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NUCLEAR ENERGY INSTITUTE

January 12, 2022

Mr. Brian Smith
Director, Division of New and Renewed Licenses
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Submittal of Proposed Revisions to Aging Management Programs XI.M33, "Selective Leaching" and XI.E3, "Inaccessible Power Cables Not Subject to 10 CFR 50.49 Environmental Qualification Requirements"

Project Number: 689

Dear Mr. Smith:

The Nuclear Energy Institute (NEI)[1], on behalf of its members, is submitting proposed revisions to section XI.M33, "Selective Leaching," of the Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report, and section XI.E3, "Inaccessible Power Cables Not Subject to 10 CFR 50.49 Environmental Qualification Requirements," of the Generic Aging Lessons Learned (GALL) Report, Revision 2, as amended by their respective Interim Staff Guidance (ISG) documents.

The proposed revisions reflect advancements in the implementation of aging management programs gained from the accumulation of operating experience and the leveraging of available risk insights. The industry sees great value in the expansion of using risk insights to focus aging management program resources on structures and components commensurate with their safety significance. The adoption of these proposed revisions could provide the foundation for additional use of risk insights to streamline and optimize the use of industry and NRC resources in the future.

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[1] The Nuclear Energy Institute (NEI) is responsible for establishing unified policy on behalf of its members relating to matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include entities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect and engineering firms, fuel cycle facilities, nuclear materials licensees, and other organizations involved in the nuclear energy industry.

If there are any questions on this matter, please contact me at 202-739-8017 or bat@nei.org.

Sincerely,

Brett Titus

Attachments

1. Selective Leaching
    a. Clean version
    b. Redline version
2. Inaccessible Power Cables
    a. Clean version
    b. Redline version

c: Ms. Lauren Gibson, NRR/DNRL/NLRP, NRC
Ms. Marieliz Johnson, NRR/DNRL/NLRP, NRC

XI.M33 SELECTIVE LEACHING

Program Description

The program for selective leaching (dealloying) of materials includes components made of gray cast iron, ductile iron, and copper alloys (except for inhibited brass) that contain greater than 15 percent zinc or greater than 8 percent aluminum exposed to a raw water, closed-cycle cooling water (CCCW), treated water, waste water, or soil environment. This aging management program (AMP) may include one-time, opportunistic and/or periodic inspections of selected components that are susceptible to selective leaching. Inspection techniques utilized determine whether loss of material due to selective leaching is occurring and whether selective leaching will affect the ability of the components to perform their intended function for the subsequent period of extended operation.

The selective leaching process involves the preferential removal of one of the alloying components from the material. Dezincification (loss of zinc from brass) and graphitic corrosion (removal of iron from gray cast iron and ductile iron) are examples of such a process. Susceptible materials exposed to high operating temperatures, stagnant-flow conditions, and a corrosive environment (e.g., acidic solutions for brasses with high zinc content and dissolved oxygen) are conducive to selective leaching. A dealloyed component often retains its shape and may appear to be unaffected; however, the functional cross-section of the material has been reduced. The aging effect attributed to selective leaching is loss of material because the affected volume has a permanent change in density and does not retain mechanical properties that can be credited for structural integrity.

Evaluation and Technical Basis

1. ***Scope of Program**:* Components include piping, valve bodies and bonnets, pump casings, and heat exchanger components that are susceptible to selective leaching. The materials of construction for these components may include gray cast iron, ductile iron, and copper alloys (except for inhibited brass) containing greater than 15 percent zinc or greater than 8 percent aluminum. These components may be exposed to raw water, CCCW, treated water, waste water, or soil.

   Depending on plant-specific operating experience (OE) and implementation of preventive actions, certain components may be excluded from the scope of this program in each 10-year inspection interval as follows:

   - The internal surfaces of internally-coated components for which loss of coating integrity is managed by Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report AMP XI.M42, “Internal Coatings/Linings for In-Scope Piping, Piping Components, Heat Exchangers, and Tanks.”

   - The external surfaces of buried components that are externally-coated in accordance with Table XI.M41-1, of GALL-SLR Report AMP XI.M41, “Buried and Underground Piping and Tanks,” and where direct visual examinations of buried piping in the scope of license renewal have not revealed any coating damage.

- The external surfaces of buried gray cast iron and ductile iron components that have been cathodically protected since installation and meet the criteria for Preventive Actions Category C in GALL-SLR Report AMP XI.M41, Table XI.M41-2, “Inspections of Buried and Underground Piping and Tanks.”

- The external surfaces of buried copper alloy components that meet the above cathodic protection recommendations, if technical justification is submitted with the subsequent license renewal application (SLRA) that demonstrates the effectiveness of cathodic protection in the prevention of selective leaching for those alloys.

2. ***Preventive Actions****:* Although the program does not provide guidance on preventive actions, water chemistry control of certain parameters (e.g., pH, concentration of corrosive contaminants, dissolved oxygen), cathodic protection, and coatings can be effective in minimizing selective leaching.

3. ***Parameters Monitored or Inspected****:* The program monitors or inspects for the presence and depth of dealloying through visual (e.g., color, porosity, abnormal surface conditions), mechanical (e.g., chipping, scraping), surface hardness, nondestructive (e.g., electromagnetic, ultrasonic), and/or destructive examinations.

4. ***Detection of Aging Effects****:* Inspections follow site procedures, with appropriate acceptance criteria, that include inspection parameters such as lighting, distance, offset, surface coverage, presence of protective coatings, and cleaning processes.

   Inspections and examinations may consist of any the following methods. The detection methods below are listed in order of increasing complexity of deployment and detection capabilities. If a given inspection method yields inconclusive or potentially unsatisfactory results, a more capable method many be chosen for follow-up inspection and disposition of results

   For gray cast iron and ductile iron:

   - Visual inspections of accessible surfaces for evidence of non-uniform texture, discolorations, and/or the presence of tubercules/corrosion scale/deposit on the internal surfaces.

   - Graphitic corrosion of cast irons cannot be reliably detected through only visual means. Therefore, visual inspections are supplemented by mechanical examination techniques, particularly in the areas of interest by visual inspection. Mechanical examination techniques may include actions such as chipping, scraping, scratching, or otherwise impacting exposed and accessible surfaces.

   - Brinell Hardness testing (where feasible, based on form and configuration) or other industry-accepted mechanical inspection techniques can be used on the affected surfaces of the selected set of components to determine if selective leaching has occurred, but is not accurate for determining the extent of selective leaching.

   - Nondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component. Technical justification demonstrating the effectiveness of the non-destructive examination process shall be included as part of the program’s documentation.

- Destructive examinations may be used to confirm the presence and depth of possible de-alloying.

For copper-based alloys:

- Visual inspections of accessible surfaces. Selective leaching may be more readily identified by visual means through a change in color, such as from a normal yellow color to a reddish copper color or green copper oxide. For copper alloys with >15% zinc, a white/gray meringue deposit may develop on the surface.

- Brinell Hardness testing (where feasible, based on form and configuration) or other industry-accepted mechanical inspection techniques can be used on the affected surfaces of the selected set of components to determine if selective leaching has occurred, but is not accurate for determining the extent of selective leaching.

- Nondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component. Technical justification demonstrating the effectiveness of the non-destructive examination process shall be maintained in an auditable and retrievable format.

- Destructive examinations may be used to confirm the presence and depth of possible de-alloying.

One-time and periodic inspections are conducted of a representative sample of each population, as directed in either Table XI.M33-1 or via risk-informed sampling methodology. A population is defined as the same material and environment combination.

Periodic inspections are conducted in the 10-year period prior to a subsequent period of extended operation and in each 10-year period during a subsequent period of extended operation. When allowed by plant and operating conditions, opportunistic inspections may be conducted when components are opened, or buried or submerged surfaces are exposed during planned maintenance activities. Where possible, inspections focus on the bounding or lead components most susceptible to aging based on time-in-service and severity of operating conditions for each population or as determined by risk-informed sampling methodology. Opportunistic inspections may be credited as periodic inspections, as long as the inspection locations selection criteria are met.

For inspection sample sizes other than directed in Table XI.M33-1 or resulting from the risk-informed sampling methodology described below, a technical justification of the methodology and sample size used for selecting components for inspection shall be included as part of the program’s documentation.

Table XI.M33-1

	Inspections per Unit [4, 6]		
Environment Grouping	**Years 50-60**	**Years 60-70**	**Years 70-80**
CCCW [2]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]
Treated Water [2]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]
Raw Water [2, 5]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]
Waste Water [2, 5]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]
Soil [2]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]

Table XI.M33-1 Footnotes	
Footnote 1:	Components exposed to Closed Cycle Water or Treated Water need not be inspected in years 60-80 if inspections in years 50-60 are found to satisfy established acceptance criteria. One-time inspections are only conducted for components exposed to CCCW or treated water when no plant-specific OE of selective leaching exists in these environments
Footnote 2:	For Ductile Iron, if selective leaching is not identified during inspections of components in the respective environment population during years 50-60, no additional inspections are required during years 60-80.
Footnote 3:	Detailed Examinations: - If the population for the given material-environment combination is >35, at least two (2) examinations shall be performed by destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) means - If the population for the given material-environment combination is <35, at least one (1) examination shall be performed by destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) means - The total number of components to be inspected for the given material-environment combination may be reduced by two for each additional component examined by destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) means, beyond the minimum specified above.
Footnote 4:	When inspections are conducted on piping, a minimum 1-foot axial length section is considered as one inspection.
Footnote 5:	For raw water and waste water environments, the populations may be combined as long as an evaluation is conducted to determine the more severe environment and the inspections and examinations are conducted on components in the most severe environment, with one inspection being conducted in the less severe environment.
Footnote 6:	Quantities specified in this table are per population. A population is defined as the same material and environment combination.

For multi-unit sites where the sample size is not based on the percentage of the population and the inspections are conducted periodically (not one-time inspections), it is acceptable to reduce the total number of inspections at the site as follows.

- For two unit sites, eight visual and mechanical inspections (for gray cast iron and ductile iron only) and two destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) examinations are conducted at each unit.
- For two unit sites with less than 35 susceptible components in a sample population at each unit, one destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) examination is performed for that sample population.
- For three unit sites, seven visual and mechanical (for gray cast iron and ductile iron only) and one destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) examination are conducted at each unit.

In order to conduct the reduced number of inspections, the applicant states in the SLRA the basis for why the operating conditions at each unit are similar enough (e.g., flowrate, chemistry, temperature, excursions) to provide representative inspection results. The basis should include consideration of potential differences such as the following:

- Have power uprates been performed and if so, could more aging have occurred on one unit that has been in the uprate period for a longer time period?
- Are there any systems which have had an out-of-spec water chemistry condition for a longer period of time or out-of-spec conditions occurred more frequently?
- For raw water systems, is the water source from different sources where one or the other is more susceptible to microbiologically influenced corrosion or other aging effects?

Dependent on plant-specific OE and implementation of preventive actions, the exclusions for external surface coatings of buried components may no longer apply and the inspection population is adjusted as follows. When minor through-coating damage has been identified in plant-specific OE, but the components are coated in accordance with Table XI.M41-1 of GALL-SLR Report AMP XI.M41, the inspection sample size may be reduced by 50 percent (inspection quantities are rounded up) of that recommended in the “detection of aging effects” program element of this AMP if the following conditions are met:

- There were no more than two instances of coating damage identified in each 10-year period of the prior operating period
- An analysis demonstrates that, if the pipe surface area affected by the coating damage is assumed to have been a through-wall hole, the pipe could be shown to meet unreinforced opening criteria of the applicable piping code

Stations that have applied the industry-accepted risk framework (EPRI TU 3002020623 Leveraging Risk Insights for Aging Management Program Implementation Update) to the AMP have the option of using risk-informed inspection sample selection or the 3% of population/10 components inspection sampling methodology.

- Risk-informed sampling methodology:
    - Any SSCs that could not be fully evaluated for the likelihood and/or consequence risk factor using the risk framework must be placed in the high category for the applicable risk factor(s).
    - A minimum of 2 SSCs classified as high consequence, regardless of likelihood, in each applicable population must be included in the inspection sample.
    - This minimum number of high consequence SSCs to be inspected may be reduced to 1 if 2 or more surrogates are inspected. A surrogate is defined as an SSC within the same population with the same or higher likelihood of failure, but with a lower consequence of failure.
    - For populations with no high consequence SSCs, a minimum of 2 SSCs should be inspected, with a focus on assessing the structural integrity of the higher consequence SSCs in the population. The SSCs to be inspected can be selected from either the highest consequence group or surrogates.
    - Stations must retain auditable records of the risk framework results and update these results as new information becomes available that may change the initial results.

5. ***Monitoring and Trending****:* Where practical, identified degradation is projected until the end of SPEO or next scheduled inspection, as applicable. Results are evaluated against acceptance criteria to confirm that the sampling bases (e.g., selection, size, frequency) will maintain the components' intended functions throughout the subsequent period of extended operation based on the projected rate and extent of degradation.

6. ***Acceptance Criteria:*** The Owner is responsible for establishing acceptance criteria which as a minimum shall include:

Table XI.M33-2

<table>
<tr><th>Acceptance Criteria[1]</th><th>Gray Cast Iron / Ductile Iron</th><th>Copper Alloy and Al Bronze</th></tr>
<tr><td>Visual Inspection</td><td rowspan="2">The presence of no more than a superficial layer of dealloying, as determined by removal of the de-alloyed material by chipping, scraping, or other destructive or semi-destructive means[2]</td><td>No noticeable change in color from the normal yellow color to the reddish copper color or green copper oxide

If green oxide is identified, it should be removed, and the base metal should be inspected for a change in color from the normal yellow color to the reddish copper color.

For copper alloys with >15% zinc, a white/gray meringue deposit may develop on the surface.</td></tr>
<tr><td>Mechanical Examination</td><td>N/A</td></tr>
<tr><td>Hardness Testing</td><td>No more than a 20 percent decrease in hardness</td><td>No more than a 20 percent decrease in hardness</td></tr>
<tr><td>Demonstrated NDE Techniques</td><td>Surface techniques: no evidence of a selective leaching beyond a superficial layer

Volumetric techniques[3]</td><td>Surface techniques: no evidence of a selective leaching beyond a superficial layer

Volumetric techniques[3]</td></tr>
<tr><td>Destructive Examinations</td><td>See Footnote 3.</td><td>See Footnote 3.</td></tr>
</table>

Table XI.M33-2 Footnotes	
Footnote 1:	Acceptance criteria may be adjusted as industry operating experience and state of the art research advances.
Footnote 2:	Mechanical examinations should be used to augment visual inspection.
Footnote 3:	The remaining wall thickness of the component, in the region of detected selective leaching, shall be quantified and evaluated against system and component design requirements. Minimum wall thickness requirements shall be met at all locations of detected selective leaching. In the evaluation of results from volumetric non-destructive and/or destructive examinations, the extent of selective leaching shall be estimated and projected through the end of the subsequent period of extended operation. No credit is used for the material properties of the dealloyed portion of the component during fitness-for-service evaluations.

7. ***Corrective Actions:*** Results that do not meet the acceptance criteria are addressed in

the applicant's corrective action program under those specific portions of the quality assurance (QA) program that are used to meet Criterion XVI, "Corrective Action," of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix B. Appendix A of the GALL-SLR Report describes how an applicant may apply its 10 CFR Part 50, Appendix B, QA program to fulfill the corrective actions element of this AMP for both safety-related and nonsafety-related structures and component (SCs) within the scope of this program.

When the acceptance criteria are not met such that it is determined that the affected component should be replaced prior to the end of the subsequent period of extended operation, additional inspections are considered for determination of the extent of condition or cause in the applicable material/environment as well as other corrective actions.

8. ***Confirmation Process****:* The confirmation process is addressed through those specific portions of the QA program that are used to meet Criterion XVI, "Corrective Action," of 10 CFR Part 50, Appendix B. Appendix A of the GALL-SLR Report describes how an applicant may apply its 10 CFR Part 50, Appendix B, QA program to fulfill the confirmation process element of this AMP for both safety-related and nonsafety-related SCs within the scope of this program.

9. ***Administrative Controls****:* Administrative controls are addressed through the QA program that is used to meet the requirements of 10 CFR Part 50, Appendix B, associated with managing the effects of aging. Appendix A of the GALL-SLR Report describes how an applicant may apply its 10 CFR Part 50, Appendix B, QA program to fulfill the administrative controls element of this AMP for both safety-related and nonsafety-related SCs within the scope of this program.

10. ***Operating Experience****:* OE shows that selective leaching has been detected in components constructed from gray cast iron, ductile iron, brass, bronze, and aluminum bronze. The following OE may be of significance to an applicant's program:

    a. U.S. Nuclear Regulatory Commission (NRC) Information Notice (IN) 20-04, Operating Experience Related To Failure Of Buried Fire Protection Main Yard Piping, December 17, 2020

    b. In March 2013, a licensee submitted an American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI relief request because it had detected weeping through aluminum bronze (susceptible to dealloying) valve bodies exposed to sea water. The degraded area was characterized by corrosion debris or wetness that returned following cleaning and drying of the surface. [Agencywide Documents Access and Management System (ADAMS) Accession No. ML13091A038 and ML14182A634].

    c. During a one-time inspection for selective leaching, a licensee identified degradation in four gray cast iron valve bodies in the service water system exposed to raw water. The mechanical test used by the licensee to identify the graphitization was tapping and scraping of the surface. The licensee sand blasted two of the valve bodies and, after all of the graphite was removed; the licensee determined that the leaching progressed to a depth of approximately 3/32 inch. Based on the estimated corrosion rate, the licensee determined that the valve bodies had adequate wall thickness for at least 20 years of additional service. (ADAMS Accession No. ML14017A289).

d. Based on visual inspections conducted as part of implementing a one-time inspection for selective leaching, a licensee identified selective leaching in a gray cast iron drain plug of an auxiliary feedwater pump outboard bearing cooler. Possible selective leaching was also found on multimatic valves on the underside of the clapper. As a result, the licensee incorporated quarterly inspections of the components in its periodic surveillance and preventive maintenance program. (ADAMS Accession No. ML13122A009).

e. In September 2008, a licensee identified the dealloying of an aluminum bronze strainer drum exposed to brackish water. This was identified after an unexpected material failure occurred, during a planned maintenance evolution at an offsite repair facility. The maintenance evolution involved rigging the strainer drum into position for a machining operation. During the rigging, the strainer drum material failed at the rigging attachment point to the strainer. This failure of the strainer drum exposed the inner portion of the drum material where dealloying of the drum was visually observed during an inspection. (ADAMS Accession No. ML092400531).

f. A licensee has reported occurrences of selective leaching of aluminum bronze components for an extensive number of years. (ADAMS Accession No. ML17142A263).

g. NRC IN 84-71, Graphitic Corrosion of Cast Iron in Salt Water, September 06, 1984.

h. NRC IN 94-59, Accelerated Dealloying of Cast Aluminum-Bronze Valves Caused by Microbiologically Induced Corrosion, August 17, 1994.

i. The basis for inclusion of ductile iron in this GALL-SLR Report AMP XI.M33, along with OE examples, is cited in the GALL-SLR and SRP-SLR Supplemental Staff Guidance document. (ADAMS Accession No. ML16041A090).

The program is informed and enhanced when necessary through the systematic and ongoing review of both plant-specific and industry OE including research and development such that the effectiveness of the AMP is evaluated consistent with the discussion in Appendix B of the GALL-SLR Report.

References

10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.” Washington, DC: U.S. Nuclear Regulatory Commission. 2016.

EPRI. EPRI TR–107514, “Age Related Degradation Inspection Method and Demonstration.” Palo Alto, California: Electric Power Research Institute. April 1998.

Fontana, M.G. *Corrosion Engineering*. McGraw Hill. pp. 86-90. 1986.

NRC. “GALL-SLR and SRP-SLR Supplemental Staff Guidance.” Agencywide Documents Access and Management System (ADAMS) Accession No. ML16041A090. Washington, DC: U.S. Nuclear Regulatory Commission. March 2016.

Selective Leaching: State-of-the-Art Technical Update. EPRI, Palo Alto, CA: 2019. 3002016057.

Ultrasonic NDE Techniques for Detection of Selective Leaching in Complex Shaped Gray Cast Iron Components. EPRI, Palo Alto, CA: 2021. 3002020830.

2021 Leveraging Risk Insights for Aging Management Program Implementation Update. EPRI, Palo Alto, CA: 2021. 3002020623.

XI.M33 SELECTIVE LEACHING REDLINE

Program Description

The program for selective leaching (dealloying) of materials includes components made of gray cast iron, ductile iron, and copper alloys (except for inhibited brass) that contain greater than 15 percent zinc or greater than 8 percent aluminum exposed to a raw water, closed-cycle cooling water (CCCW), treated water, waste water, or soil environment. ~~Depending on the environment, the~~This aging management program (AMP) ~~includes~~may include one-time, ~~or~~ opportunistic and/or periodic ~~visual~~ inspections of selected components that are susceptible to selective leaching~~, coupled with mechanical examination~~. Inspection techniques ~~(e.g., chipping, scraping). Destructive examinations of components to determine the presence of and depth of dealloying through-wall thickness are also conducted. These techniques can~~utilized determine whether loss of material due to selective leaching is occurring and whether selective leaching will affect the ability of the components to perform their intended function for the subsequent period of extended operation.

The selective leaching process involves the preferential removal of one of the alloying components from the material. Dezincification (loss of zinc from brass) and~~ graphitization or~~ graphitic corrosion (removal of iron from gray cast iron and ductile iron) are examples of such a process. Susceptible materials exposed to high operating temperatures, stagnant-flow conditions, and a corrosive environment (e.g., acidic solutions for brasses with high zinc content and dissolved oxygen) are conducive to selective leaching. A dealloyed component often retains its shape and may appear to be unaffected; however, the functional cross-section of the material has been reduced. The aging effect attributed to selective leaching is loss of material because the affected volume has a permanent change in density and does not retain mechanical properties that can be credited for structural integrity.

Evaluation and Technical Basis

1. ***Scope of Program**:* Components include piping, valve bodies and bonnets, pump casings, and heat exchanger components that are susceptible to selective leaching. The materials of construction for these components may include gray cast iron, ductile iron, and copper alloys (except for inhibited brass) containing greater than 15 percent zinc or greater than 8 percent aluminum. These components may be exposed to raw water, CCCW, treated water, waste water, or soil.

   Depending on plant-specific operating experience (OE) and implementation of preventive actions, certain components may be excluded from the scope of this program in each 10-year inspection interval as follows:

   - The internal surfaces of internally-coated components for which loss of coating integrity is managed by Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report AMP XI.M42, "Internal Coatings/Linings for In-Scope Piping, Piping Components, Heat Exchangers, and Tanks."

   - The external surfaces of buried components that are externally-coated in accordance with Table XI.M41-1, of GALL-SLR Report AMP XI.M41, "Buried and Underground Piping and Tanks," and where direct visual examinations of buried piping in the scope of license renewal have not revealed any coating damage.

- The external surfaces of buried gray cast iron and ductile iron components that have been cathodically protected since installation and meet the criteria for Preventive Actions Category C in GALL-SLR Report AMP XI.M41, Table XI.M41-2, “Inspections of Buried and Underground Piping and Tanks.”

- The external surfaces of buried copper alloy components that meet the above cathodic protection recommendations, if technical justification is submitted with the subsequent license renewal application (SLRA) that demonstrates the effectiveness of cathodic protection in the prevention of selective leaching for those alloys.

2. ***Preventive Actions***: Although the program does not provide guidance on preventive actions, water chemistry control of certain parameters (e.g., pH, concentration of corrosive contaminants, dissolved oxygen), cathodic protection, and coatings can be effective in minimizing selective leaching.

~~1.~~ ***Parameters Monitored or Inspected***: ~~This~~The program monitors or inspects for the presence and depth of dealloying through visual ~~appearance~~

3. (e.g., color, porosity, abnormal surface conditions), ~~surface conditions through~~ mechanical ~~examination techniques~~ (e.g., chipping, scraping), ~~and the presence of~~surface hardness, nondestructive (e.g., electromagnetic, ultrasonic), and ~~depth of dealloying through-wall thickness through~~ /or destructive examinations.

4. ***Detection of Aging Effects***: Inspections ~~and examinations consist of the following:~~follow site procedures, with appropriate acceptance criteria, that include inspection parameters such as lighting, distance, offset, surface coverage, presence of protective coatings, and cleaning processes.

Inspections and examinations may consist of any the following methods. The detection methods below are listed in order of increasing complexity of deployment and detection capabilities. If a given inspection method yields inconclusive or potentially unsatisfactory results, a more capable method many be chosen for follow-up inspection and disposition of results

For gray cast iron and ductile iron:

- Visual inspections of ~~all~~ accessible surfaces~~. In certain copper~~ for evidence of non-uniform texture, discolorations, and/or the presence of tubercules/corrosion scale/deposit on the internal surfaces.

- Graphitic corrosion of cast irons cannot be reliably detected through only visual means. Therefore, visual inspections are supplemented by mechanical examination techniques~~;~~, particularly in the areas of interest by visual inspection. Mechanical examination techniques may include actions such as chipping, scraping, scratching, or otherwise impacting exposed and accessible surfaces.

- Brinell Hardness testing (where feasible, based ~~alloys~~on form and configuration) or other industry-accepted mechanical inspection techniques can be used on the affected surfaces of the selected set of components to determine if selective leaching ~~can be detected by visual inspection~~ has occurred, but is not accurate for determining the extent of selective leaching.

- Nondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component. Technical justification demonstrating the effectiveness of the non-destructive examination process shall be included as part of the program's documentation.

- Destructive examinations may be used to confirm the presence and depth of possible de-alloying.

For copper-based alloys:

- Visual inspections of accessible surfaces. Selective leaching may be more readily identified by visual means through a change in color, such as from a normal yellow color to a reddish copper color or green copper oxide. ~~Graphitized cast iron cannot be reliably identified through visual examination, as the appearance of the graphite surface layer created by selective leaching does not always differ appreciably from the typical cast iron~~ For copper alloys with >15% zinc, a white/gray meringue deposit may develop on the surface.

- ~~Mechanical examination techniques, such as chipping and scraping, augment visual inspections for gray cast iron and ductile iron components.~~

- Brinell Hardness testing (where feasible, based on form and configuration) or other industry-accepted mechanical inspection techniques can be used on the affected surfaces of the selected set of components to determine if selective leaching has occurred, but is not accurate for determining the extent of selective leaching.

- Nondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component. Technical justification demonstrating the effectiveness of the non-destructive examination process shall be maintained in an auditable and retrievable format.

- Destructive examinations ~~are~~may be used to ~~determine~~confirm the presence ~~of~~ and depth of ~~dealloying through-wall thickness of components~~possible de-alloying.

One-time and periodic inspections are conducted of a representative sample of each population~~.~~, as directed in either Table XI.M33-1 or via risk-informed sampling methodology. A population is defined as the same material and environment combination. ~~Opportunistic inspections are conducted whenever components are opened, or buried or submerged surfaces are exposed.~~

~~One-time inspections are only conducted for components exposed to CCCW or treated water when no plant-specific OE of selective leaching exists in these environments. In the 10-year period prior to a subsequent period of extended operation, a sample of 3 percent of the population or a maximum of 10 components per population at each unit are visually and mechanically (for gray cast iron and ductile iron components) inspected. Inspections, where possible, focus on the bounding or lead components most susceptible to aging based on time-in-service and severity of operating conditions for each population.~~

~~Opportunistic and periodic inspections are conducted for components exposed to raw water, waste water, or soil, and for components in CCCW or treated water where~~

~~plant-specific OE includes selective leaching in these environments. Opportunistic inspections are conducted whenever components are opened, or buried or submerged surfaces are exposed.~~ Periodic inspections are conducted in the 10-year period prior to a subsequent period of extended operation and in each 10-year period during a subsequent period of extended operation. ~~If the inspection conducted for ductile iron in the 10-year period prior to a subsequent period of extended operation (i.e., the initial inspection) meets acceptance criteria, periodic inspections do not need to be conducted during the subsequent period of extended operation for ductile iron. In these periodic inspections, a sample of 3 percent of the population or a maximum of 10 components per population are visually and mechanically (for gray cast iron and ductile iron components) inspected at each unit. When inspections are conducted on piping, a 1-foot axial length section is considered as one inspection. In addition, for sample populations with greater than 35 susceptible components, two destructive examinations are performed in each material and environment population in each 10-year period at each unit. When there are less than 35 susceptible components in a sample population, one destructive examination is performed for that population. Otherwise, a technical justification of the methodology and sample size used for selecting components for inspection is included as part of the program's documentation. The number of visual and mechanical inspections may be reduced by two for each component that is destructively examined beyond the minimum number of destructive examinations recommended in each 10-year interval. Inspections, where possible,~~When allowed by plant and operating conditions, opportunistic inspections may be conducted when components are opened, or buried or submerged surfaces are exposed during planned maintenance activities. Where possible, inspections focus on the bounding or lead components most susceptible to aging based on time-in-service and severity of operating conditions for each population~~.~~ or as determined by risk-informed sampling methodology.

Opportunistic inspections may be credited as periodic inspections, as long as the inspection locations selection criteria are met.

For inspection sample sizes other than directed in Table XI.M33-1 or resulting from the risk-informed sampling methodology described below, a technical justification of the methodology and sample size used for selecting components for inspection shall be included as part of the program's documentation.

Table XI.M33-1

	Inspections per Unit [4, 6]		
Environment Grouping	**Years 50-60**	**Years 60-70**	**Years 70-80**
CCCW [2]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]
Treated Water [2]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]	3%, maximum of 10 components [1, 3]
Raw Water [2, 5]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]
Waste Water [2, 5]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]
Soil [2]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]	3%, maximum of 10 components [3]

Table XI.M33-1 Footnotes	
Footnote 1:	Components exposed to Closed Cycle Water or Treated Water need not be inspected in years 60-80 if inspections in years 50-60 are found to satisfy established acceptance criteria. One-time inspections are only conducted for components exposed to CCCW or treated water when no plant-specific OE of selective leaching exists in these environments
Footnote 2:	For Ductile Iron, if selective leaching is not identified during inspections of components in the respective environment population during years 50-60, no additional inspections are required during years 60-80.
Footnote 3:	Detailed Examinations: - If the population for the given material-environment combination is >35, at least two (2) examinations shall be performed by destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) means - If the population for the given material-environment combination is <35, at least one (1) examination shall be performed by destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) means - The total number of components to be inspected for the given material-environment combination may be reduced by two for each additional component examined by destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) means, beyond the minimum specified above.
Footnote 4:	When inspections are conducted on piping, a minimum 1-foot axial length section is considered as one inspection.
Footnote 5:	For raw water and waste water environments, the populations may be combined as long as an evaluation is conducted to determine the more severe environment and the inspections and examinations are conducted on components in the most severe environment, with one inspection being conducted in the less severe environment.
Footnote 6:	Quantities specified in this table are per population. A population is defined as the same material and environment combination.

For multi-unit sites where the sample size is not based on the percentage of the population and the inspections are conducted periodically (not one-time inspections), it is acceptable to reduce the total number of inspections at the site as follows.

- For two unit sites, eight visual and mechanical inspections (for gray cast iron and ductile iron only) and two destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) examinations are conducted at each unit.

- For two unit sites with less than 35 susceptible components in a sample population at each unit, one destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) examination is performed for that sample population.

- For three unit sites, seven visual and mechanical (for gray cast iron and ductile iron only) and one destructive or volumetric nondestructive (demonstrated capable of detecting selective leaching) examination are conducted at each unit.

In order to conduct the reduced number of inspections, the applicant states in the SLRA the basis for why the operating conditions at each unit are similar enough (e.g., flowrate, chemistry, temperature, excursions) to provide representative inspection results. The basis should include consideration of potential differences such as the following:

- Have power uprates been performed and if so, could more aging have occurred on one unit that has been in the uprate period for a longer time period?

- Are there any systems which have had an out-of-spec water chemistry condition for a longer period of time or out-of-spec conditions occurred more frequently?

- For raw water systems, is the water source from different sources where one or the other is more susceptible to microbiologically influenced corrosion or other aging effects?

~~For raw water and waste water environments, the populations may be combined as long as an evaluation is conducted to determine the more severe environment and the~~

inspections and examinations are conducted on components in the most severe environment, with one inspection being conducted in the less severe environment.

Dependent on plant-specific OE and implementation of preventive actions, the exclusions for external surface coatings of buried components may no longer apply and the inspection population is adjusted as follows. When minor through--coating damage has been identified in plant-specific OE, but the components are coated in accordance with Table XI.M41-1 of GALL-SLR Report AMP XI.M41, the inspection sample size may be reduced by 50 percent (inspection quantities are rounded up) of that recommended in the "detection of aging effects" program element of this AMP if the following conditions are met:

- There were no more than two instances of coating damage identified in each 10-year period of the prior operating period
- An analysis demonstrates that, if the pipe surface area affected by the coating damage is assumed to have been a through-wall hole, the pipe could be shown to meet unreinforced opening criteria of the applicable piping code

Inspections follow site procedures that include inspection parameters such as lighting, distance, offset, surface coverage, presence of protective coatings, and cleaning processes.

Stations that have applied the industry-accepted risk framework (EPRI TU 3002020623 Leveraging Risk Insights for Aging Management Program Implementation Update) to the AMP have the option of using risk-informed inspection sample selection or the 3% of population/10 components inspection sampling methodology.

- Risk-informed sampling methodology:
  - Any SSCs that could not be fully evaluated for the likelihood and/or consequence risk factor using the risk framework must be placed in the high category for the applicable risk factor(s).
  - A minimum of 2 SSCs classified as high consequence, regardless of likelihood, in each applicable population must be included in the inspection sample.
  - This minimum number of high consequence SSCs to be inspected may be reduced to 1 if 2 or more surrogates are inspected. A surrogate is defined as an SSC within the same population with the same or higher likelihood of failure, but with a lower consequence of failure.
  - For populations with no high consequence SSCs, a minimum of 2 SSCs should be inspected, with a focus on assessing the structural integrity of the higher consequence SSCs in the population. The SSCs to be inspected can be selected from either the highest consequence group or surrogates.
  - Stations must retain auditable records of the risk framework results and update these results as new information becomes available that may change the initial results.

5. ***Monitoring and Trending***: Where practical, identified degradation is projected until the end of SPEO or next scheduled inspection, as applicable. Results are evaluated against acceptance criteria to confirm that the sampling bases (e.g., selection, size, frequency) will maintain the components' intended functions throughout the subsequent period of extended operation based on the projected rate and extent of degradation.

~~2. ***Acceptance Criteria***: The acceptance criteria are: (a) for copper-based alloys, no noticeable change in color from the normal yellow color to the reddish copper color or green copper oxide; (b) for gray cast iron and ductile iron, the absence of a surface layer that can be easily removed by chipping or scraping or identified in the destructive examinations, (c) the presence of no more than a superficial layer of dealloying, as determined by removal of the dealloyed material by mechanical removal, and (d) the components meet system design requirements such as minimum wall thickness, when extended to the end of the subsequent period of extended operation. When evaluating a component in relation to criterion (c) no credit is used for the material properties of the dealloyed portion of the component.~~

6. ***Acceptance Criteria**:* The Owner is responsible for establishing acceptance criteria which as a minimum shall include:

Table XI.M33-2

Acceptance Criteria[1]	Gray Cast Iron / Ductile Iron	Copper Alloy and Al Bronze
Visual Inspection	The presence of no more than a superficial layer of dealloying, as determined by removal of the de-alloyed material by chipping, scraping, or other destructive or semi-destructive means[2]	No noticeable change in color from the normal yellow color to the reddish copper color or green copper oxide If green oxide is identified, it should be removed, and the base metal should be inspected for a change in color from the normal yellow color to the reddish copper color. For copper alloys with >15% zinc, a white/gray meringue deposit may develop on the surface.
Mechanical Examination		N/A
Hardness Testing	No more than a 20 percent decrease in hardness	No more than a 20 percent decrease in hardness
Demonstrated NDE Techniques	Surface techniques: no evidence of a selective leaching beyond a superficial layer Volumetric techniques[3]	Surface techniques: no evidence of a selective leaching beyond a superficial layer Volumetric techniques[3].
Destructive Examinations	See Footnote 3.	See Footnote 3.

Table XI.M33-2 Footnotes	
Footnote 1:	Acceptance criteria may be adjusted as industry operating experience and state of the art research advances.
Footnote 2:	Mechanical examinations should be used to augment visual inspection.
Footnote 3:	The remaining wall thickness of the component, in the region of detected selective leaching, shall be quantified and evaluated against system and component design requirements. Minimum wall thickness requirements shall be met at all locations of detected selective leaching. In the evaluation of results from volumetric non-destructive and/or destructive examinations, the extent of selective leaching shall be estimated and projected through the end of the subsequent period of extended operation. No credit is used for the material properties of the dealloyed portion of the component during fitness-for-service evaluations.

~~6.~~7. ***Corrective Actions**:* Results that do not meet the acceptance criteria are addressed in the applicant's corrective action program under those specific portions of the quality assurance (QA) program that are used to meet Criterion XVI, "Corrective Action," of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix B. Appendix A of the GALL-SLR Report describes how an applicant may apply its 10 CFR Part 50, Appendix B, QA program to fulfill the corrective actions element of this AMP for both safety-related and nonsafety-related structures and component (SCs) within the scope of this program.

When the acceptance criteria are not met such that it is determined that the affected component should be replaced prior to the end of the subsequent period of extended operation, additional inspections are considered for determination of the extent of condition or cause in the applicable material/environment as well as other corrective actions.

operation, additional inspections are performed if the cause of the aging effect for each applicable material and environment is not corrected by repair or replacement for all components constructed of the same material and exposed to the same environment. The number of additional inspections is equal to the number of failed inspections for each material and environment population with a minimum of five additional visual and mechanical inspections when visual and mechanical inspections(s) did not meet acceptance criteria, or 20 percent of each applicable material and environment combination is inspected, whichever is less, and a minimum of one additional destructive examination when destruction examination(s) did not meet acceptance criteria. If subsequent inspections do not meet acceptance criteria, an extent of condition and extent of cause analysis is conducted to determine the further extent of inspections. The timing of the additional inspections is based on the severity of the degradation identified and is commensurate with the potential for loss of intended function. However, in all cases, the additional inspections are completed within the interval in which the original inspection was conducted or, if identified in the latter half of the current inspection interval, within the next refueling outage interval. These additional inspections conducted in the next inspection interval cannot also be credited towards the number of inspections in the latter interval. Additional samples are inspected for any recurring degradation to ensure corrective actions appropriately address the associated causes. At multi-unit sites, the additional inspections include inspections at all of the units with the same material, environment, and aging effect combination.

The program includes a process to evaluate difficult-to-access surfaces (e.g., heat exchanger shell interiors, exterior of heat exchanger tubes) if unacceptable inspection findings occur within the same material and environment population.

7.8. ***Confirmation Process****:* The confirmation process is addressed through those specific portions of the QA program that are used to meet Criterion XVI, "Corrective Action," of 10 CFR Part 50, Appendix B. Appendix A of the GALL-SLR Report describes how an applicant may apply its 10 CFR Part 50, Appendix B, QA program to fulfill the confirmation process element of this AMP for both safety-related and nonsafety-related SCs within the scope of this program.

8.9. ***Administrative Controls****:* Administrative controls are addressed through the QA program that is used to meet the requirements of 10 CFR Part 50, Appendix B, associated with managing the effects of aging. Appendix A of the GALL-SLR Report describes how an applicant may apply its 10 CFR Part 50, Appendix B, QA program to fulfill the administrative controls element of this AMP for both safety-related and nonsafety-related SCs within the scope of this program.

9.10. ***Operating Experience****:* OE shows that selective leaching has been detected in components constructed from gray cast iron, ductile iron, brass, bronze, and aluminum bronze. The following OE may be of significance to an applicant's program:

a. U.S. Nuclear Regulatory Commission (NRC) Information Notice (IN) 20-04, Operating Experience Related To Failure Of Buried Fire Protection Main Yard Piping, December 17, 2020

a.b. In March 2013, a licensee submitted an American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section XI relief request because it had detected weeping through aluminum bronze (susceptible to dealloying) valve bodies exposed to sea water. The degraded area was characterized by corrosion debris or wetness that returned following cleaning and drying of the surface.

[Agencywide Documents Access and Management System (ADAMS) Accession No. ML13091A038 and ML14182A634].

b.c. During a one-time inspection for selective leaching, a licensee identified degradation in four gray cast iron valve bodies in the service water system exposed to raw water. The mechanical test used by the licensee to identify the graphitization was tapping and scraping of the surface. The licensee sand blasted two of the valve bodies and, after all of the graphite was removed; the licensee determined that the leaching progressed to a depth of approximately 3/32 inch. Based on the estimated corrosion rate, the licensee determined that the valve bodies had adequate wall thickness for at least 20 years of additional service. (ADAMS Accession No. ML14017A289).

c.d. Based on visual inspections conducted as part of implementing a one-time inspection for selective leaching, a licensee identified selective leaching in a gray cast iron drain plug of an auxiliary feedwater pump outboard bearing cooler. Possible selective leaching was also found on multimatic valves on the underside of the clapper. As a result, the licensee incorporated quarterly inspections of the components in its periodic surveillance and preventive maintenance program. (ADAMS Accession No. ML13122A009).

d.e. In September 2008, a licensee identified the dealloying of an aluminum bronze strainer drum exposed to brackish water. This was identified after an unexpected material failure occurred, during a planned maintenance evolution at an offsite repair facility. The maintenance evolution involved rigging the strainer drum into position for a machining operation. During the rigging, the strainer drum material failed at the rigging attachment point to the strainer. This failure of the strainer drum exposed the inner portion of the drum material where dealloying of the drum was visually observed during an inspection. (ADAMS Accession No. ML092400531).

e.f. A licensee has reported occurrences of selective leaching of aluminum bronze components for an extensive number of years. (ADAMS Accession No. ML17142A263).

f.g. U.S. Nuclear Regulatory Commission (NRC) Information Notice (IN)NRC IN 84-71, Graphitic Corrosion of Cast Iron in Salt Water, September 06, 1984.

g.h. NRC IN 94-59, Accelerated Dealloying of Cast Aluminum-Bronze Valves Caused by Microbiologically Induced Corrosion, August 17, 1994.

h.i. The basis for inclusion of ductile iron in this GALL-SLR Report AMP XI.M33, along with OE examples, is cited in the GALL-SLR and SRP-SLR Supplemental Staff Guidance document. (ADAMS Accession No. ML16041A090).

The program is informed and enhanced when necessary through the systematic and ongoing review of both plant-specific and industry OE including research and development such that the effectiveness of the AMP is evaluated consistent with the discussion in Appendix B of the GALL-SLR Report.

References

10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.” Washington, DC: U.S. Nuclear Regulatory Commission. 2016.

EPRI. EPRI TR–107514, “Age Related Degradation Inspection Method and Demonstration.” Palo Alto, California: Electric Power Research Institute. April 1998.

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NRC. “GALL-SLR and SRP-SLR Supplemental Staff Guidance.” Agencywide Documents Access and Management System (ADAMS) Accession No. ML16041A090. Washington, DC: U.S. Nuclear Regulatory Commission. March 2016.

Selective Leaching: State-of-the-Art Technical Update. EPRI, Palo Alto, CA: 2019. 3002016057.

Ultrasonic NDE Techniques for Detection of Selective Leaching in Complex Shaped Gray Cast Iron Components. EPRI, Palo Alto, CA: 2021. 3002020830.

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XI.E3 INACCESSIBLE POWER CABLES NOT SUBJECT TO 10 CFR 50.49 ENVIRONMENTAL QUALIFICATION REQUIREMENTS

4. ***Detection of Aging Effects:*** For power cables exposed to significant moisture, test frequencies are adjusted based on test results (including trending of degradation where applicable) and operating experience. Cable testing should occur at least once every 6 years. A 6-year interval provides multiple data points during a 20-year period, which can be used to characterize the degradation rate. This is an adequate period to monitor performance of the cable and take appropriate corrective actions since experience has shown that although a slow process, aging degradation could be significant. The first tests for license renewal are to be completed prior to the period of extended operation with subsequent tests performed at least every 6 years thereafter. Medium-voltage cables (operated > 2 kV up to 35kV) that have been tested at least twice in the “good” range per the criteria established for dielectric loss in EPRI Report 3002000557 and with an insulation type that does not have operating experience of “good” cable failures due to significant moisture effects may be considered to extend the test frequency from every 6 years to every 10 years. The applicant can assess the condition of the cable insulation with reasonable confidence using one or more of the following techniques: Dielectric Loss (Dissipation Factor/Power Factor), AC Voltage Withstand, Partial Discharge, Step Voltage, Time Domain Reflectometry, Insulation Resistance and Polarization Index, Line Resonance Analysis, or other testing that is state-of- the-art at the time the tests are performed. One or more tests are used to determine the condition of the cables so they will continue to meet their intended function during the period of extended operation.

XI.E3 INACCESSIBLE POWER CABLES NOT SUBJECT TO 10 CFR 50.49 ENVIRONMENTAL QUALIFICATION REQUIREMENTS - REDLINE

4. ***Detection of Aging Effects:*** For power cables exposed to significant moisture, test frequencies are adjusted based on test results (including trending of degradation where applicable) and operating experience. Cable testing should occur at least once every 6 years. A 6-year interval provides multiple data points during a 20-year period, which can be used to characterize the degradation rate. This is an adequate period to monitor performance of the cable and take appropriate corrective actions since experience has shown that although a slow process, aging degradation could be significant. The first tests for license renewal are to be completed prior to the period of extended operation with subsequent tests performed at least every 6 years thereafter. Medium-voltage cables (operated > 2 kV up to 35kV) that have been tested at least twice in the "good" range per the criteria established for dielectric loss in EPRI Report 3002000557 and with an insulation type that does not have operating experience of "good" cable failures due to significant moisture effects may be considered to extend the test frequency from every 6 years to every 10 years. The applicant can assess the condition of the cable insulation with reasonable confidence using one or more of the following techniques: Dielectric Loss (Dissipation Factor/Power Factor), AC Voltage Withstand, Partial Discharge, Step Voltage, Time Domain Reflectometry, Insulation Resistance and Polarization Index, Line Resonance Analysis, or other testing that is state-of- the-art at the time the tests are performed. One or more tests are used to determine the condition of the cables so they will continue to meet their intended function during the period of extended operation.