISCC for stainless steel components when exposed to moisture and aggressive chemicals in a coastal location, near salted roads, or in the path of effluent downwind from the cooling tower(s),
- Loss of material due to radiation-induced crevice corrosion, pitting corrosion, and SCC for stainless steel DSC shell.

ISP may use inspections results from other general or specific licensee inspections if it can be demonstrated that the other licensee inspections are bounding. Parameters to be considered in making a bounding determination include: similar or more benign environmental conditions, similar storage system design components, similar stored fuel parameters, heat load, and operational history. The criteria for DSC selection or the bounding determination shall be justified and documented. Justification of these bounding demonstrations needs to follow the same methodology used in the licensing and design basis calculations.

C.13.4.2 Preventive Actions

The program is a condition-monitoring program that does not include preventive actions.

C.13.4.3 Parameters Monitored or Inspected

The surface monitoring portion of the AMP consists of collection and measurements of chloride salts on the surfaces of selected DSC shell(s) on different positions of the DSC shell surface to get a representation of the spatial variation of the chloride concentration, if any. The surface chloride concentration data are monitored, correlated, and trended, and compared to NDE results to monitor for CISCC initiation threshold.

The visual inspection portion of the AMP consists of visual inspections to monitor for material degradation of the DSC shell assembly.

- DSC surfaces, welds and HAZs, and crevice locations near the DSC support rails are visually inspected for discontinuities and imperfections.

Parameters Monitored or Inspected for Identified Aging Effects

Aging Effect	Aging Mechanism	Parameter(s) Monitored
Loss of Material	Crevice Corrosion	Surface Condition
Loss of Material	Pitting Corrosion	Surface Condition
Loss of Material	Galvanic Corrosion	Surface Condition
Cracking	Stress Corrosion Cracking	Surface Condition, Cracks

C.13.4.4 Detection of Aging Effects

A minimum of one DSC from each originating ISFSI is selected for inspection. The DSC(s) selected for inspection is based on the following considerations/criteria, which provide the basis for the selection of a bounding DSC(s):

1. Time in service: Storage duration (time in service at originating ISFSI and WCS CISF) is related to surface temperature and deposition of contaminants. The DSC(s) selected for inspection is from the pool of DSCs with longest time in service.

2. Initial heat load: The DSC selected for inspection is from a pool 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.

3. DSC Fabrication and Design Considerations: A review of the design drawings and DSC fabrication package is performed to further screen-in the DSC(s) from the pool of candidates selected based on (1) and (2). Fabrication weld maps, if available, should be reviewed to identity locations of the circumferential and longitudinal welds, and external configurations of the inner bottom cover-to-shell weld (e.g., ASME Figure NB-4243-1(c)). These features are verified against the fabrication drawings for the specific DSC(s) under consideration for inspection.

4. HSM array configuration relative to climatological and geographical features: DSCs inside HSMs oriented such that the inlet 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 chloride aerosol contaminants (e.g., off-shore, salted roads, cooling towers, if present).

Visual inspections and surface sampling for chlorides are performed at intervals of 5 years ± 1 year. The ± 1 year is provided for inspection planning and potential limited availability of vendor remote non-destructive examination (NDE) equipment. The first examination will be performed on the selected DSC(s) prior to entering their period of extended operation. The same DSC(s) are used for each subsequent examination for trending.

This section is newly added.

Visual inspection, surface deposit sampling, and other NDE can be conducted remotely by inserting the inspection and/or sampling devices through the HSM vents or through the annular gap between the DSC and HSM front door opening. Visual examinations follow procedures consistent with the ASME Code, Section XI, IWA-2200 [C.13-3].

Within the HSM cavity, certain surface areas of the DSC may be inaccessible for inspection. This program addresses detection of aging affects for inaccessible areas by the inspection findings in accessible areas.

As much of the DSC surface as can be accessed is examined by VT-3 to ascertain its general condition, including evidence of water stains, discoloration, and surface deposits.

Areas subject to VT-1[2] examination are

- the confinement boundary weld seams and their HAZ,
- the confinement boundary adjacent to the sliding rail surface that it rests upon,
- the confinement boundary surfaces with water staining or with discoloration indicative of corrosion products observed by the VT-3 inspection, and
- the outer top cover plate, welds, and HAZ, if accessible, or if the DSC needs to be completely withdrawn into the transfer cask.

Less than 100% coverage is acceptable if it can demonstrate that the areas sampled for inspection bound or are representative of the balance of the subject area.

Localized corrosion (e.g., pitting and crevice corrosion), stains, discolorations and stress corrosion cracks location and size are documented, if any. Appearance and location of atmospheric deposits on the canister surfaces are recorded.

When indications of aging degradation are detected via the visual NDE method, an NDE method more sensitive than VT-1 is recommended to quantify the degradation in order to evaluate for continued service and to ensure the DSC will continue to perform its intended function. The surface or volumetric NDE portion of the AMP consists of appropriate available NDE techniques.

[2] According to ASME Section XI IWA-2211, the VT-1 visual examination is conducted to detect discontinuities and imperfections on the surface of components, including such conditions as cracks, wear, or corrosion. The VT-1 examination procedure is capable of resolving demonstration characters height of 1.1 mm in accordance with ASME Section XI Table IWA-2211-1 "Visual Examinations." Remote inspection camera resolution capability shall meet VT-1 illumination, distance, and character height requirements for examination effectiveness.

This section is newly added.

The examination system shall be, as a minimum, capable of detecting flaws sizes meeting the allowable flaws in ASME B&PV Code Section XI IWB-3514.3 [C.13-3].

Personnel performing visual examinations shall be qualified and certified in accordance with ASME XI, IWA-2300, including the requirements of ASME XI, Appendix VI.

Qualification of other NDE personnel shall be in accordance with ASME XI, IWA-2300. Personnel performing ultrasonic examinations shall also meet the additional certification requirements of ASME XI Appendix VII. In addition, they shall have a current certification for ASME XI, Appendix VIII, Supplement 2, for detection, depth sizing, and length sizing of IGSCC in austenitic materials. Inspection procedures and personnel for surface sampling are qualified in accordance with site-controlled procedures and processes, as prescribed in the TN Americas 10 CFR Part 72, Subpart G Program.

C.13.4.5 Monitoring and Trending

A baseline inspection is performed as part of the monitoring and trending activities so that the inspection results can be used for subsequent trending. Deficiencies are documented using approved site processes and procedures, so that results can be trended and corrected. This monitoring should be conducted in accordance with the TN Americas 10 CFR Part 72, Subpart G Program.

C.13.4.6 Acceptance Criteria

The acceptance criteria are defined to ensure that the need for corrective actions will be identified before loss of intended functions. Visual examination via the use of remote digital camera is based on ASME VT-3 or VT-1 examination or equivalent (ASME Section XI Table IWA-2211-1) [C.13-3]. Any indications of relevant degradation detected are evaluated for continued service in TN America's corrective action program.

Inspection acceptance criteria for the VT-3 examination are no indications of pitting, rust, discoloration, or any indication of surface degradation.

Inspection acceptance criteria for the VT-1 examination are as follows:

- No indications of pitting or crevice corrosion,
- No indications of stress corrosion cracking,
- No indications of corrosion products near crevices,
- No indications of corrosion products on or adjacent to confinement boundary welds, and
- No indications of galvanic corrosion as evidenced by red-orange corrosion products emanating from crevice locations (support rail plate-to-DSC shell interface).

If, based on the results of the inspection, the DSC is determined to be free of any indications of corrosion or other degradation that could lead to the loss of intended function, no further actions are necessary until the next inspection.

If the DSC is determined to contain confirmed or suspected indications of corrosion or degradation, additional engineering evaluations are performed to demonstrate that the DSC will remain able to perform its design bases functions until the next inspection. ASME Code Section XI provides specific rules for evaluating flaw indications that may be detected during the inspections. If flaw indications are found, the flaw geometry is determined from the inspection results in accordance with Section XI, IWA-3300 [C.13-3]. The flaw dimensions are assessed and compared with the allowable flaw dimensions in Section XI, IWB-3514 [C.13-3] acceptance standards. If the flaw size is less than the allowable flaw size in the IWB-3514.1 acceptance standards, the flaw is acceptable with no need for further evaluation. If the flaw size exceeds the allowable flaw size in the IWB-3514.1 acceptance standards, the flaw must be evaluated using the acceptance criteria in IWB-3640. The procedures in ASME Section XI Appendix C [C.13-3] may be used for these evaluations.

When visual examination detects evidence of localized corrosion, the affected areas will be further examined to determine the extent and the depth of penetration. The additional information would be that required to evaluate defects, depending on the nature of the defects observed:

- Surface-connected crack length, for example by VT-1, or eddy current examination, for evaluation in accordance with ASME Code Section XI, IWB-3514.3.
- Surface-connected crack length and depth, for example by eddy current, UT, or both, for evaluation in accordance with IWB-3514.3 or IWB-3640.
- For macroscopic corrosion conditions such as crevice corrosion or concentrated pitting, the extent and depth of the corrosion would be determined by visual examination for evaluation of minimum shell thickness in accordance with ASME Code Section III, NB-3000.

If aging effects are identified in accessible locations, further evaluation of the aging effects in inaccessible locations is conducted via TN America's corrective action program to ensure the aging effect is adequately managed and that the component's intended function is maintained during the period of extended operation.

This section is newly added.

C.13.4.7 Corrective Actions

Site QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of the TN Americas 10 CFR Part 72, Subpart G Program. TN America's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determinations 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 function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging need to follow the same methodology used in the licensing and design basis calculations. Extent of condition investigation may trigger additional inspections via a different method, increased inspection frequency and/or expanded inspection sample size, as described next.

Identification of localized corrosion or stress corrosion cracking requires an expansion of the sample size to determine the extent of condition at the site. Canisters with confirmed localized corrosion or stress corrosion cracking must be evaluated for continued service. Canisters with localized corrosion or stress corrosion cracking that do not meet the prescribed evaluation criteria must be repaired or replaced.

<u>Disposition of Canisters with Aging Effects</u>

Confirmation of localized corrosion or stress corrosion cracking requires inspection of additional canisters at the same location to determine the extent of condition. Priority for additional inspections should be to canisters with similar time in service and initial thermal loading.

Extent of condition disposition is commensurate with in-service inspection results:

- Canisters with no evidence of corrosion are permitted to remain in service and will continue to be evaluated at 5-year intervals with no expansion of sampling.
  - Canisters with rust deposits that are determined to be a result of iron contamination but do not have evidence of localized corrosion or stress corrosion cracking are permitted to remain in service and will continue to be evaluated at 5-year intervals with no expansion of sampling.
- Canisters that show evidence of localized corrosion or stress corrosion cracking that does not exceed the acceptance standards in IWB-3514.1 are permitted to remain in service and will be evaluated at 5-year intervals. Sample size should be increased to assess candidate canisters with similar susceptibility assessments as determined from the selection criteria in Section C.13.4.4.

This section is newly added.

- Canisters that show evidence of localized corrosion or stress corrosion cracking that exceeds the acceptance standards in IWB-3514.1 but meet the acceptance criteria identified in IWB-3640, including the required evaluation per IWB-3641(a), using the prescribed evaluation procedures, are permitted to remain in service and should be evaluated at 3-year intervals. Sample size should be increased to assess candidate canisters with similar susceptibility assessments as determined from the selection criteria in Section C.13.4.4.
- Canisters that show evidence of localized corrosion or stress corrosion cracking that exceeds acceptance criteria identified in IWB-3640 are not permitted to remain in service. Sample size should be increased to assess candidate canisters with similar susceptibility assessments as determined from the selection criteria in Section C.13.4.4.

C.13.4.8 Confirmation Process

Confirmatory actions, as needed, are implemented as part of TN America's corrective action program. *See also* Section C.13.4.7.

C.13.4.9 Administrative Controls

Administrative controls under TN America's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of TN Americas 10 CFR Part 72, Subpart G Program, and will continue for the period of extended operation. 10 CFR Part 72 [C.13-26] 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. 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 industry as outlined in NEI 14-03 [C.13-2]. *See also* Section C.13.4.7.

C.13.4.10 Operating Experience

Information Notice 2012-20 [C.13-6]

NRC Information Notice 2012-20 "Potential Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canisters" describes the potential for CISCC of austenitic stainless steel DCS canisters. CISCC could affect the ability of the spent fuel storage canisters to perform their confinement function during the period of extended operation. Several instances of CISCC have occurred in austenitic stainless steel components that were exposed to atmospheric conditions near saltwater bodies.

In the fall of 2009, three examples of CISCC, which extended through-wall, were discovered at a nuclear station in the weld HAZ of Type 304 stainless steel piping. The piping included 24-inch, Schedule 10 emergency core cooling system (ECCS) suction piping; 6-inch, schedule 10 alternate boration gravity feed to charging line piping; and an ECCS mini flow return to refueling water storage tank. While the through-wall failures were attributed to CISCC, surface pitting was also observed on the surface of the pipes, with a greater concentration in the weld HAZ. All three pipes were exposed to the outside ambient coastal atmosphere. Through-wall cracks developed after an estimated 25 years of service.

In 2005, at a nuclear station, a through-wall crack in a Type 304 stainless steel spent fuel pool cooling line was detected and attributed to CISCC. The 8-inch, Schedule 10S, seamless pipe was located in a room with a grating steel door that exposed the piping to atmospheric conditions. The crack initiated on the outer diameter at the base of a pit located on the bottom side of the pipe, approximately 0.5-inch downstream from a flange butt weld. The design temperature and pressure for this pipe was 100 °C (212 °F) and 1.03 MPag (150 psig), respectively.

Several failures in austenitic stainless steels have been attributed to CISCC. The components that have failed because of this failure mechanism at nuclear power plants, as discussed above, are made from the same types of austenitic stainless steels typically used to fabricate DCS system canisters. Empirical data have demonstrated that this failure mechanism is reproducible in Type 304 and 304L stainless steel as well as in Type 316L stainless steel. Accordingly, all types of austenitic stainless steels typically used to fabricate DCS system canisters (304, 304L, 316, and 316L) are susceptible to this failure mechanism.

<u>Calvert Cliffs Nuclear Power Plant Experience</u>

Data analysis for the deposited salt collected from the DSC surface has been conducted at Calvert Cliffs in 2012. The salt deposits collected on the actual canister surface in the field also contain other inorganic multiple species together with chloride [C.13-7, C.13-8, C.13-9]. The visual inspection on the DSC surfaces showed that the upper horizontal surface of the DSC canister was covered with dust layers of soil/clay and concrete constituents while the canister side and lower parts were visually metallic. The analysis of the deposits collected from the upper horizontal surface taken from the 11 o'clock position showed a relatively high concentration of sulfate, phosphate, and nitrate with little amount of chloride content (highest measured concentration was 5.2 mg/m^2). The major cations in the deposits were silicon, iron, and calcium, along with lower levels of magnesium, aluminum, potassium, titanium, and zinc. X-ray diffraction analysis revealed multiple crystal phases of the deposits including calcium carbonate, aluminum hydroxide, and silicon containing oxide or silicates complex. No visual indications of cracking were noted from the inspection.

This section is newly added.

As demonstrated from the inspection results at the Calvert Cliffs ISFSI, the deposits accumulated on the canister surfaces in particular for the upper horizontal surface area contained multiple other soluble and non-soluble species together with chloride content. These other types of anions and cations can affect chemistry of the deliquesced chloride salt solution. For example, the alkaline nature of the concrete constituents such as calcium carbonates and aluminum hydroxide can act to buffer the acidic deliquesced salt brine to be more benign. This is consistent with the buffering effect of carbonate and alumino-silicate that reduced the localized corrosion of Alloy 22 in brine in geologic depository studies. To some extent, inorganic ions such as nitrate and sulfate, and metal cations are also known as inhibitors of the pitting corrosion of stainless steel and aluminum. At this time, however, it is unknown how the presence of the other species would affect the susceptibility of the stainless steel canister to CISCC.

Learning AMP

The "DSC Aging Management Program for the Effects of CISCC" is a "learning" AMP. This means that this AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from site-specific inspection findings, related industry OE, and related industry research. Site-specific and industry OE is captured through ISPs OE review process.

The ongoing review of both site-specific and industry OE will continue through the period of extended operation to ensure that the program continues to be effective in managing the identified aging effects. Reviews of OE in the future may identify areas where AMPs should be enhanced or new programs developed.

ISP is to maintain the effectiveness of this AMP under its QA program used to meet the criteria of 10 CFR Part 72, Subpart G [C.13-5 and C.13-26].

In addition to the ongoing OE review, this AMP requires periodic written evaluations as described in Table C.13-1, 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 new information relevant to aging management is assessed, as it becomes available, 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 TN America's corrective action program, is required to continue operation. Tollgate assessment reports are not required to be submitted to the NRC, but are available for inspection. Appendix A of NEI 14-03 [C.13-2], provides guidance on the performance criteria for the tollgate assessments.

The tollgate schedule may be accelerated (i.e., the next tollgate is performed earlier) whenever sufficient new information has accumulated that could warrant a change in the AMP.

This section is newly added.

C.13.5 HSM Aging Management Program for External and Internal Surfaces

C.13.5.1 Scope of Program

The scope of the HSM AMP for external and internal surfaces program includes visual inspection of accessible concrete and steel components including HSM walls, roof, and floor slab (if applicable), HSM access door, DSC support structure and rail assembly, heat shields, air inlet and outlet vents, embedments and anchorages (i.e., structural connections including anchor bolts, cast-in-place bolts, through-bolts, and mounting hardware). This AMP also examines the ISFSI storage pad for evidence of concrete degradation.

The materials, environments, and aging effects requiring management for the HSM interior and exterior surfaces and structural components (to maintain shielding, structural, heat transfer, and retrievablity intended safety functions) are as follows:

Materials

HSM structural components subject to AMR are constructed of the following material:

- Reinforced concrete
- Carbon steel
- Stainless steel
- Aluminum

Environments

HSM structural components subject to AMR are exposed to the following environments:

- Sheltered
- Embedded
- External

Aging Effects Requiring Management

The following aging effects associated with the HSM structural components require management:

- Loss of material (spalling, scaling) and cracking due to freeze-thaw actions for reinforced concrete,
- Cracking; loss of bond; and loss of material (spalling, scaling) due to corrosion of embedded steel for reinforced concrete;
- Cracking due to expansion from reaction with aggregates (alkali-silica reaction (ASR)) for reinforced concrete,

This section is newly added.

- Increase in porosity and permeability; cracking; loss of material (spalling, scaling) due to aggressive chemical attack for reinforced concrete,
- Cracking due to increased stress levels from settlement for reinforced concrete,
- Loss of material due to general, pitting, and crevice corrosion for carbon steel components,
- Loss of material due to pitting and crevice corrosion for aluminum and stainless steel components, and
- Loss of material due to galvanic corrosion of Nitronic® DSC support rail plates.

For coated HSM carbon steel subcomponents, no credit is taken in the AMR for coating for the prevention of aging effect. However, this AMP will manage loss of coating integrity due to blistering, cracking, flaking, peeling, or physical damage.

C.13.5.2 Preventive Actions

The program is a condition monitoring program that does not include preventive actions.

C.13.5.3 Parameters Monitored or Inspected

For each material/aging effect combination, the specific parameters monitored or inspected depend on the particular HSM subcomponent. Parameters monitored or inspected are commensurate with industry codes, standards, and guidelines and consider industry and site-specific OE. ACI 349.3R [C.13-11] and ANSI/ASCE 11 [C.13-14] provide an acceptable basis for selection of parameters to be monitored or inspected for concrete and steel structural elements.

For concrete structures, parameters monitored include: (1) cracking, loss of bond, and loss of material (spalling and scaling) due to corrosion of embedded steel, freeze-thaw, or aggressive chemical attack; (2) cracking due to expansion from reaction with aggregates ASR; (3) increase in porosity and permeability due to leaching of calcium hydroxide and carbonation or aggressive chemical attack; (4) reduction of concrete anchorage capacity due to local concrete degradation; (5) cracking and distortion due to settlement.

The condition of below-grade concrete is monitored by groundwater chemistry sampling of the following parameters:

- pH
- sulfate concentration
- chloride concentration

This section is newly added.

Carbon steel, stainless steel, and aluminum components are monitored for loss of material due to general, pitting, galvanic corrosion, and crevice corrosion. Other conditions such as loose or missing anchors, and missing or degraded grout are also part of the inspection.

For coated HSM carbon steel subcomponents, this AMP manages loss of coating integrity due to blistering, cracking, flaking, peeling, or physical damage.

C.13.5.4 Detection of Aging Effects

Visual inspections of the exterior and interior surfaces of HSM structures and structural components and the accessible portions of the storage pad are conducted prior to entering the period of extended operation and at least once every 5 years ± 1 year thereafter, consistent with industry standards (ACI 349.3R) [C.13-11]. The groundwater chemistry sampling is performed prior to entering the period of extended operation and every 5 years ± 1 year thereafter, in order to trend the potential for corrosive environment existing in the area of the ISFSI. The ± 1 year is provided for inspection planning and potential limited availability of vendor remote NDE equipment. The same HSM(s) shall be used for each subsequent examination for the purpose of trending.

Inspection of the interior surfaces of concrete structures and structural components may be performed using a video camera, or fiber-optic scope or borescope technology through the openings of the storage system (e.g., air inlets, air outlets, and access door). Remote inspection system is qualified and demonstrated to have sufficient resolution capability and enhanced lighting to resolve the acceptance criteria in Section C.13.5.6.

The program consists of periodic visual inspections by personnel qualified to monitor structures and components for applicable aging effects, such as those described in the ACI 349.3R [C.13-11], ACI 201.1R [C.13-13], and ANSI/ASCE 11 [C.13-14]. Groundwater chemistry sampling is used to monitor the condition of the below-grade inaccessible portions of the storage pad.

Inspector qualifications should be consistent with industry guidelines and standards. Qualifications of inspection and evaluation personnel specified in ACI 349.3R [C.13-11] are acceptable for license renewal, as prescribed in 10 CFR 72.158.

Within the HSM cavity, certain surface areas are inaccessible for remote camera inspection (e.g., concrete surfaces behind heat shields, portion of the interior rear shield wall). This program addresses detection of aging affects for inaccessible areas by the inspection findings in accessible areas.

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 at a frequency of five years.

C.13.5.5 Monitoring and Trending

The first (baseline) inspection ascertains the condition of the HSMs at the beginning of the period of extended operation. The conditions of the HSMs observed in subsequent inspections are compared with the baseline conditions of the HSMs for trending purposes.

ACI 349.3R [C.13-11] prescribes that crack maps should be developed, monitored, and trended as a means of identifying progressive growth of defects that may indicate degradation due to specific aging effects such as ASR-induced expansion, freeze-thaw, or corrosion of rebar. Crack maps should be compared with those from previous inspections to identify accelerated degradation of the structure during the period of extended operation.

Deficiencies are documented using approved processes and procedures, so that results can be trended and corrected. This monitoring is conducted in accordance with the provisions of TN Americas 10 CFR Part 72, Subpart G Program.

C.13.5.6 Acceptance Criteria

The HSM AMP for external and internal surfaces calls for inspection results to be evaluated by qualified engineering personnel based on acceptance criteria selected for each structure and aging effect to ensure that the need for corrective actions is identified before loss of intended function occurs. The criteria are derived from design basis codes and standards and are to include ACI 349.3R [C.13-11], ACI 318 [C.13-15], ANSI/ASCE 11 [C.13-14], ASME Code [C.13-3], or the relevant AISC specifications, as applicable, and consider industry and facility OE. The criteria are directed at the identification and evaluation of degradation that may affect the ability of the HSM to perform its intended function. Loose bolts and nuts and cracked bolts are not acceptable unless approved by engineering evaluation.

<u>Metallic Components</u>

Inspection parameters for metallic components include the following:

For metallic surfaces, any of the following indications of relevant degradation detected are evaluated:

- Corrosion and material wastage (loss of material),
- Crevice, pitting, and galvanic corrosion (loss of material),
- Worn, flaking, or oxide-coated surfaces (loss of material),
- Corrosion stains on adjacent components and structures (loss of material),
- Surface cracks (cracking), or
- Stains caused by leaking rainwater

For carbon steel surfaces, one acceptable method for characterizing and quantifying the amount of corrosion (rust) present on a painted steel surface is ASTM D610-08 [C.13-16]. This test method covers the evaluation of the degree of rusting (spot rusting, general rusting, pinpoint rusting, and hybrid rusting) using visual standards and descriptions of 11 rust grades. In this method, Rust Grade 10 corresponds to no rust or less than 0.01% of surface rusted, Rust Grade 4 corresponds to rusting greater than 3% to the extent of 10% of surface rusted, and Rust Grade 0 corresponds to approximately 100% of surface rusted. In addition to determining the source of the corrosion, noted degradation shall be trended and evaluated under TN America's corrective action program.

For stainless steel and aluminum HSM subcomponents (e.g., stainless steel DSC support structure (HSM Model 152 only) heat shields, vent screens, and frames), a characterization method similar to ASTM D610 can be utilized to document, evaluate and trend crevice and pitting corrosion, if found.

Concrete Components

Inspection parameters for concrete components include the following:

Concrete acceptance criteria from ACI 349.3R [C.13-11] represent acceptable conditions for observed degradation that has been determined to be inactive. These criteria are termed second-tier for structures possessing 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 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 without requiring any further evaluation:

- Absence of leaching and chemical attack, including microbiological chemical attack,
- Absence of signs of corrosion in the steel reinforcement,
- Absence of drummy areas (poorly consolidated concrete, air void with paste deficiencies per ACI 201.1R),
-
- Scaling less than
  - Spalling less than
- Absence of corrosion staining of undefined source on concrete surfaces,
-

- Passive settlements or deflections within the original design limits.

The acceptance criteria for the groundwater chemistry sampling program are:

- pH $\geq$ 5.5
- Chlorides $\leq$ 500 ppm
- Sulfates $\leq$ 1500 ppm

These criteria are consistent with guidance provided in NUREG-1801 [C.13-12] and would demonstrate that the ISFSI concrete pad is not exposed to an aggressive soil and groundwater environment. For sites that exceed the above criteria (i.e., ISFSI sites with an aggressive soil and groundwater environment), a site-specific ISFSI concrete pad AMP is to be implemented as part of corrective action program.

If aging effects are identified in accessible locations, further evaluation of the aging effects in inaccessible locations is conducted via TN America's corrective action program to ensure the aging effect is adequately managed and that the component's intended function is maintained during the period of extended operation.

<u>Coatings</u>

Inspection parameters for coatings include the following:

Coating acceptance criteria are established in accordance with ASTM D7167-12 [C.13-17]. Acceptable coatings are free of peeling or delamination. Blistering, cracking, flaking, rusting, and physical damage are evaluated by a nuclear coatings specialist to determine acceptability.

Standard definitions of degradation mechanisms, in accordance with ASTM D4538-05 [C.13-18] and EPRI 1019157 [C.13-19], are as follows:

- Blistering - formation of bubbles in a coating (paint) film
- Cracking - formation of breaks in a coating film that extend through to the underlying surface
- Flaking - detachment of pieces of the film itself either from its substrate or from coating (paint) previously applied
- Peeling - separation of one or more coats or layers of a coating from the substrate
- Delamination - separation of one coat or layer from another coat or layer or from the substrate
- Rusting - corrosion that occurs when the applied coating thickness is insufficient to completely or adequately cover steel surfaces
- Physical Damage - removal or reduction of thickness of coating by mechanical damage

Repair, rehabilitation, or corrective action of an unacceptable condition should be performed in accordance with an applicable rehabilitation standard such as ACI 224.1R [C.13-20], ACI 364.1R [C.13-21] or ACI 562-13 [C.13-22].

C.13.5.7 Corrective Actions

Site QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of TN Americas 10 CFR Part 72, Subpart G Program. TN America's corrective action program ensures that conditions adverse to quality are promptly identified and corrected, including root cause determinations 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 function is maintained consistent with current licensing basis conditions. Evaluations performed to assess conditions associated with aging need to follow the same methodology used in the licensing and design basis calculations. Extent of condition investigation per TN America's corrective action program may trigger additional inspections via a different method, increased inspection frequency and/or expanded inspection sample size.

C.13.5.8 Confirmation Process

Confirmatory actions, as needed, are implemented as part of TN America's corrective action program. *See also* Section C.13.5.7.

C.13.5.9 Administrative Controls

Administrative controls under TN America's QA procedures and corrective action program provide a formal review and approval process. Administrative controls are implemented in accordance with the requirements of TN Americas 10 CFR Part 72, Subpart G Program, and will continue for the period of extended operation. 10 CFR 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. 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 industry as outlined in NEI 14-03 [C.13-2]. *See also* Section C.13.5.7.

This section is newly added.

C.13.5.10 Operating Experience

The HSM AMP for external and internal surfaces is modeled after the regulatory philosophy of 10 CFR 50.65 [C.13-10] structures monitoring program. Structures monitoring programs have been implemented for managing aging effects during the extended period of license renewal of the operating reactor plants. NUREG-1522 [C.13-23] documents the results of a survey in 1992 to obtain information on the types of distress in the concrete and steel structures and components, the type of repairs performed, and the durability of the repairs. Licensees who responded to the survey reported cracking, scaling, and leaching of concrete structures. The degradation was attributed to drying shrinkage, freeze-thaw, and abrasion. The degradation also includes corrosion of component support members and anchor bolts, cracks and other deterioration of masonry walls, and groundwater leakage and seepage into underground structures. The degradations at coastal sites were more severe than those observed at inland sites because of exposure to brackish water or seawater.

Information Notice IN 2013-07 "Premature Degradation of Spent Fuel Storage Cask Structures and Components from Environmental Moisture" describes OE on NUHOMS® HSMs installed at the TMI-2 INL site where water contributed to an accelerated aging process of concrete structures of the spent fuel storage system. Water entered cracks and crevices around the anchor bolt blockout through holes in the concrete roof structure, and when subjected to freezing temperatures, generated mechanical forces that produced cracks in the concrete. These cracks provided additional and larger pathways for water to enter the interior of the concrete, which resulted in larger cracks from subsequent freezing temperatures and promoted efflorescence. If remedial actions had not been taken, this accelerated aging process could have inhibited the ability of the concrete structure to perform its design function of protecting the canister system containing the radioactive material, as well as protecting personnel from ionizing radiation during normal and accident conditions. This example shows the importance of periodically monitoring the physical condition of a spent nuclear fuel storage system. By obtaining baseline measurements and performing periodic evaluations, accelerated degradation can be detected before the structures and components of a storage system become unable to perform their intended function, and corrective actions can be implemented.

<u>NUHOMS® Operating Experience</u>

Chapter 3, Section 3 of reference [C.13-29] provides a detailed description of NUHOMS® CoC 1004 OE.

<u>Calvert Cliffs' Operating Experience</u>

In 2012, Calvert Cliffs performed an inspection of the interior of two NUHOMS® HSMs, and the exterior of the DSCs as part of their license renewal application [C.13-4]. The visual inspection was conducted by remote and direct means with a remote controlled high definition PTZ camera system.

The accessible surfaces of the HSM concrete walls, roof, and floor all appeared to be in good condition with little to no signs of spalling or cracking. There was additional evidence of localized water intrusion to the interior of the module in the form of a few concrete stalactites. These stalactites were seen only near the rear outlet vent, which suggests that the source of the water intrusion is the outlet vent stack. Broken stalactite debris was observed on the surface of the heat shields beneath the ceiling. Stalactites are formed when water leaches calcium hydroxide out of the concrete ceiling, which precipitates as calcium carbonate on contact with carbon dioxide in the air. Water was observed to flow inward along concrete surface cracks, though water had not penetrated to the rebar, and the pure white color of the stalactites was present on the concrete surface. Therefore, concrete leaching could also occur in these surface cracks.

A condition report was initiated to evaluate whether their presence could have implications for performance of the intended functions of the HSM prior to the next aging management inspection. A coating of dirt and dust was present on the floor of both HSMs, but no debris or standing water was noted. In both HSM-15 and HSM-1, the DSC structural support beams and rails were in good condition, with the coating intact in most areas. There was a large buildup of dust on the transverse support beams horizontal surfaces particularly on the beams at the back end of the module. There were no signs of loose or missing bolting or fasteners. General corrosion of the carbon steel surface and bolting hardware was observed. The small areas of general surface corrosion observed do not represent a current challenge to the function of the DSC structural supports.

TMI-2 at Idaho National Laboratory Experience

The Three Mile Island Nuclear Generating Station, Unit 2 ISFSI uses NUHOMS-12T HSMs. In 2000, the licensee Department of Energy Idaho National Laboratory (INL), noted cracks in the HSMs and concluded they were cosmetic and insignificant. However, in 2007, the licensee observed continued cracking, crazing and spalling, as well as increased efflorescence on the HSM surfaces. The efflorescence was a solid, whitish crystalline material that was determined through sampling and analysis to be calcium carbonate. The licensee performed an evaluation in 2007, during which it determined that the HSMs were capable of performing their design basis functions. In 2008, the licensee noted that 28 of the 30 HSMs had cracks, mostly emanating from the anchor bolt blockout holes with widths up to 0.95 cm (0.38 in.). At that time, the licensee determined that the HSMs appeared to be prematurely deteriorating and that continued crack growth could affect the ability of the HSMs to fulfill their originally planned 50-year design service life. Subsequent evaluations by the licensee initiated the development of an annual inspection plan for the HSMs and base mat, as well as an examination of the inside of the HSMs. The evaluation included a field investigation and laboratory analysis to evaluate the concrete material quality, strength, and long-term durability potential. The conclusion reached was that water had entered the anchor bolt blockout holes on the roof of the HSMs. Subsequent freeze-thaw cycles initiated the crack formation. Repetition of the process resulted in both continued crack growth and the efflorescence growth identified in 2007 [C.13-24].

The licensee performed an extensive effort to correct the degrading concrete of their HSMs since 2011. Despite the observed cracking, the HSMs continued to fulfill fully their safety functions. The licensee committed to perform follow-up concrete inspections. This included: (1) an annual visual inspection of the repaired areas for any signs of additional cracking from freeze/thaw action; (2) that the personnel performing the inspection or evaluations would meet the requirements of American Concrete Institute (ACI) 349.3R-02, Chapter 11, "Qualifications of Evaluation Team;" (3) that visual inspections of accessible HSM concrete surfaces for aging effects would be performed per instructions contained in ACI 349.3R-02, Section 3.5.1, Visual Inspections and ACI 201.IR-08, "Guide for Conducting a Visual Inspection of Concrete in Service." Based on completion of the HSM concrete repairs, combined with licensee plans to implement a baseline inspection and an aging monitoring program on the HSM's, the NRC inspector follow-up item (IFI) has been closed [C.13-25].

Learning AMP

The "HSM Aging Management Program for External and Internal Surfaces" is a "learning" AMP. This means that this AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from site-specific inspection findings, related industry OE, and related industry research. Site-specific and industry OE is captured through ISP's OE review process.

This section is newly added.

The ongoing review of both site-specific and industry OE will continue through the period of extended operation to ensure that the program continues to be effective in managing the identified aging effects. Reviews of OE by the licensee in the future may identify areas where AMPs should be enhanced or new programs developed.

ISP is to maintain the effectiveness of this AMP under its QA program used to meet the criteria of 10 CFR Part 72, Subpart G [C.13-5 and C.13-26].

C.13.6 References

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C.13-2 NEI 14-03, "Format, Content, and Implementation Guidance for Cask Storage Operations-Based Aging Management," Revision 1, September 2015.

C.13-3 ASME B&PV Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components." The ASME Boiler and Pressure Vessel Code, 2010, The American Society of Mechanical Engineers.

C.13-4 Calvert Cliffs Nuclear Power Plant, Independent Spent Fuel Storage Installation, Material License No. SNM-2505, Docket No. 72-8, "Response to Request for Supplemental Information, RE: Calvert Cliffs Independent Spent Fuel Storage Installation License Renewal Application," (TAC No- L24475), July 27, 2012 [ML12212A216].

C.13-5 NRC Regulatory Issue Summary 2014-09, "Maintaining the Effectiveness of License Renewal Aging Management Programs," August 6, 2014.

C.13-6 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, Office of Nuclear Material Safety and Safeguards.

C.13-7 J. Massari, "Calvert Cliffs ISFSI License Renewal and Expansion," Presentation at the NEI Used Fuel Management Conference, St. Petersburg, FL, May 7-9, 2013.

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C.13-9 EPRI Letter (2013), "CCNPP Canister Inspection Chemical Analysis Results of Samples Collected," March 25, 2013.

C.13-10 10 CFR 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Office of the Federal Register.

C.13-11 ACI 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures, American Concrete Institute," 2002.

C.13-12 NUREG-1801, Revision 2, "Generic Aging Lessons Learned (GALL) Report-Final Report," December 2010.

C.13-13 ACI 201.1R, "Guide for Making a Condition Survey of Concrete in Service," American Concrete Institute, 2008.

C.13-14 ANSI/ASCE 11-90, 99, "Guideline for Structural Condition Assessment of Existing Buildings," American Society of Civil Engineers.

This section is newly added.

C.13-15 American Concrete Institute, "Building Code Requirements for Reinforced Concrete," (ACI 318-83, 95) ACI, Detroit, MI (1983, 1995).

C.13-16 ASTM D610-08, "Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces," American Society for Testing and Materials, November 2012.

C.13-17 ASTM D7167-12, "Standard Guide for Establishing Procedures to Monitor the Performance of Safety-Related Coating Service Level III Lining Systems in an Operating Nuclear Power Plant, ASTM International," West Conshohocken, PA, 2012.

C.13-18 ASTM D4538-05, "Standard Terminology Relating to Protective Coating and Lining Work for Power Generation Facilities," ASTM International, West Conshohocken, PA, 2005.

C.13-19 EPRI Report 1019157, "Guideline on Nuclear Safety-Related Coatings," Revision 2, (Formerly TR-109937 and 1003102), Electric Power Research Institute, December 2009.

C.13-20 ACI 224.1R-07, "Cause, Evaluation, and Repair of Cracks in Concrete Structures," American Concrete Institute, 2007.

C.13-21 ACI 364.1R-07, "Guide for Evaluation of Concrete Structures before Rehabilitation," American Concrete Institute, 2007.

C.13-22 ACI 562-13, "Evaluation, Repair, and Rehabilitation of Concrete Building," American Concrete Institute, 2013.

C.13-23 NUREG-1522, "Assessment of Inservice Conditions of Safety-Related Nuclear Plant Structures," June 1995.

C.13-24 NRC Information Notice 2013-07, "Premature Degradation of Spent Fuel Storage Cask Structures and Components from Environmental Moisture," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards.

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C.13-26 10 CFR Part 72, Subpart G, Quality Assurance Criteria for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor Related Greater Than Class C Waste, Office of the Federal Register.

C.13-27 ASME B&PV Code, Section V, "Nondestructive Examination," The ASME Boiler and Pressure Vessel Code, 2010 edition.

C.13-28 NUREG-1927, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance," U.S. Nuclear Regulatory Commission, Revision 0, March 2011.

C.13-29 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).

C.13-30 Letter from Meraj Rahimi (NRC) to Jayant Bondre (TN Americas LLC), "Renewal of Initial Certificate and Amendments Nos. 1 through 11and 13 Revision 1 and Amendment No. 14 of Certificate of Compliance No. 1004 for the Standardized NUHOMS® Horizontal Modular Storage System," December 4, 2017, (ADAMS Accession Number ML17338A092).

Table C.13-1
DSC AMP for the Effects of CISCC Tollgates

Tollgate	Year	Assessment
1	prior to T_o	Perform initial inspection of selected DSCs as specified in Section C.13.4.4 and as updated at the time that planning for the inspection begins.
2	$T_o + 5$ (note 1)	Evaluate information from the following sources and perform a written assessment of the aggregate impact of the information, including but not limited to corrective actions required and the effectiveness of the CISCC AMP: • Results of research and development programs focused specifically on initiation, propagation, inspection, and mitigation of atmospheric CISCC, such as those conducted by Electric Power Research Institute (EPRI), Central Research Institute of Electric Power Industry (CRIEPI), the Department of Energy (DOE), and DOE/University programs • Results of tollgate 1 inspections, including trending of chloride surface concentration, temperature, and humidity conditions compared to the latest research on CISCC initiation. • Relevant results of other domestic and international nuclear and non-nuclear research. • Relevant domestic and international nuclear and non-nuclear OE. • Relevant results of domestic and international performance monitoring for welded canister dry storage systems. • Relevant results of domestic and international inspections of welded canister dry storage systems. • Availability of improved technologies to inspect DSCs for stress corrosion cracking and for chemistry of surface deposits.
3	T_o+10	Evaluate additional information gained from the sources listed in tollgate 2 along with any new relevant sources and perform a written assessment of the aggregate impact of the information, including results of tollgate 2. The age-related degradation mechanisms evaluated at this tollgate and the time at which it is conducted may be adjusted based on the results of the tollgate 2 assessment.
4	T_o+20	Same as tollgate 2 as informed by the results of tollgates 2 and 3
5	T_o+30	Same as tollgate 3 as informed by the results of tollgates 2, 3, and 4

Notes:
(1) T_o is twenty years after the first DSC at the ISFSI was loaded.