Leveraging Risk Insights in Aging Management

June 2, 2022

NUCLEAR ENERGY INSTITUTE

Agenda

Topic	Presenters			
Background and Overview	Brett Titus Nuclear Energy Institute (NEI)			
Selective Leaching	Jolynn Oquist Xcel Energy	Barry Thurston Constellation Energy	Fernando Ferrante EPRI*	Dylan Cimock EPRI
Inaccessible Non-EQ Cables	Andrew Burgess Ameren Missouri	Drew Mantey EPRI	Jessica Bock EPRI	
Next Steps	Brett Titus NEI			

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Background and Overview

Risk Insights for Aging Management

- Since 1995, the NRC and industry have significantly expanded use of PRA & risk insights:
  - Maintenance Rule
  - Risk-informed Oversight
  - Risk-Informed Plant Licensing Basis Changes
  - Risk-Informed In-Service Inspection
  - Risk-Informed Categorization of SSCs (§ 50.69)
  - Risk-Informed Technical Specifications
  - Risk-Informed Fire Protection

- All operating reactors have invested heavily on site-specific PRA models that added significant quality and level of detail since the 1990s

- While the focus of each risk-informed application may be different, there are insights that can be leveraged to inform aging management effects

Risk Insights for Aging Management

- CY22 - Development of NEI Technical Report on Risk Insights for Aging Management
- May 2, 2022 - Publication of EPRI Report, *Leveraging Risk Insights for Aging Management Program Implementation: 2022*
- March 10, 2022 – Regulatory Information Conference Technical Session (https://ric.nrc.gov/docs/abstracts/sessionabstract-33.html)
- January 12, 2022 - Submitted Selective Leaching and Inaccessible Cable AMP mark-ups for incorporation into GALL-SLR and GALL

Selective Leaching

Background

- Utility implementation of the Selective Leaching (SL) Aging Management Program (AMP) has identified areas for improvement
- Selective Leaching industry operating experience provides new information that can be used in revising the Selective Leaching AMP
- Ongoing research by the industry and EPRI has identified opportunities to improve the effectiveness and efficiency of the Selective Leaching AMP

Intent Of Proposed Changes to SL AMP

- Objective 1: improve clarity of element 4 by re-structuring from long paragraphs to bullets and tables, using XI.M41 as a model.

- Objective 2: introduce the allowance for new NDE techniques, based on recent advancements and demonstrations of NDE technology

- Objective 3: introduce use of risk-insights into sample methodologies

- Objective 4: streamline the required corrective actions to credit utilities' well-established Corrective Action Program to determine appropriate extent of condition and extent of cause commensurate with safety significance

SL - Staff Question #1

Inspection Sample Size Reduction

- The extent of inspections for selective leaching during the subsequent period of extended operation (i.e., 3 percent with a maximum of 10 components per GALL-SLR guidance) was reduced when compared to the extent of inspections for selective leaching during the initial period of extended operation (i.e., 20 percent with a maximum of 25 components per GALL Report, Revision 2 guidance) based on six deterministic factors outlined in NUREG-2222, “Disposition of Public Comments on the Draft Subsequent License Renewal Guidance Documents NUREG–2191 and NUREG–2192.”
- The NEI document proposes a further reduction down to 2-3 components per population. Please provide the technical basis for this reduction.

Response Summary

- NEI proposal provides the option to use existing GALL-SLR sampling requirements or a risk-informed sampling methodology.
- Proposed revisions to Element 4 restructured existing sampling requirements into a tabular format - but did not change sampling quantities.
- Risk-informed sampling methodology may not reduce the number of components inspected.
- Risk-informed sampling methodology will drive smarter sampling than existing guidance.
- The risk insights framework was developed very similarly to other previously NRC-approved risk-informed categorization methodologies.

SL - Staff Question #1

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- The NEI document proposes a further reduction down to 2-3 components per population. Please provide the technical basis for this reduction.

Detailed Response

- Large revisions to Element 4 were largely focused on recommending a re-structuring of the existing content to improve the readability and flow of the AMP. Changes included taking large paragraphs and converting into a table format with footnotes and bullet points, similar to how XI.M41 is structured.
- New proposed Table XI.M33-1 addresses inspections on a per unit basis, including for all populations “3%, maximum of 10 components” – consistent with GALL-SLR.
- Risk-informed sampling methodology results in the same number or more inspections for sample populations up to 116.
- At the pilot plant in the EPRI study, proposed risk-informed sampling methodology would result in more inspections than required by current GALL-SLR requirements.

SL - Staff Question #1

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- The NEI document proposes a further reduction down to 2-3 components per population. Please provide the technical basis for this reduction.

Detailed Response (cont.)

- Lesser inspection quantities are justified considering:
  - Current guidance is susceptibility/probability biased. Component consequence of failure is not considered. Risk-informed sampling methodology considers both susceptibility/probability and consequence of failure.
  - Risk-informed sampling is based on a systematic, structured process that identifies the highest risk components in a given population and selects inspection samples based on assessing the structural integrity of those highest risk components.
  - Guidance on inspection sample selection does not need to drive inspections of components whose failure is within currently acceptable bounds of incremental plant safety risk as determined through PRA.
  - Populations are overly inflated if lower risk components are included; however, they should be (and are) considered for inspection as surrogates.
  - Proposed guidance is intended to set the minimum required inspections given that populations will vary significantly.

SL - Staff Question #1

Inspection Sample Size Reduction

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- The NEI document proposes a further reduction down to 2-3 components per population. Please provide the technical basis for this reduction.

Detailed Response (cont.)

- Similar RI-categorization and sampling methodologies have been applied to pressure boundary components and approved by the NRC:
  - Foundational methodology is in NRC-approved topical report TR-112657, REV B-A.
  - A key component of this methodology is the EPRI RI-ISI Risk Matrix, in which pressure boundary components are assigned to one of seven risk categories based upon the results of separate and independent evaluations (i.e. consequence of failure set to 1.0, failure potential evaluation is conducted even if the consequence of failure is low).
  - Significant industry experience with applying RI-ISI to safety related and non-safety related systems has shown portions of the pressure boundary receiving increased inspections (e.g. those with higher failure potential and consequence). Other portions of the pressure boundary may see a reduction in inspections.

SL - Staff Question #1

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- The NEI document proposes a further reduction down to 2-3 components per population. Please provide the technical basis for this reduction.

Detailed Response (cont.)

- Similar RI-categorization and sampling methodologies have been applied to pressure boundary components and approved by the NRC:
  - Per TR-112657, REV B-A, eliminating a large population of piping inspections in safety related systems in lowest risk locations will have a negligible on plant risk, to the point that a quantitative change in risk assessment is not required when eliminating these inspections.
  - Industry experience with RI-ISI has shown that when there is a reduction in the inspection population for other risk categories, the NRC approved change in risk acceptance criteria is always met. Further demonstrating the robustness of the evaluation processes (e.g. consequence of failure, failure potential), criteria (e.g. CCDP/CLERP ranges) and inspection populations.

SL - Staff Question #1

NEI

GALL-SLR

4. ***Detection of Aging Effects***: Inspections and examinations consist of the following:

- Visual inspections of all accessible surfaces. In certain copper-based alloys selective leaching can be detected by visual inspection through a change in color 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 surface.
- Mechanical examination techniques, such as chipping and scraping, augment visual inspections for gray cast iron and ductile iron components.
- Destructive examinations are used to determine the presence of and depth of dealloying through-wall thickness of components.

One-time and periodic inspections are conducted of a representative sample of each population. 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

Proposed Changes

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.

Table XI.M33-1

Environment Grouping	Inspections per Unit [4, 6]		
	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]

SL - Staff Question #1

GALL-SLR

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

XI.M33-2

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

Proposed Changes

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.

SL - Staff Question #1

GALL-SLR

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 and two destructive 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 examination is performed for that sample population. For three unit sites, seven visual and mechanical and one destructive 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?

Proposed Changes

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.

SL - Staff Question #1

GALL-SLR

Proposed Changes

- 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.

SL - Staff Question #2

Re-Introduction of Hardness Testing

- Hardness testing was replaced with mechanical examination techniques and destructive examinations with the issuance of GALL-SLR.
- Hardness testing can theoretically identify the presence of selective leaching but is unable to characterize the extent of selective leaching.
- Please provide the technical basis for re-introducing hardness testing.

Response Summary

- Hardness testing was proposed to be re-introduced as it can be an effective means to support detection of selective leaching.
- The intent of re-introducing hardness testing was to maximize the number of available inspection techniques utilities are able to leverage in order to detect the presence of the selective leaching in components.

SL - Staff Question #2

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- Please provide the technical basis for re-introducing hardness testing.

Detailed Response

- Hardness testing is a point measurement and does not reveal information about the condition of a component in other areas away from where the test was done.
  - However, hardness testing is proven to identify whether selective leaching has occurred where the test has been done.
- The proposed wording of XI.M33 acknowledges that it is not effective at characterizing the extent or depth of selective leaching.
- Industry operating experience has found successful use of hardness testing in conjunction with visual exams.
- As such, it can be a useful tool to confirm selective leaching in suspected areas found through visual inspection. In this context, hardness testing can improve the objectivity of visual inspection and should not be discarded.

SL - Staff Question #2

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- Hardness testing can theoretically identify the presence of selective leaching but is unable to characterize the extent of selective leaching.
- Please provide the technical basis for re-introducing hardness testing.

Detailed Response

- Proposed changes to Element 4 also state, “If a given inspection method yields inconclusive or potentially unsatisfactory results, a more capable method may be chosen for follow-up inspection and disposition of results.”
- The proposed changes are structured such that if acceptance criteria were not satisfied, the inspection would either need to be considered unsatisfactory, or the extent of selective leaching would need to be further investigated using more capable techniques.
- Use of hardness testing is analogous to a “screening” approach for selective leaching.

SL - Staff Question #2

Proposed Changes

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.

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.

SL - Staff Question #3

Credit for Undefined Future NDE Techniques

- The NEI document introduces "[n]ondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component" as an inspection method.
- The AMP should identify specific NDE techniques which are capable of detecting selective leaching in cast irons and copper alloys. (See reference below which notes that NDE for selective leaching has not achieved widespread acceptance.)
  - Uhlig's Corrosion Handbook, 3rd Edition, page 148, "Several researchers have reported on attempts to develop method of in situ nondestructive inspection for dealloying, but they have not achieved widespread acceptance."

Response Summary

- Selective leaching is an inherently difficult aging mechanism to detect. The proposed revisions to XI.M33 include recommendations to permit the use of nondestructive examination techniques in order to maximize the available methods that utilities can leverage in order to detect selective leaching.
- Recommendations to permit NDE techniques are based largely on EPRI research (see next page), including 2 recently published reports in 2021.
  - 3002020830, Ultrasonic NDE Techniques for Detection of Selective Leaching in Complex Shaped Gray Cast Iron Components
  - 3002020832, Electromagnetic NDE Techniques for Detection of Selective Leaching in Gray Cast Iron Piping

SL – Staff Question #3

EPRI Selective Leaching NDE Research

Title	Product ID	Year
Selective Leaching NDE Technical Basis Document – 2022 Research Update	TBD	2022
Ultrasonic NDE Techniques for Detection of Selective Leaching in Complex Shaped Gray Cast Iron Components	**3002020830**	**2021**
Electromagnetic NDE Techniques for Detection of Selective Leaching in Gray Cast Iron Piping	**3002020832**	**2021**
Selective Leaching: *State-of-the-Art Technical Update*	3002016057	2019
Guidance for Conducting Ultrasonic Examinations for the Detection of Selective Leaching	3002013168	2018
Assessment of Available Nondestructive Evaluation Techniques for Selective Leaching: *Technology Review*	3002008013	2016
Correlation of Selectively Leaching Thickness to Hardness for Gray Cast Iron and Brass	1025218	2012
Update to NDE for Selective Leaching of Gray Cast Iron Components	1019111	2009
NDE for Selective Leaching of Gray Cast Iron Components	1018939	2009

SL - Staff Question #3

Credit for Undefined Future NDE Techniques

- The NEI document introduces “[n]ondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component” as an inspection method.

- The AMP should identify specific NDE techniques which are capable of detecting selective leaching in cast irons and copper alloys. (See reference below which notes that NDE for selective leaching has not achieved widespread acceptance.)
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Detailed Response

- Proposed wording to address NDE techniques in XI.M33 specified that the techniques shall be volumetric in nature. More specific forms of NDE were not listed for the following reasons:

  - Use of the term volumetric was intended to capture both ultrasonic and electromagnetic techniques recently demonstrated in EPRI research.

  - Many electromagnetic NDE techniques go by vendor-specific names.

  - Use of the generic term volumetric aligns with similar wording found in other AMPs (e.g., XI.M30, XI.M38, XI.M41) and was intended to convey that the methods would be capable of detecting wall loss (vs. surface techniques).

  - Desire for flexibility in AMP implementation to allow use of technology as it continues to evolve and advance beyond today’s state-of-the-art. A statement included that the NDE methods must be demonstrated to be able to detect selective leaching. Similar concepts can be found in XI.M41 Element 4.

SL - Staff Question #3

Credit for Undefined Future NDE Techniques

- The NEI document introduces “[n]ondestructive examination techniques demonstrated to be capable of detecting the presence and/or extent of selective leaching on the component” as an inspection method.
- The AMP should identify specific NDE techniques which are capable of detecting selective leaching in cast irons and copper alloys. (See reference below which notes that NDE for selective leaching has not achieved widespread acceptance.)
  - Uhlig’s Corrosion Handbook, 3rd Edition, page 148, "Several researchers have reported on attempts to develop method of in situ nondestructive inspection for dealloying, but they have not achieved widespread acceptance."

Detailed Response

- Each inspection technique referenced for SL (visual, mechanical, hardness) will have their own specific set of capabilities and limitations. Allowance for relatively new, or future, NDE techniques is intended to permit utilities to better leverage new technology to more effectively and efficiently implement this aging management program.

SL - Staff Question #4

Reliance on One Inspection Technique

- GALL-SLR Report AMP XI.M33 recommends visual/mechanical and destructive examinations for each population.
- The NEI proposal states "[i]nspections and examinations may consist of any [of] the following methods" (referring to either visual/mechanical, hardness, nondestructive, or destructive examinations).
- Please provide the basis for going from two inspections techniques in our current guidance down to one inspection technique.

Response Summary

- The referenced wording in Question #4, cited from the proposed NEI revisions, was not intended to address the quantity of inspection techniques that are to be performed.
- Rather – the cited paragraph was intended to simply introduce the types of inspections that are acceptable in a more structured manner:
  - By material type
  - In successive order of increasing complexity (to deploy) and capability of detection

SL - Staff Question #4

Reliance on One Inspection Technique

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- Please provide the basis for going from two inspections techniques in our current guidance down to one inspection technique.

Detailed Response

- Inspection quantities listed in proposed Table XI.M33-1 reference footnote 3. Footnote 3 similarly states that for the inspections to be performed for a given population, some quantity shall be of a nondestructive or destructive variety.
  - This is similar to the existing guidance in GALL-SLR.
  - The only intended difference is that (demonstrated) volumetric NDE techniques could be deployed in lieu of the destructive testing as an option.
- The only time a single inspection technique would apply to a population would be if 100% of the population were to be inspected by volumetric NDE or destructive examination.

SL - Staff Question #4

Reliance on One Inspection Technique

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Detailed Response

- NUREG-2221 characterizes destructive exams as providing quantitative assessments of SL, while the other techniques (visual/mechanical) are referred to as providing qualitative assessments.
- Given this characterization, it is proposed that volumetric NDE techniques can be viewed in a similar perspective as that of destructive exams as they can provide a measurable or quantifiable extent of wall loss.
  - Refer to previously cited EPRI Reports on NDE.

SL - Staff Question #4

Current XI.M33

4. ***Detection of Aging Effects***: Inspections and examinations consist of the following:

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- Mechanical examination techniques, such as chipping and scraping, augment visual inspections for gray cast iron and ductile iron components.
- Destructive examinations are used to determine the presence of and depth of dealloying through-wall thickness of components.

Proposed XI.M33

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.

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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.

SL - Staff Question #4

Current XI.M33

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

Proposed XI.M33

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.

SL - Staff Question #5

Samples Based on Consequence

- When using the risk-informed sampling methodology, inspections focus on consequence not risk (i.e., the product of susceptibility and consequence).
- Is susceptibility to selective leaching considered while using this methodology?

Response Summary

- Susceptibility to selective leaching is considered in a qualitative manner to provide input into the process along with consequence information.
- This is included to provide better insight into high/low consequence impacts and to avoid overly conservative assessment of the SSC population.
- The consequence information is still available, such that the susceptibility is not unduly driving decisions on inspection focus.
- Based on engineering and research insights, considering susceptibility and loss of intended function for the SSC would provide a more complete picture of the inspection focus (along with consequence).

SL - Staff Question #5

Samples Based on Consequence

- When using the risk-informed sampling methodology, inspections focus on consequence not risk (i.e., the product of susceptibility and consequence).
- Is susceptibility to selective leaching considered while using this methodology?

Detailed Response

- Current aging management guidance from the GALL-SLR takes into consideration only likelihood of / susceptibility to selective leaching for in-scope SSCs when determining sample selection.
- For selective leaching there has been a limited understanding of material and environmental susceptibility factors that lead to the inception and/or progression of selective leaching hence, the likelihood of occurrence.
- The pilots and research performed indicate an approach that leverages risk insights to sample selection can be implemented that includes consideration of both likelihood and/or consequence of failures.
- The approach allows for conservative decisions to be made that do not over-rely on risk results (risk-based) nor give undue credit to qualitative susceptibility attributes.
- The framework does not discount consequence-based information, which are included in the framework, with a rationale for the appropriateness/basis of its inclusion.

SL - Staff Question #5

Samples Based on Consequence

- When using the risk-informed sampling methodology, inspections focus on consequence not risk (i.e., the product of susceptibility and consequence).
- Is susceptibility to selective leaching considered while using this methodology?

Detailed Response

- The attributes used to consider susceptibility to selective leaching, the scoring used, and the criteria for high/medium/low likelihood results are provided in the EPRI document.
- Susceptibility to selective leaching is used to place all SSCs on the risk matrix- which is the key output of the risk insights framework
- The placement of SSCs on the risk matrix is then used directly to determine not only sampling for inspections, but most importantly, to determine the ideal aging management strategies for in-scope SSCs.
- Susceptibility to selective leaching is specifically referenced in the definition of a surrogate component, which can be inspected in lieu of higher consequence components.

SL - Staff Question #5

Samples Based on Consequence

- When using the risk-informed sampling methodology, inspections focus on consequence not risk (i.e., the product of susceptibility and consequence).
- Is susceptibility to selective leaching considered while using this methodology?

Detailed Response

- Additional precedent from NRC-approved RI-categorization methodologies.
  - For RI-repair / replacement (RI-RRA) and 10CFR50.69 purposes, plants are using essentially the consequence portion of the RI-ISI methodology contained in TR-112657, REV B-A.
  - As such, this is a consequence-based approach to pressure boundary categorization rather than a pure risk approach.
  - The rationale behind this change in approach was that RI-RRA and 10CFR50.69 can be applied to many different pressure boundary component types and possibly subjected to a wide spectrum of degradation mechanisms,.
  - This conservative approach to component categorization (i.e. failure probability of 1.0) also provided a more streamlined (i.e. less costly) categorization process.
  - In contrast, this change is focused solely on the selective leaching mechanism.
  - Substantial work was undertaken to understand this mechanism and the attributes necessary for this mechanism to be operative in pressure boundary components that are within the scope of LR/SLR AMP programs.
  - As such, coupling of these two separate and independent evaluations (i.e. consequence of failure equal to 1.0, failure potential due selective leakage) is consistent with previously NRC RI-applications and provides a more informed approach to AMP for the selective leaching mechanism

SL - Staff Question #6

Removal of Prescriptive Corrective Actions

- The "corrective actions" program element of AMP XI.M33 (with the issuance of GALL-SLR) was revised to include specific recommendations for conducting extent of condition examinations when acceptance criteria are not met.
- This is consistent with several other GALL-SLR Report AMPs.
- The NEI document proposes deleting this language, please provide a technical basis for this change.

Response

- The Corrective Action Program is a well-established and regulated program at the utilities.
- The proposed change credits the Corrective Action Program to determine the appropriate causal analysis, extent of condition, extent of cause, etc., commensurate with safety significance of the identified issue.
- This proposed change cross-cuts several AMPs.

Inaccessible Power Cables Not Subject to 10 CFR 50.49 Environmental Qualification Requirements

Cables – Staff Question #1

Duration between testing

- Please specify a duration between testing for the provision “have been tested at least twice in the “good” range” (is this once -6 years prior to entering the period of extended operation and once more when entering the period of extended operation?).
- Do the test results need to be tested in the “good” range twice consecutively?

Response

- Cables should be tested on a 6-year frequency and two consecutive good test are required to extend to a 10-year frequency.
- The two consecutive tests can occur anytime prior to or during the PEO.

Cables – Staff Question #2

Insulation type and moisture effects

- Which insulation type(s) does not have an operating experience of “good” cable failures due to significant moisture effects?

Response

- Certain cable types have more operating experience of cable failures (e.g., XLPE, a compact EPR design, and black EPRs). However, since the industry adoption of the VLF tan delta test method there have been no known industry OE for any cable type that suggests failures soon after a “good” tan delta test as a common occurrence.
- Cable insulations that have a higher number of failure OEs was considered in the XI.E3 RIAM pilot. Each insulation type has different characteristics when exposed to water or other adverse environments. This was accounted for in development of the likelihood table. For instance, XLPE, butyl rubber, and compact insulation were weighted higher because they are more susceptible to long-term, water-related degradation mechanisms compared to pink/brown EPR or tree-resistance XLPE.

Cables – Staff Question #3

Data Trending

- NEI is proposing to increase the testing frequency by approximately 66% using two relatively undefined data points.
- Explain how using only two data points can establish a meaningful trend to inform changes to testing frequency.

Response

- EPRI PMBD vulnerability study indicates no increased failure rate for cables unless the test frequency is > a 10-year test period.
- EPRI review of industry test data since 2009 had no instances of long-term wetted cables failing when tested on a 6-year frequency, and very cables that tested “good” did not test less than “good” on subsequent tests.
- The test data points are very well defined by three different acceptance criteria (3002000557) each time the cable is tested. The acceptance criteria is based on an expert solicitation (1021070) and validated by EPRI review of industry test data between 2009-2015 (3002005321, 1025262).
- It is not just two data points that establish the trend, but every tests of a particular cable insulation type at each plant that uses that insulation are used to establish the health of a particular insulation type. When combined with industry OE shared via the EPRI Cable User Group provided input into the weighting factors in the Cable Pilot study.
- Using two consecutive tests helps to ensure the cable remains in good condition over a longer period. This helps to better understand the cable characteristics and responses in the installed environment prior to considering extending the monitoring frequency.
- If the test frequency is extended to a 10 years, if any subsequent test results suggests additional degradation is occurring, then accelerated test frequency or corrective action should be pursued accordingly based on the severity of the results.

Electrical Slides Back-up Information

Table 5-1
Tan δ assessment criteria for XLPE (in terms of x 10^3; 0.1 Hz test frequency)

Condition	Tan δ		Absolute Value of the Difference in Tan δ Between 0.5 V_0 and 1.5 V_0 (1, 2)		Percent Standard Deviation of Tan δ Measurements at Any Step of Test Voltage
Good	≤1.2	or	≤ 0.6	or	≤0.02
Further study required	>1.2, ≤ 2.2	or	>0.6, ≤ 1.0	or	>0.02, ≤0.04
Action required	>2.2	or	>1.0	or	>0.04

Notes for Table 5-1:
1. Differentials may be taken at 1 V_0 and 2 V_0 at the user's option. See the text preceding this table.
2. The difference in tan δ is normally positive. Negative differences should be treated as very significant and might indicate a problem with a test or the presence of a significant defect.

Table 5-2
Tan δ assessment criteria for butyl rubber and black EPR (in terms of x 10^3; 0.1 Hz test frequency)(1)

Condition	Tan δ		Absolute Value of the Difference in Tan δ Between 0.5 V_0 and 1.5 V_0 (2, 3)		Percent Standard Deviation of Tan δ Measurements at Any Step of Test Voltage
Good	≤12	or	≤3	or	≤0.02
Further study required	>12, ≤ 50	or	>3, ≤ 10	or	>0.02, ≤0.04
Action required	>50	or	>10	or	>0.04

Notes for Table 5-2:
1. This is based on the analysis performed in EPRI Report 1025262 [26].
2. Differentials may be taken at 1 V_0 and 2 V_0 at the user's option. See the text preceding these tables.
3. The difference in tan δ is normally positive. Negative differences should be treated as very significant and might indicate a problem with a test or the presence of a significant defect.

Table 5-3
Tan δ assessment criteria for pink EPR(1) (in terms of x 10^3; 0.1 Hz test frequency)(2)

Condition	Tan δ		Absolute Value of the Difference in Tan δ Between 0.5 V_0 and 1.5 V_0 (3, 4)		Percent Standard Deviation of Tan δ Measurements at Any Step of Test Voltage
Good	≤15	or	≤3	or	≤0.02
Further study required	>15, ≤30	or	>3, <8	or	>0.02, ≤0.04
Action required	>30	or	>8	or	>0.04

Notes for Table 5-3:
1. This may also be used for "Gray" UniBlend EPR. (The approximate time of manufacture is from the late 1970s on.)
2. This is based on analysis performed in EPRI report 1025262 [26]
3. Differentials may be taken at 1 V_0 and 2 V_0 at the user's option. See the text preceding these tables.
4. The difference in tan δ is normally positive. Negative differences should be treated as very significant and might indicate a problem with a test or the presence of a significant defect.

Table 5-4
Tan δ assessment criteria for brown EPR (in terms of x 10^3; 0.1 Hz test frequency)(1)

Condition	Tan δ		Absolute Value of the Difference in Tan δ Between 0.5 V_0 and 1.5 V_0 (2, 3)		Percent Standard Deviation of Tan δ Measurements at Any Step of Test Voltage
Good	≤50	or	≤5	or	≤0.02
Further study required	50, ≤60	or	>5, ≤15	or	>0.02, ≤0.04
Action required	>60	or	>15	or	>0.04

Notes for Table 5-4:
1. This is based on Figures C-3 and C-4 in EPRI report 1021070 [16] and consultation with tan δ testers.
2. Differentials may be taken at 1 V_0 and 2 V_0 at the user's option. See the text preceding these tables.
3. The difference in tan δ is normally positive. Negative differences should be treated as very significant and might indicate a problem with a test or the presence of a significant defect.

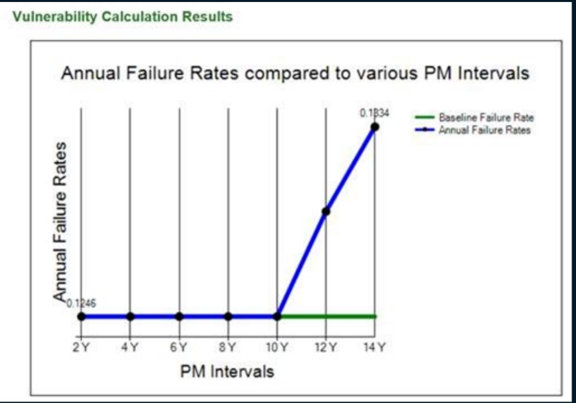
EPRI Report 3002000557 VLF Tan Delta Acceptance Criteria for Various Insulation types

Table 3-2
Tan δ test-identified cable issues summary table by insulation type

Insulation Type	Circuits Tested (Percent of Total Circuits)	Number of Circuit Issues	Deteriorated Component Identified		
			Termination	Splice	Insulation
Butyl rubber	14 (3%)	0	0	0	0
EPR, black	126 (23%)	13 (38%)	2	4*	7**
EPR black, hybrid	22 (4%)	1			
EPR, black, compact	15(3%)	1 (3%)	0	0	1
EPR, black, non-shielded	3(<1%)	0	0	0	0
EPR, brown	50 (9%)	2 (4%)	1	1	0
EPR, pink	181 (34%)	12 (35%)	5	3	4
EPR, pink, compact	74 (14%)	5 (17%)	1	1	3
EPR, pink/brown hybrid	6(1%)	0	0	0	0
TRXLPE	26(5%)	0	0	0	0
XLPE	11(2%)	0	0	0	0
XLPE, lead sheath	13(2%)	0	0	0	0
Totals	541***	34 (6.3%)	9 (26.5%)	9 (26.5%)	15 (47%)

* One circuit had deteriorated insulation and a deteriorated splice.
** Three cables were replaced due to historical issues, not high tan δ results.
*** The 541 circuits comprise approximately 1800 individual cables.

EPRI Report 3002005321 breakdown of cable issues for cables evaluated between 2009-2015



EPRI Preventive Maintenance Basis Database Vulnerability Result

Next Steps

- Additional Review of Technical Supporting Documents (?)
- Future public meeting(s)
- Schedule

