FINAL LICENSE RENEWAL INTERIM STAFF GUIDANCE
LR-ISG-2012-01

WALL THINNING DUE TO EROSION MECHANISMS

INTRODUCTION

This license renewal interim staff guidance (LR-ISG), LR-ISG-2012-01, provides interim guidance for an approach acceptable to the U.S. Nuclear Regulatory Commission (NRC) staff to manage the effects of aging during the period of extended operation for wall thinning due to various erosion mechanisms for piping and components within the scope of the License Renewal Rule (Title 10 of the *Code of Federal Regulations* Part 54 (10 CFR Part 54), "Requirements for Renewal of Operating Licenses for Nuclear Power Plants"). This LR-ISG revises NUREG-1801, Rev. 2, "Generic Aging Lessons Learned (GALL) Report," aging management program (AMP) XI.M17, "Flow-Accelerated Corrosion." It also supplements, or revises, related aging management recommendations in the GALL Report and NUREG-1800, Rev. 2, "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants" (SRP-LR).

DISCUSSION

Wall thinning due to erosion mechanisms has caused problems in the past and continues to be encountered in some operating reactor systems. Recent licensee event reports (254/2009-004-00, 237/2007-003-00, 277/2006-003-00) have documented inoperable equipment resulting from erosion which occurred during infrequent test activities and for piping that had previously been replaced with chromium-molybdenum material that was resistant to flow-accelerated corrosion (FAC). The staff has determined that existing guidance in the SRP-LR and the GALL Report does not adequately address wall thinning due to erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement. Erosion, similar to FAC, is a wall-thinning phenomenon related to fluid dynamics. However, each wall-thinning mechanism has unique causes, and effective aging management of wall thinning requires consideration of these individual mechanisms.

The NRC and industry guidance for the aging management of erosion mechanisms is largely absent, but in the case of cavitation erosion, industry guidelines (Electric Power Research Institute (EPRI) 1010639, Revision 4, "Non-Class 1 Mechanical Implementation Guideline and Mechanical Tools") state that it is typically associated with improper operation and is not an applicable aging effect because it is considered to be a design deficiency. The industry guidelines also state that this deficiency will be corrected during the current term of operation. In that regard, the Statement of Considerations (60 FR 22461, 22469; May 8, 1995) for 10 CFR Part 54 notes that corrective actions that should be taken to address functional degradation logically include cause determinations, which could involve mechanisms other than aging (e.g., improper operation), but those corrective actions should focus on prevention, elimination, or management of the effects caused by these mechanisms. During recent license renewal reviews, the staff found instances where applicants continued to experience loss of material due to cavitation erosion because the design deficiency was not corrected. In some of these cases, the applicants did not identify loss of material due to erosion as an aging effect requiring management, even though they conducted ongoing wall thickness monitoring and periodic repairs to in-scope components.

As noted in SRP-LR Section 2.1.3.2.2, “Long-Lived,” passive components that are not replaced on the basis of a qualified life or specified time period require an aging management review (AMR) under 10 CFR 54.21(a)(1)(ii). SRP-LR Section 2.1.3.2.2 also states that components replaced on the basis of condition are not generically excluded from an AMR, and condition monitoring may be evaluated as a program to ensure functionality during the period of extended operation. If an applicant has implemented a replacement strategy for susceptible items, such as replacement frequency that utilizes actual wall thinning data from past plant-specific operating experience, then the staff recognizes these items do not meet the definition of long-lived, passive components; therefore, they do not have to be managed for aging within the context of license renewal. However, if other strategies to manage the aging of the susceptible items are utilized, such as replacement based on periodic monitoring for loss of material by wall thickness measurements, then these items should be managed for aging, and this LR-ISG is applicable.

GALL Report AMP XI.M17, “Flow-Accelerated Corrosion,” manages wall thinning due to FAC. It is well established and widely used by industry. However, the existing guidance in this program is not fully applicable to wall thinning due to erosion mechanisms. For example, the “monitoring and trending” program element of AMP XI.M17 includes the use of software to identify locations most susceptible to wall thinning due to FAC, but the software does not identify locations most susceptible to erosion. Also, the “corrective actions” program element of AMP XI.M17 includes the replacement of susceptible components with FAC-resistant material, which does not necessarily prevent wall thinning due to erosion mechanisms. As such, additional consideration is needed to address wall thinning due to erosion mechanisms. As noted in EPRI guidelines in Nuclear Safety Analysis Center (NSAC)-202L, Revision 2 (April 1999) or Revision 3 (May 2006), “Recommendations for an Effective Flow-Accelerated Corrosion Program,” (NSAC-202L-R2 or -R3), if wall thinning has been caused by a mechanism other than FAC (e.g., erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement), and it is being managed through periodic monitoring, then an appropriate inspection program to address the suspected phenomenon should be developed.

<u>Clarifications to Definitions</u>

Section IX.E, “Aging Effects,” of the GALL Report currently includes “erosion,” and “flow-accelerated corrosion,” in its definition of “loss of material,” but only includes “cavitation” for concrete structures. Section IX.F, “Significant Aging Mechanisms,” of the GALL Report defines “erosion” as the “loss of material from a solid surface…due to mechanical interaction between that surface and a fluid.” In addition, it defines “flow-accelerated corrosion” as the “co-joint activity involving corrosion and erosion in the presence of a moving corrosive fluid leading to the accelerated loss of material.” Although the GALL Report definition associates FAC with erosion, NSAC-202L-R3 states that FAC is sometimes, but incorrectly, called erosion corrosion and notes that erosion is not part of the FAC degradation mechanism. Since erosion is not involved in the FAC process, as the GALL Report definition suggests, this may lead to some confusion and inconsistencies in how NRC guidance is applied. In addition, Section IX.E of the GALL Report currently defines “wall thinning” as an aging effect that “is a specific type of loss of material attributed to general corrosion or flow-accelerated corrosion.” In light of this discussion, the definitions of these aging effects and their associated mechanisms need to be revised to include additional mechanisms associated with erosion.

Although the GALL Report defines “erosion” and includes it as one of the mechanisms which causes loss of material, there are currently no specific AMR items for piping, piping components, or piping elements that cite loss of material due to erosion. This aspect has been recognized by the industry in EPRI Report 1010639, Section 3.1.6, which cites erosion as a plausible aging mechanism where particulates are not controlled or a two-phase flow is present. Within AMPs in the GALL Report, only AMP XI.M20, “Open-Cycle Cooling Water System,” includes erosion in its description of aging effects being managed, and this is only due to the presence of solid particles in raw water systems. There are, however, several other AMPs that discuss erosion in the “parameters monitored,” “detection of aging effects,” and “acceptance criteria,” program elements, but the AMR items associated with these other AMPs do not address piping, piping components or piping elements.

Erosion in piping is the result of fluid motion. It may take many forms including cavitation, flashing, liquid droplet impingement, and solid particle impingement. Due to the wide variety of conditions that can lead to erosion, erosion has been observed in many types of water systems. Erosion mechanisms are sometimes perceived as being comparable to wall thinning due to FAC; however, these other mechanisms are not addressed in the prediction methodology for FAC programs. Based on staff reviews of industry-wide operating experience, these additional mechanisms require further consideration to ensure that passive components are being maintained consistent with the current licensing basis.

Changes to the Flow-Accelerated Corrosion Aging Management Program

GALL Report AMP XI.M17, “Flow-Accelerated Corrosion,” relies on implementation of NSAC-202L-R2 or -R3. In 1989, the NRC issued Generic Letter 89-08, “Erosion/Corrosion-Induced Pipe Wall Thinning,” to ensure that operating nuclear power plants had developed these types of programs to address long-term degradation due to FAC. In general, FAC programs include analyses to determine critical locations, inspections to identify the extent of wall thinning at these locations, and follow-up inspections to monitor degradation rates. Corrective actions are taken as necessary to repair or replace the component subject to ongoing degradation to ensure it continues to meet the current licensing basis.

The FAC guideline, NSAC-202L-R2 and -R3, states that it does not address other wall-thinning mechanisms, such as cavitation or erosive wear. The staff notes that these other wall-thinning mechanisms are fundamentally different and require alternate analyses to predict susceptible locations and potentially require different solutions. However, the staff notes that the existing FAC program provides a useful methodology to plan and perform component inspections, and to record and trend inspection data. In that respect, NSAC-202L-R2 or -R3 notes that if the wear mechanism has not been identified, then inspections of components replaced with FAC-resistant materials should continue because these materials do not protect against damage from erosion mechanisms such as cavitation and liquid impingement. The staff’s review of operating experience has shown that, in some cases, wall thinning is caused by a combination of mechanisms, which includes FAC and some type of erosion (Callaway 1999, Dresden 2007).

These alternate wall-thinning mechanisms have been recognized in EPRI 1011231, “Cavitation, Flashing, Liquid Droplet Impingement, and Solid Particle Erosion in Nuclear Power Plant Piping Systems.” In addition, EPRI 112657, Revision B-A, “Revised Risk-Informed Inservice Inspection Evaluation Procedure,” includes “erosion cavitation” in the same “flow sensitive” category as FAC. Section 4.4.2 of NSAC-202L-R3 provides guidance for "Susceptible-Not-Modeled" lines, where reasonably accurate analytical models cannot be developed due to unknown or widely varying operating conditions. Lines or locations that are being monitored for wall thinning due to erosion mechanisms may be included with these other non-modeled lines and treated in a comparable fashion.

In its reviews of recent license renewal applications (LRAs) (e.g., Duane Arnold, Palo Verde, Columbia, South Texas Project), the staff noted that applicants were monitoring wall thinning due to various erosion mechanisms, including cavitation during infrequent operational alignments, such as surveillance activities or pump starts/stops. In addition, the staff noted some recent licensee event reports that documented inoperable equipment associated with erosion mechanisms (Dresden 2007, Quad Cities 2009). As stated, it is the staff's view that, if an applicant has resolved these types of situations (e.g., cavitation) by eliminating the source of the degradation through design or operating parameter changes, and after follow-up inspections confirmed that the degradation source was eliminated, then it would be expected that no further aging management activities for the specific concern that was eliminated would be required. The design change and effectiveness confirmation activities associated with these situations would be part of the normal corrective action program and would be considered in a license renewal review through ongoing operating experience reviews. However, if an applicant has decided to periodically monitor a component's condition instead of resolving erosion through a design change, then these monitoring activities should become part of an AMP to ensure the applicable code-required wall thicknesses are maintained consistent with the current licensing basis. In addition, if an applicant has resolved these types of situations by substituting more resistant material and not eliminating the source of the degradation, then periodic monitoring should continue. Although every plant site may not encounter erosion mechanisms, if ongoing monitoring of wall thinning due to erosion is not included as part of any other AMP, then these monitoring activities should be included in the FAC program.

ACTION

The staff has determined that the existing guidance in the SRP-LR and GALL Report does not adequately address aging management of wall thinning due to erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement. Consequently, the staff is taking the following actions:

1. The staff revised the definition of "wall thinning" in the GALL Report Table IX.E, "Selected Use of Terms for Describing and Standardizing AGING EFFECTS," to include erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement.

2. The staff revised the definition of "flow-accelerated corrosion," and "erosion," in the GALL Report Table IX.F, "Selected Definitions & Use of Terms for Describing and Standardizing AGING MECHANISMS," in order to better align them with the definitions commonly used in industry and to include specific forms of erosion, respectively.

3. The staff revised GALL Report AMP XI.M17 to include the following activities for applicants that have identified and chosen to monitor wall thinning due to erosion mechanisms:

- Identify susceptible locations based on the extent-of-condition reviews from corrective actions in response to plant-specific and industry operating experience. While this is clearly a corrective action program activity, its applicability to AMRs is also clear. As noted in SRP-LR Section A.1.2.3.4, a program based solely on detecting component failures should not be considered an effective AMP. For example, for wall thinning due to cavitation, in addition to addressing the loss of material, the extent of condition may need to consider the consequences of vibrational loading caused by cavitation.

- If an applicant has chosen to implement design changes which will eliminate the source of the erosion mechanism, then the confirmation process discussed in SRP-LR Section A.1.2.3.8 should periodically verify the effectiveness of the corrective actions. Periodic wall thickness measurements may be required until the effectiveness of the corrective actions has been confirmed.

- If an applicant has chosen to periodically monitor wall thickness as its basis for ensuring that the intended function(s) will be maintained in the period of extended operation, then this activity is part of a monitoring AMP that needs to be reviewed. As noted in SRP-LR Section 2.1.3.2.2, for periodic replacements based on condition, condition monitoring may be evaluated in the integrated plant assessment as a program to ensure functionality during the period of extended operation.

In addition, the staff revised GALL Report AMP XI.M17 in order to organize information in a more coherent manner and to correct inconsistencies. The "scope of program" specifies high-energy systems, and the staff notes that the term "high-energy" is not consistently defined, but it is typically associated with high pressure systems. Although this was the initial focus of the NRC's generic communication in this area, as correctly noted in NSAC-202L-R2 or -R3, "pressure does not affect the level of FAC wear," but a "failure in a low-pressure system could have significant consequences." Therefore, the reference to high-energy systems was deleted in the "scope of program" to better align the AMP with the more accurately stated scope of NSAC-202L-R2 or -R3.

4. The staff revised SRP-LR Table 3.0-1, "FSAR Supplement for Aging Management of Applicable Systems," for GALL Report Chapter XI.M17 to align it with the proposed change made to the scope of the program and revised SRP-LR Tables 3.1-1, 3.2-1, 3.3-1, and 3.4-1 by adding aging management review items to align the guidance with the change made to the scope of GALL Report AMP XI.M17. The staff also added associated items in the GALL Report to correspond with the new items in the SRP-LR.

The revised portions of the SRP-LR and the GALL Report are documented in Appendix A, "Revised SRP-LR," and Appendix B, "Revised GALL Report." The extent and locations of these changes are clarified in Appendix C, "Mark-Up Showing Changes to the SRP-LR," and Appendix D, "Mark-Up Showing Changes to the GALL Report."

The guidance in this final LR-ISG is approved. The staff will follow this guidance during its reviews of LRAs, and will incorporate this final LR-ISG into the next formal revision of the associated license renewal guidance documents. Current and future license renewal applicants should address this and all other active final LR-ISGs as stated in Nuclear Energy Institute (NEI) 95-10, Revision 6, "Industry Guidelines for Implementing the Requirements of

10 CFR Part 54 – License Renewal Rule." On July 13, 2012, the staff issued a *Federal Register* notice (77 FR 41457) to request public comments on the draft LR-ISG. In response, the NRC received comments from NEI by letter dated August 27, 2012. The NRC staff considered these comments in developing the final LR-ISG-2012-01. The staff's responses to these comments are in Appendix E, "Resolution of Public Comments on Draft LR-ISG-2012-01."

NEWLY IDENTIFIED SYSTEMS, STRUCTURES, AND COMPONENTS UNDER 10 CFR 54.37(b)

This LR-ISG addresses how wall thinning due to erosion mechanisms can be managed. It does not address whether components subject to wall thinning are within the scope of license renewal under 10 CFR 54.4. The NRC is not proposing to treat components being managed for wall thinning due to erosion mechanisms as "newly identified" systems, structures, and components (SSCs) under 10 CFR 54.37(b). Therefore, any additional action on such components which the NRC may impose upon current holders of renewed operating licenses under 10 CFR Part 54 would not fall within the scope of 10 CFR 54.37(b).

BACKFITTING AND ISSUE FINALITY

This LR-ISG contains guidance as to one acceptable approach for managing the effects of aging during the period of extended operation caused by erosion mechanisms for components within the scope of license renewal. Set forth below is the staff's discussion on compliance with the requirements of the Backfit Rule, 10 CFR 50.109.

<u>Compliance with the Backfit Rule and Issue Finality</u>

Issuance of this LR-ISG does not constitute backfitting as defined in 10 CFR 50.109(a)(1), and the NRC staff did not prepare a backfit analysis for issuing this LR-ISG. There are several rationales for this conclusion, depending upon the status of the nuclear power plant licensee.

Licensees who are currently in the license renewal process – The backfitting provisions in 10 CFR 50.109 do not protect an applicant, as backfitting policy considerations are not applicable to an applicant. Therefore, issuance of this LR-ISG does not constitute backfitting as defined in 10 CFR 50.109(a)(1). There are, currently, no combined license renewal applicants, and therefore the changes and new positions presented in the LR-ISG may be made without consideration of the issue finality provisions in 10 CFR Part 52.

Licensees who already hold a renewed license – This guidance is non-binding and the LR-ISG does not require current holders of renewed licenses to take any action (i.e., programmatic or plant hardware changes for managing the aging of components caused by erosion mechanisms). However, current holders of renewed licenses should treat this guidance as operating experience and take actions as appropriate to ensure that applicable AMPs are, and will remain, effective. If, in the future, the NRC decides to take additional action and impose requirements for management of components affected by erosion mechanisms, then the NRC will follow the requirements of the Backfit Rule.

Current operating license holders or combined license holders who have not applied for renewed licenses – The backfitting provisions in 10 CFR 50.109 do not protect a future applicant, as backfitting policy considerations are not applicable to a future applicant.

Therefore, issuance of this LR-ISG does not constitute backfitting as defined in 10 CFR 50.109(a)(1). The issue finality provisions of Part 52 do not extend to the aging management matters covered by Part 54, as evidenced by the requirement in 10 CFR 52.107 stating that applications for renewal of a combined license must be in accordance with 10 CFR Part 54.

CONGRESSIONAL REVIEW ACT

This ISG is a rule as designated in the Congressional Review Act (5 USC, Sec. 801-808). However, the Office of Management and Budget has determined that LR-ISG-2012-01 is not a major rule as designated under the Congressional Review Act.

REFERENCES

5 USC, Section 801, Congressional Review of Agency Rulemaking, Office of the Law Revision Counsel of the House of Representatives, 2012.

10 CFR Part 50, Domestic Licensing of Production and Utilization Facilities, Office of the Federal Register, National Archives and Records Administration, 2012.

10 CFR Part 52, Licenses, Certifications, and Approvals for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, 2012.

10 CFR Part 54, Requirements for Renewal of Operating Licenses for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, 2012.

EPRI TR-112657, “Revised Risk-Informed Inservice Inspection Evaluation Procedure,” Revision B-A, Electric Power Research Institute, Palo Alto, CA, December 1999 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML013470102).

EPRI 1010639, “Non-Class 1 Mechanical Implementation Guideline and Mechanical Tools, Revision 4,” Electric Power Research Institute, Palo Alto, CA, January 2006.

EPRI 1011231, “Recommendations for Controlling Cavitation, Flashing, Liquid Droplet Impingement, and Solid Particle Erosion in Nuclear Power Plant Piping Systems.” Electric Power Research Institute, Palo Alto, CA, November 2004.

Letter from C.R. Costanzo, NextEra Energy Duane Arnold, LLC to Document Control Desk, NRC, February 2, 2010, Subject: Response to Request for Additional Information, Letter No. NG-10-0043 (ADAMS Accession No. ML100350390).

Letter from J.H. Hesser, APS Palo Verde Nuclear Generating Station, to Document Control Desk, NRC, July 30, 2010, Subject: Response to Follow-up Request for Additional Information, Letter No. 102-06233-JHH/GAM (ADAMS Accession No. ML102240166).

Letter from S.K. Gambhir, Energy Northwest, Columbia Generating Station, to Document Control Desk, NRC, January 28, 2011, Subject: Response to Request for Additional Information, Letter No. G02-11-029, (ADAMS Accession No. ML110320419).

Letter from D.W. Rencurrel, South Texas Project, to Document Control Desk, NRC, November 21, 2011, Subject: Response to Requests for Additional Information, Letter No. NOC-AE-11002742, (ADAMS Accession No. ML11335A131).

Letter from Jason Remer, Nuclear Energy Institute, to Cindy Bladey, NRC, August 27, 2012, Subject: Industry Comments on Draft License Renewal Interim Staff Guidance, LR-ISG-2012-01, “Wall Thinning Due to Erosion Mechanisms,” (ADAMS Accession No. ML12244A004).

Licensee Event Report 483/1999-003-01, Callaway Unit 1, “Manual Reactor Trip Due to Heater Drain System Pipe Rupture Caused by Flow Accelerated Corrosion,” May 1, 2000 (ADAMS Accession No. ML003712775).

Licensee Event Report 277/2006-003-00, Peach Bottom Unit 2, “Elbow Leak on Piping Attached to Suppression Pool Results in Loss of Containment Integrity,” December 4, 2006 (ADAMS Accession No. ML063420059).

Licensee Event Report 237/2007-003-00, Dresden Unit 2, “High Pressure Coolant Injection System Declared Inoperable,” September 24, 2007 (ADAMS Accession No. ML072750663).

Licensee Event Report 254/2009-004-00, Quad Cities Unit 1, “Pinhole Leak in Core Spray Piping Results in Loss of Containment Integrity and Plant Shutdown for Repairs,” November 6, 2009 (ADAMS Accession No. ML093170206).

NEI 95-10, “Industry Guideline for Implementing the Requirements of 10 CFR Part 54 – License Renewal Rule, Revision 6, Nuclear Energy Institute, Washington, D.C., June 2005 (ADAMS Accession No. ML051860406).

NRC Generic Letter 89-08, “Erosion/Corrosion-Induced Pipe Wall Thinning,” Washington, D.C., May 2, 1989 (ADAMS Accession No. ML072780548).

NRC NUREG-1800, “Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants,” Revision 2, Washington, D.C., December 2010 (ADAMS Accession No. ML103490036).

NRC NUREG-1801, “Generic Aging Lessons Learned (GALL) Report,” Revision 2, Washington, D.C., December 2010 (ADAMS Accession No. ML103490041).

NSAC 202L, “Recommendations for an Effective Flow Accelerated Corrosion Program,” Revision 2, Electric Power Research Institute, Nuclear Safety Analysis Center, Palo Alto, CA, April 1999.

NSAC 202L, “Recommendations for an Effective Flow Accelerated Corrosion Program,” Revision 3, Electric Power Research Institute, Nuclear Safety Analysis Center, Palo Alto, CA, May 2006.

Appendices

Appendix A, Revised SRP-LR

Appendix B, Revised GALL Report

Appendix C, Mark-up Showing Changes to the SRP-LR

Appendix D, Mark-up Showing Changes to the GALL Report

Appendix E, Resolution of Public Comments on Draft LR-ISG-2012-01

Appendix A

Revised SRP-LR

Table 3.0-1 FSAR Supplement for Aging Management of Applicable Systems

GALL Chapter	GALL Program	Description of Program	Implementation Schedule	Applicable GALL Report and SRP-LR Chapter References
XI.M17	Flow-Accelerated Corrosion (FAC)	The program consists of (a) conducting appropriate analysis and baseline inspections, (b) determining the extent of thinning and replacement/repair of components, and (c) performing follow-up inspections to confirm or quantify and take long-term corrective actions. The program relies on implementation of EPRI guidelines of NSAC-202L-R2 or -R3. [Where applicable, the program also manages wall thinning due to erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement.]	Existing Program	GALL IV / SRP 3.1 GALL V / SRP 3.2 GALL VII / SRP 3.3 GALL VIII / SRP 3.4

Table 3.1-1 Summary of Aging Management Programs for Reactor Vessel, Internals, and Reactor Coolant System Evaluated in Chapter IV of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
110	BWR	Any material, piping, piping components, and piping elements exposed to reactor coolant	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No	IV.C1.R-406	N/A

Table 3.2-1 Summary of Aging Management Programs for Engineered Safety Features Evaluated in Chapter V of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
65	BWR/ PWR	Any material, piping, piping components, and piping elements exposed to treated water, treated water (borated)	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No	V.D1.E-407 V.D2.E-408	N/A N/A

Table 3.3-1 Summary of Aging Management Programs for Auxiliary Systems Evaluated in Chapter VII of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
126	BWR/ PWR	Any material, piping, piping components, and piping elements exposed to treated water, treated water (borated), raw water	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No	VII.C1.A-409 VII.E1.A-407 VII.E3.A-408	N/A N/A N/A

Table 3.3-2 Aging Management Programs for Auxiliary Systems for Aging Management of Auxiliary Systems

GALL Report Chapter/AMP	Program Name
Chapter XI.M17	Flow-Accelerated Corrosion

Table 3.4-1 Summary of Aging Management Programs for Steam and Power Conversion System Evaluated in Chapter VIII of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
60	BWR/ PWR	Any material, piping, piping components, and piping elements exposed to treated water	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No	VIII.D1.S-408 VIII.D2.S-408 VII.G.S-408	N/A N/A N/A

Appendix B

Revised GALL Report

IV REACTOR VESSEL, INTERNALS, AND REACTOR COOLANT SYSTEM
C1 Reactor Coolant Pressure Boundary (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
IV.C1. R-406		Piping, piping components, and piping elements	Any	Reactor Coolant	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No

V ENGINEERED SAFETY FEATURES
D1 Emergency Core Cooling System (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
V.D1. E-407		Piping, piping components, and piping elements	Any	Treated Water (borated)	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No

V ENGINEERED SAFETY FEATURES
D2 Emergency Core Cooling System (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
V.D2. E-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No

VII AUXILIARY SYSTEMS
C1 Open-Cycle Cooling Water System (Service Water System)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.C1 .A-409		Piping, piping components, and piping elements	Any	Raw water	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No

VII AUXILIARY SYSTEMS
E1 Chemical and Volume Control System (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.E1.A-407		Piping, piping components, and piping elements	Any	Treated water (borated)	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

VII AUXILIARY SYSTEMS
E3 Reactor Water Cleanup System (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.E3.A-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

VIII STEAM AND POWER CONVERSION SYSTEM
D1 Feedwater Systems (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VIII.D1.S-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

VIII STEAM AND POWER CONVERSION SYSTEM
D2 Feedwater Systems (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VIII.D2.S-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

VIII G — STEAM AND POWER CONVERSION SYSTEM
Auxiliary Feedwater System (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VIII.G. S-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, “Flow-Accelerated Corrosion”	No

Table IX.E, Selected Use of Terms for Describing and Standardizing AGING EFFECTS

Term	Usage in this document
Wall thinning	Wall thinning is a specific type of loss of material attributed in the AMR items to general corrosion, flow-accelerated corrosion, and erosion mechanisms including cavitation, flashing, droplet impingement, or solid particle impingement.

Table IX.F, Selected Definitions & Use of Terms for Describing and Standardizing AGING MECHANISMS

Term	Definition as used in this document
Erosion	Erosion is the progressive loss of material due to the mechanical interaction between a surface and a moving fluid. Different forms of erosion include cavitation, flashing, droplet impingement, and solid particle impingement.
Flow-accelerated corrosion (FAC)	Flow-accelerated corrosion is a corrosion mechanism which results in wall thinning of carbon steel components exposed to moving, high temperature, low-oxygen water, such as PWR primary and secondary water, and BWR reactor coolant. FAC is the result of dissolution of the surface film of the steel which is transported away from the site of dissolution by the movement of water. [Ref. 27]

XI.M17 FLOW-ACCELERATED CORROSION

Program Description

This program manages wall thinning caused by flow-accelerated corrosion (FAC) and may be used to manage wall thinning due to various erosion mechanisms. The program relies on implementation of the Electric Power Research Institute (EPRI) guidelines in the Nuclear Safety Analysis Center (NSAC)-202L-R2 or -R3 for an effective FAC program. The program includes performing (a) an analysis to determine critical locations, (b) limited baseline inspections to determine the extent of thinning at these locations, and (c) follow-up inspections to confirm the predictions, or repairing or replacing components as necessary. NSAC-202L-R2 or -R3 provides general guidelines for the FAC program. To provide reasonable assurance that all the aging effects caused by FAC are properly managed, the program includes the use of a predictive code, such as CHECWORKS, that uses the implementation guidance of NSAC-202L-R2 or -R3 to satisfy the criteria specified in 10 CFR Part 50, Appendix B, for development of procedures and control of special processes. With appropriate considerations, this program may also manage wall thinning caused by mechanisms other than FAC, in situations where periodic monitoring is used in lieu of eliminating the cause of various erosion mechanism(s).

Evaluation and Technical Basis

1. ***Scope of Program***: The FAC program, described by the EPRI guidelines in NSAC-202L-R2 or -R3, includes procedures or administrative controls to assure that structural integrity is maintained for carbon steel piping containing two-phase and single-phase fluids. This program also covers valve bodies that retain pressure in these systems. The FAC program was originally outlined in NUREG-1344 and was further described through the Nuclear Regulatory Commission (NRC) Generic Letter 89-08, “Erosion/Corrosion-Induced Pipe Wall Thinning.” The program may also include piping, piping components, and piping elements that are susceptible to erosion wall-thinning mechanisms such as cavitation, flashing, droplet impingement, or solid particle impingement in various water systems. Since there are no known materials that are immune to wall thinning due to erosion, piping and components of any material may be included in the erosion portion of the program.

2. ***Preventive Actions***: The FAC program is an analysis, inspection, and verification program; no preventive action has been recommended in this program. However, it is noted that monitoring of water chemistry to control pH and dissolved oxygen content are effective in reducing FAC, and the selection of appropriate piping material, geometry, and hydrodynamic conditions can be effective in reducing both FAC and erosion mechanisms.

3. ***Parameters Monitored/Inspected***: The aging management program monitors the effects of wall thinning due to FAC and erosion on the intended function of piping and components by measuring wall thickness.

4. ***Detection of Aging Effects***: Degradation of piping and components occurs by wall thinning. For FAC, the inspection program delineated in NSAC-202L-R2 or -R3 consists of identification of susceptible locations, as indicated by operating conditions or special considerations. This program specifies ultrasonic or radiographic testing to detect wall thinning. A representative sample of components is selected based on the most susceptible locations for wall thickness measurements at a frequency in accordance with NSAC-202L guidelines to ensure that degradation is identified and mitigated before the component integrity is challenged. The extent and schedule of the inspections ensure detection of wall thinning before the loss of intended function.

For erosion mechanisms, the program includes the identification of susceptible locations based on the extent-of-condition reviews from corrective actions in response to plant-specific or industry operating experience. Components in this category can be treated in a manner similar to other “susceptible–not-modeled” lines discussed in NSAC-202L-R2 or -R3. EPRI 1011231 provides guidance for identifying potential damage locations. EPRI TR-112657, “Revised Risk-Informed Inservice Inspection Evaluation Procedure,” Revision B-A, or NUREG/CR-6031, “Cavitation Guide for Control Valves,” provides additional insights for cavitation. For cavitation, in addition to wall thinning, the extent-of-condition review may need to consider the consequences of vibrational loading caused by cavitation.

5. ***Monitoring and Trending*:** For FAC mechanisms, CHECWORKS or a similar predictive code estimates component degradation, as indicated by specific plant data, including material, hydrodynamic, and operating conditions. CHECWORKS was developed and benchmarked by comparing CHECWORKS predictions against actual component thickness measurements obtained from many plants. Data from each component inspection is used to calibrate the wear rates calculated in the predictive model with the observed field data. The use of such a predictive code to develop an inspection schedule provides reasonable assurance that structural integrity will be maintained between inspections. The program includes the evaluation of inspection results to determine if additional inspections are needed to ensure that the extent of wall thinning is adequately determined, that intended function will not be lost, and that corrective actions are adequately identified. Previous wear rate predictions due to FAC may change after a power uprate is implemented. The program includes updating wear rates in CHECWORKS according to power uprate conditions. Subsequent field measurements are used to calibrate or benchmark the predicted wear rates.

   For erosion mechanisms, the program includes trending of wall thickness measurements at susceptible locations to adjust the monitoring frequency and to predict the remaining service life of the component for scheduling repairs or replacements. Inspection results are evaluated to determine if assumptions in the extent-of-condition review remain valid. If degradation is associated with infrequent operational alignments, such as surveillances or pump starts/stops, then trending activities may need to consider the number or duration of these occurrences. Periodic wall thickness measurements of replacement components may be required and should continue until the effectiveness of corrective actions has been confirmed.

6. ***Acceptance Criteria*:** Components are suitable for continued service if calculations determine that the predicted wall thickness at the next scheduled inspection is greater than or equal to the minimum allowable wall thickness. The minimum allowable wall thickness is typically the thickness needed to satisfy the hoop stress allowable under the original code of construction, but additional code requirements may also need to be met. A reasonable safety factor should be applied to the predicted wear rate determination to account for inaccuracies in the wear rate calculations and may need to consider uncertainties of ultrasonic testing measurements. As discussed in NSAC-202L-R3, the minimum safety factor should never be less than 1.1.

7. ***Corrective Actions*:** The program includes reevaluation, repair, or replacement of components for which the acceptance criteria are not satisfied, prior to their return to service. For FAC, long-term corrective actions could include adjusting operating parameters or replacing components with FAC-resistant materials. However, if the wear mechanism has not been identified, then the replaced components should remain in the inspection program because FAC-resistant materials do not protect against other damage

mechanisms. When components are replaced with FAC-resistant materials, the susceptible components immediately downstream should be monitored to identify any increased wear due to the "entrance effect" as discussed in EPRI 1015072.

For erosion mechanisms, long-term corrective actions to eliminate the cause could include adjusting operating parameters or changing component designs; however, the effectiveness of these corrective actions should be verified. Periodic monitoring activities should continue for any components replaced with an alternate material, since a material that is completely erosion resistant is not available. As discussed in the Appendix for the GALL Report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.

8. ***Confirmation Process***: Site quality assurance (QA) procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. As discussed in the Appendix for the GALL Report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.

9. ***Administrative Controls***: Site QA procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. As discussed in the Appendix for the GALL Report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.

10. ***Operating Experience***: Wall-thinning problems in single-phase systems have occurred in feedwater and condensate systems (NRC IE Bulletin No. 87-01; NRC Information Notice [IN] 92-35, IN 95-11, IN 2006-08) and in two-phase piping in extraction steam lines (NRC IN 89-53, IN 97-84) and moisture separator reheater and feedwater heater drains (NRC IN 89-53, IN 91-18, IN 93-21, IN 97-84). Observed wall thinning may be due to mechanisms other than FAC or, less commonly, due to a combination of mechanisms (NRC IN 99-19, Licensee Event Report (LER) 483/1999-003-01, LER 277/2006-003-00, LER 237/2007-003-00, LER 254/2009-004-00).

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Appendix C

Mark-up Showing Changes to the SRP-LR

Additions shown in underlineand bold
Deletions marked with strikethrough

Table 3.0-1 FSAR Supplement for Aging Management of Applicable Systems

GALL Chapter	GALL Program	Description of Program	Implementation Schedule	Applicable GALL Report and SRP-LR Chapter References
XI.M17	Flow-Accelerated Corrosion (FAC)	The program consists of (a) conducting appropriate analysis and baseline inspections, (b) determining the extent of thinning and replacement/repair of components, and (c) performing follow-up inspection to confirm or quantify and take long-term corrective actions. The program relies on implementation of EPRI guidelines of NSAC-202L-R2 or -R3. **[Where applicable, the program also manages wall thinning due to erosion mechanisms such as cavitation, flashing, droplet impingement, and solid particle impingement.]**	Existing Program	GALL IV / SRP 3.1 GALL V / SRP 3.2 **GALL VII / SRP 3.3** GALL VIII / SRP 3.4

Table 3.1-1 Summary of Aging Management Programs for Reactor Vessel, Internals, and Reactor Coolant System Evaluated in Chapter IV of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
110	**BWR/**	**Any material, piping, piping components, and piping elements exposed to reactor coolant**	**Wall thinning due to erosion**	**Chapter XI.M17, “Flow-Accelerated Corrosion”**	**No**	**IV.C1.R-406**	**N/A**

Table 3.2-1 Summary of Aging Management Programs for Engineered Safety Features Evaluated in Chapter V of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
65	BWR/ PWR	Any material, piping, piping components, and piping elements exposed to treated water, treated water (borated)	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No	V.D1.E-407 V.D2.E-408	N/A N/A

Table 3.3-1 Summary of Aging Management Programs for Auxiliary Systems Evaluated in Chapter VII of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
126	BWR/ PWR	Any material, piping, piping components, and piping elements exposed to treated water, treated water (borated), raw water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No	VII.C1.A-409 VII.E1.A-407 VII.E3.A-408	N/A N/A N/A

Table 3.3-2 Aging Management Programs Recommended for Aging Management of Auxiliary Systems

GALL Report Chapter/AMP	Program Name
Chapter XI.M17	Flow-Accelerated Corrosion

Table 3.4-1 Summary of Aging Management Programs for Steam and Power Conversion System Evaluated in Chapter VIII of the GALL Report

ID	Type	Component	Aging Effect/ Mechanism	Aging Management Programs	Further Evaluation Recommended	Rev2 Item	Rev1 Item
60	BWR/ PWR	Any material, piping, piping components, and piping elements exposed to treated water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No	VIII.D1.S-408 VIII.D2.S-408 VII.G.S-408	N/A N/A N/A

Appendix D

Mark-up Showing Changes to the GALL Report

Additions shown in underline and bold
Deletions marked with strikethrough

IV REACTOR VESSEL, INTERNALS, AND REACTOR COOLANT SYSTEM
C1 Reactor Coolant Pressure Boundary (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
IV.C1 R-406		Piping, piping components, and piping elements	Any	Reactor Coolant	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

V ENGINEERED SAFETY FEATURES
D1 Emergency Core Cooling System (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
V.D1 E-407		Piping, piping components, and piping elements	Any	Treated Water (borated)	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

V ENGINEERED SAFETY FEATURES
D2 Emergency Core Cooling System (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
V.D2 E-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

VII AUXILIARY SYSTEMS
C1 Open-Cycle Cooling Water System (Service Water System)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.C1 A-409		Piping, piping components, and piping elements	Any	Raw water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

VII AUXILIARY SYSTEMS
E1 Chemical and Volume Control System (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.E1 A-407		**Piping, piping components, and piping elements**	**Any**	**Treated water (borated)**	**Wall thinning due to erosion**	**Chapter XI.M17, "Flow-Accelerated Corrosion"**	**No**

VII AUXILIARY SYSTEMS
E3 Reactor Water Cleanup System (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VII.E3 A-408		**Piping, piping components, and piping elements**	**Any**	**Treated water**	**Wall thinning due to erosion**	**Chapter XI.M17, "Flow-Accelerated Corrosion"**	**No**

VIII STEAM AND POWER CONVERSION SYSTEM
D1 Feedwater Systems (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VIII.D1 S-408		**Piping, piping components, and piping elements**	**Any**	**Treated water**	**Wall thinning due to erosion**	**Chapter XI.M17, "Flow-Accelerated Corrosion"**	**No**

VIII STEAM AND POWER CONVERSION SYSTEM
D2 Feedwater Systems (BWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VIII.D2 S-408		**Piping, piping components, and piping elements**	**Any**	**Treated water**	**Wall thinning due to erosion**	**Chapter XI.M17, "Flow-Accelerated Corrosion"**	**No**

VIII STEAM AND POWER CONVERSION SYSTEM
G Auxiliary Feedwater System (PWR)

Item	Link	Structure and/or Component	Material	Environment	Aging Effect/ Mechanism	Aging Management Program (AMP)	Further Evaluation
VIII.G S-408		Piping, piping components, and piping elements	Any	Treated water	Wall thinning due to erosion	Chapter XI.M17, "Flow-Accelerated Corrosion"	No

Table IX.E, Selected Use of Terms for Describing and Standardizing AGING EFFECTS

Term	Usage in this document
Wall thinning	Wall thinning is a specific type of loss of material attributed in the AMR ~~line~~ items to general corrosion, ~~or~~ flow-accelerated corrosion, **and erosion mechanisms including cavitation, flashing, droplet impingement, or solid particle impingement.**

Table IX.F, Selected Definitions & Use of Terms for Describing and Standardizing AGING MECHANISMS

Term	Definition as used in this document
Erosion	Erosion~~, or~~ **is** the progressive loss of material ~~from a solid surface, is~~ due to the mechanical interaction between ~~that~~ **a** surface and a **moving** fluid~~, a multicomponent fluid, or solid particles carried by the fluid~~. **Different forms of erosion include cavitation, flashing, droplet impingement, and solid particle impingement.**
Flow-accelerated corrosion (FAC)	Flow-accelerated corrosion~~, also termed "erosion-corrosion," is a co-joint activity involving corrosion and erosion in the presence of a moving corrosive fluid, leading to the accelerated loss of material. Susceptibility may be determined using the review process outlined in Section 4.2 of NSAC-202L-R2 and R3 recommendations for an effective FAC program.~~ **is a corrosion mechanism which results in wall thinning of carbon steel components exposed to moving, high temperature, low-oxygen water, such as PWR primary and secondary water, and BWR reactor coolant. FAC is the result of dissolution of the surface film of the steel which is transported away from the site of dissolution by the movement of water.** [Ref. 27]

XI.M17 FLOW-ACCELERATED CORROSION

Program Description

This program manages wall thinning caused by flow-accelerated corrosion (FAC) and may be used to manage wall thinning due to various erosion mechanisms. The program relies on implementation of the Electric Power Research Institute (EPRI) guidelines in the Nuclear Safety Analysis Center (NSAC)-202L-R2 or **-**R3 for an effective ~~flow-accelerated corrosion (~~FAC~~)~~ program. The program includes performing (a) an analysis to determine critical locations, (b) limited baseline inspections to determine the extent of thinning at these locations, and (c) follow-up inspections to confirm the predictions, or repairing or replacing components as necessary. NSAC-202L-R2 or **-**R3 provides general guidelines for the FAC program. To provide reasonable assurance that all the aging effects caused by FAC are properly managed, the program includes the use of a predictive code, such as CHECWORKS, that uses the implementation guidance of NSAC-202L-R2 or -R3 to satisfy the criteria specified in 10 CFR Part 50, Appendix B, for development of procedures and control of special processes. **With appropriate considerations, this program may also manage wall thinning caused by mechanisms other than FAC, in situations where periodic monitoring is used in lieu of eliminating the cause of various erosion mechanism(s).**

Evaluation and Technical Basis

1. ***Scope of Program:*** The FAC program, described by the EPRI guidelines in NSAC-202L-R2 or **-**R3, includes procedures or administrative controls to assure that ~~the~~ structural integrity **is maintained for carbon steel piping containing two-phase and single-phase fluids** ~~of all carbon steel lines containing high-energy fluids (two-phase as well as single-phase) is maintained~~. **This program also covers** ~~V~~**v**alve bodies **that** retain~~ing~~ pressure in these ~~high-energy~~ systems ~~are also covered by the program~~. The FAC program was originally outlined in NUREG-1344 and was further described through the Nuclear Regulatory Commission (NRC) Generic Letter 89-08**, "Erosion/Corrosion-Induced Pipe Wall Thinning."** **The program may also include piping, piping components, and piping elements that are susceptible to erosion wall-thinning mechanisms such as cavitation, flashing, droplet impingement, or solid particle impingement in various water systems. Since there are no known materials that are immune to wall thinning due to erosion, piping and components of any material may be included in the erosion portion of the program.**

2. ***Preventive Actions:*** The FAC program is an analysis, inspection, and verification program; no preventive action has been recommended in this program. However, it is noted that monitoring of water chemistry to control pH and dissolved oxygen content **are effective in reducing FAC,** and **the** selection of appropriate piping material, geometry, and hydrodynamic conditions, **can be** effective in reducing **both** FAC **and erosion mechanisms**.

3. ***Parameters Monitored/Inspected:*** The aging management program monitors the effects of ~~loss of material~~ **wall thinning** due to ~~wall thinning~~ **FAC and erosion** on the intended function of piping and components by measuring wall thickness.

4. ***Detection of Aging Effects:*** Degradation of piping and components occurs by wall thinning. **For FAC,** ~~T~~the inspection program delineated in NSAC-202L-R2 or **-**R3 consists of identification of susceptible locations, as indicated by operating conditions or special considerations. **This program specifies** ~~U~~**u**ltrasonic or radiographic testing ~~is used~~ to detect wall thinning. A representative sample of components is selected based on the most susceptible locations for wall thickness measurements at a frequency in accordance with

NSAC**-**202L guidelines to ensure that degradation is identified and mitigated before the component integrity is challenged. The extent and schedule of the inspections ensure detection of wall thinning before the loss of intended function.

For erosion mechanisms, the program includes the identification of susceptible locations based on the extent-of-condition reviews from corrective actions in response to plant-specific or industry operating experience. Components in this category may be treated in a manner similar to other "susceptible-not-modeled" lines discussed in NSAC-202L-R2 or -R3. EPRI 1011231 provides guidance for identifying potential damage locations. EPRI TR-112657, "Revised Risk-Informed Inservice Inspection Evaluation Procedure," Revision B-A, or NUREG/CR-6031, "Cavitation Guide for Control Valves," provides additional insights for cavitation. For cavitation, in addition to wall-thinning, the extent-of-condition review may need to consider the consequences of vibrational loading caused by cavitation.

5. ***Monitoring and Trending:*** **For FAC mechanisms,** CHECWORKS or a similar predictive code estimates component degradation~~ in the systems conducive to FAC~~, as indicated by specific plant data, including material, hydrodynamic, and operating conditions. ~~CHECWORKS is acceptable because it provides a bounding analysis for FAC. The analysis is bounding because in general the predicted wear rates and component thicknesses are conservative when compared to actual field measurements.~~ **CHECWORKS was developed and benchmarked by comparing CHECWORKS predictions against actual component thickness measurements obtained from many plants. Data from each component inspection is used to calibrate the wear rates calculated in the predictive model with the observed field data.** ~~It is recognized that CHECWORKS is not always conservative in predicting component thickness; therefore, when measurements show the predictions to be non-conservative, the model must be re-calibrated using the latest field data. CHECWORKS was developed and benchmarked by comparing CHECWORKS predictions against actual measured component thickness measurements obtained from many plants.~~ The **use of such a predictive code to develop an** inspection schedule ~~developed by the licensee on the basis of the results of such a predictive code~~ provides reasonable assurance that structural integrity will be maintained between inspections. **The program includes the evaluation of** ~~I~~**i**nspection results ~~are evaluated~~ to determine if additional inspections are needed to ensure that the extent of wall thinning is adequately determined, that intended function will not be lost, and that corrective actions are adequately identified. Previous wear rate predictions due to FAC may change after a power uprate is implemented. **The program includes updating** ~~W~~**w**ear rates ~~are updated~~ in CHECWORKS according to power uprate conditions. Subsequent field measurements are used to calibrate or benchmark the predicted wear rates.

   For erosion mechanisms, the program includes trending of wall thickness measurements at susceptible locations to adjust the monitoring frequency and to predict the remaining service life of the component for scheduling repairs or replacements. Inspection results are evaluated to determine if assumptions in the extent-of-condition review remain valid. If degradation is associated with infrequent operational alignments, such as surveillances or pump starts/stops, then trending activities may need to consider the number or duration of these occurrences. Periodic wall thickness measurements of replacement components may be required and should continue until the effectiveness of corrective actions has been confirmed.

6. ***Acceptance Criteria:*** ~~Inspection results are input for a predictive computer code, such as CHECWORKS, to calculate the number of refueling or operating cycles remaining before the component reaches the minimum allowable wall thickness. If calculations indicate that an~~

~~area will reach the minimum allowed wall thickness before the next scheduled outage, corrective action should be considered~~. **Components are suitable for continued service if calculations determine that the predicted wall thickness at the next scheduled inspection is greater than or equal to the minimum allowable wall thickness. The minimum allowable wall thickness is typically the thickness needed to satisfy the hoop stress allowable under the original code of construction, but additional code requirements may also need to be met. A reasonable safety factor should be applied to the predicted wear rate determination to account for inaccuracies in the wear rate calculations and may need to consider uncertainties of ultrasonic testing measurements. As discussed in NSAC-202L-R3, the minimum safety factor should never be less than 1.1.**

7. ***Corrective Actions:*** **The program includes reevaluation, repair or replacement of** ~~Prior to service,~~ components for which the acceptance criteria are not satisfied, **prior to their return to service** ~~are reevaluated, repaired, or replaced~~. **For FAC,** ~~L~~**l**ong-term corrective actions could include adjusting operating parameters or ~~selecting~~ **replacing components with FAC-resistant** materials ~~resistant to FAC~~. **However, if the wear mechanism has not been identified, then the replaced components should remain in the inspection program because FAC-resistant materials do not protect against other damage mechanisms.** When ~~susceptible~~ components are replaced with FAC-resistant materials, ~~such as high Cr material,~~ the **susceptible components immediately** downstream ~~components~~ should be monitored ~~closely~~ to ~~mitigate~~ **identify** any increased wear **due to the "entrance effect" as discussed in EPRI 1015072**.

   For erosion mechanisms, long-term corrective actions to eliminate the cause could include adjusting operating parameters or changing component designs; however, the effectiveness of these corrective actions should be verified. Periodic monitoring activities should continue for any components replaced with an alternate material, since a material that is completely erosion resistant is not available. As discussed in the Appendix for **the** GALL **Report**, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.

8. ***Confirmation Process:*** Site quality assurance (QA) procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. As discussed in the Appendix for **the** GALL **Report**, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.

9. ***Administrative Controls:*** Site QA procedures, review and approval processes, and administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B. As discussed in the Appendix for **the** GALL **Report**, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.

10. ***Operating Experience:*** Wall-thinning problems in single-phase systems have occurred in feedwater and condensate systems (NRC IE Bulletin No. 87-01; NRC Information Notice [IN] ~~81-28, IN~~ 92-35, IN 95-11, IN 2006-08) and in two-phase piping in extraction steam lines (NRC IN 89-53, IN 97-84) and moisture separat**or**~~ion~~ reheater and feedwater heater drains (NRC IN 89-53, IN 91-18, IN 93-21, IN 97-84). Observed wall thinning may be due to mechanisms other than FAC~~, which require alternate materials to resolve the issue~~ **or less commonly, due to a combination of mechanisms (NRC IN 99-19, Licensee Event Report (LER) 483/1999-003-01, LER 277/2006-003-00,** LER ~~50-~~237/2007-003-00, **LER 254/2009-004-00**).

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Appendix E

Resolution of Public Comments on Draft LR-ISG-2012-01

Appendix E: Resolution of Public Comments on Draft LR-ISG-2012-01

Note: The Nuclear Energy Institute (NEI) submitted comments by letter dated August 27, 2012 (ADAMS Accession No. ML12244A004), which integrated multiple industry comments on the subject LR-ISG, including those submitted separately by Wolf Creek Nuclear Operating Corporation in a letter dated August 23, 2012 (ADAMS Accession No. ML12250A668). NEI's submittal letter contains two separate attachments. In the table below, the first column, No., refers to the attachment number (either 1 or 2) followed by the comment number from NEI's comment letter. The "Comment" and "Proposed Resolution" columns are from NEI's comment letter. The "Staff Response" column is self-explanatory.

No.	Comment	Proposed Resolution	Staff Response
1-1	General: The inclusion or addition of mechanical erosion mechanisms into the FAC AMP XI.M17 would be confusing and possibly detrimental to the currently well bounded and structured industry FAC programs. The susceptibility bases of industry FAC programs are clearly defined and the inclusion of erosion mechanisms would cross many of those boundaries. This would result in the FAC program having two separate sets of susceptibility criteria for FAC and erosion, as well as separate methods for selecting inspections and strategies; therefore, it makes sense to respond by creating a separate erosion program rather than mixing it into the current program. The inclusion or addition of mechanical erosion mechanisms into the FAC AMP (XI.M17) would significantly detract from the effectiveness of the current industry FAC programs in that the scope of the current programs would require expansion away from the focused "FAC susceptible" systems and components to the incorporation of virtually all piping systems into the program regardless of their susceptibility to FAC. Additionally significant changes to the current FAC program structures along with new guidance would be needed to facilitate new methodologies required for ranking of susceptible locations, new or updated "fitness for services" methodologies for determination of remaining service life (i.e. – linear vs. non-linear wear) and guidance for recommended mitigation strategies.	Create a separate AMP for mechanical erosion mechanisms. If a separate AMP is not created, consider revising XI.M38 - Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components instead. Create plant specific program AMR [aging management review] lines or create a separate AMP for mechanical erosion mechanisms in ESF and Steam & Power Conversion Systems. Consider management of erosion in safety related cooling water systems with AMP XI.M20 Open-Cycle Cooling Water System.	The staff disagrees with this comment and the proposed resolution. Mechanical erosion mechanisms have been detected and are being managed by several sites that have recently submitted license renewal applications (LRAs) through the FAC or Open-Cycle Cooling Water System AMPs. The staff, however, is unaware of any site that has previously proposed a separate AMP to address mechanical erosion mechanisms. The staff cautions, as noted in the LR-ISG, that GALL Report AMP XI.M20 implements the recommendations of Generic Letter 89-13, which only addressed erosion due to the presence of solid particles in raw water systems. As such, if mechanisms other than solid particle erosion are being managed by GALL Report AMP XI.M20, then this is inconsistent with the GALL Report, and an enhancement for the AMP should be included in the LRA. This LR-ISG reflects one approach to manage erosion mechanisms that is acceptable to the staff and does not preclude an applicant from creating a plant-specific AMP or from managing erosion mechanisms through an existing AMP by making appropriate enhancements. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-2	General: LR-ISG-2012-01 does not address a key consideration of operating experience associated with many of the erosion related phenomena such [as] damaging cavitation, or solid particle impingement. Many plants have chosen to “manage” or address erosion phenomena with a design modification or in some cases with a periodic replacement program. Both of these “management” techniques are example of operating experience that does require an aging management program.	Create plant specific program AMR lines or create a separate AMP for mechanical erosion mechanisms in ESF and Steam & Power Conversion Systems. Consider management of erosion in safety related cooling water systems with AMP XI.M20 Open-Cycle Cooling Water System.	The staff disagrees with the initial statement in the comment and the proposed resolution. As stated in the LR-ISG, if an applicant resolves erosion issues through design or operational changes, then no further age management activities would be required. Similarly, if a component is periodically replaced based on a fixed replacement frequency, then the component does not meet the definition of a “long-lived” component and it is not managed for aging in license renewal. Regarding the proposal to create a plant-specific AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
1-3	General: The inclusion or addition of mechanical erosion mechanisms into the clearly defined and bounded FAC AMP (XI.M17) would require significant program changes and conflicts with NSAC 202L-R3 and associated predictive codes such as CHECKWORKS. During aging management program reviews several exceptions would be required to incorporate management of erosion into the FAC program. For example management of erosion in cooling water systems and several ESF systems would require an exception to the FAC program exemptions for fluid temperatures less than 200F, systems with high levels of dissolved oxygen, and system with stainless steel (chrome content) piping. In addition NSAC 202L-R3 states that if wall thinning is being developed by mechanism other than FAC, an appropriate inspection program should be developed.	Create plant specific program AMR lines or create a separate AMP for mechanical erosion mechanisms in ESF and Steam & Power Conversion Systems. Consider management of erosion in safety related cooling water systems with AMP XI.M20 Open-Cycle Cooling Water System.	The staff disagrees with this comment and the proposed resolution. The staff does not expect the applicant to use the FAC program to predict erosion. Rather, the LR-ISG allows the FAC program to monitor components where erosion has been identified, similar to other components that are susceptible to FAC but cannot be modeled using the predictive software of the FAC program. Regarding the proposal to create a separate AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-4	General: LR-ISG-2012-01 clearly defines FAC and erosion as two different aging mechanisms that cause loss of material. Detection, analysis, and corrective action associated with erosion related phenomena such as damaging cavitation, and solid particle impingement are beyond the predictive tools of the FAC program. GALL includes specialized aging management program such as XI.M33 Selective Leaching and XI.M35 OTI of ASME Code Class 1 Small-Bore Piping for unique aging mechanisms and/or component considerations.	Create plant specific program AMR lines or create a separate AMP for mechanical erosion mechanisms in ESF and Steam & Power Conversion Systems. Consider management of erosion in safety related cooling water systems with AMP XI.M20 Open-Cycle Cooling Water System.	The staff disagrees with this comment and the proposed resolution. The LR-ISG allows the FAC program to monitor components where erosion has been identified, similar to other components that are susceptible to FAC but cannot be modeled using the predictive software of the FAC program. Regarding the proposal to create a plant-specific AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
1-5	General: Erosion→Erosion-corrosion→Corrosion is a continuum, moving from a purely mechanical effect to a purely electrochemical effect. FAC is a special case of erosion-corrosion since it only afflicts carbon steel under very specific environmental conditions (i.e., temperature, pH, dissolved oxygen, all of which control the solubility of magnetite and its susceptibility to removal by turbulence).	Add one or more paragraphs that state what is discussed in the comment, noting that FAC programs have been shown to effectively address FAC; however, solutions for FAC will not necessarily be effective for erosion or for erosion-corrosion phenomena of other materials.	The staff understands the comment, but does not agree that the LR-ISG should be revised. The effectiveness of the FAC program is implied by its existence in the GALL Report, but see comment 1-11 for additional discussion regarding the effectiveness of the FAC program. The LR-ISG and revised AMP XI.M17 currently distinguish between FAC and erosion and clearly state that no material is completely resistant to erosion mechanisms. No change was made to the LR-ISG in response to this comment.
1-6	General: Where treated water is monitored for particulates, erosion would only be due to cavitation in a single phase environment or only be due to droplet impingement or flashing in a two phase environment.	Consider adding this kind of guidance/information.	The staff disagrees with the comment and the proposed resolution. SRP-LR Sections 3.1.2.2.8 and 3.2.2.2.4 describe erosion in treated water that is not due to cavitation or droplet impingement. No change was made to the LR-ISG in response to this comment.
1-7	Page 2, 1st paragraph 3rd sentence: The CHECWORKS™ software does not specifically "identify locations susceptible to wall thinning" or "predict susceptible locations related to erosion." Susceptibility is defined and documented by programs engineers based on specific criteria and the software evaluates or predicts a relative rate of FAC wear for each component in the susceptible lines.	Reword: For example, the "monitoring and trending" program element of GALL Report AMP XI.M17 includes the use of software to identify locations **most** susceptible to wall thinning due to FAC, but the software does not **identify locations most susceptible to erosion.**	The staff agrees with the comment and changed the LR-ISG as proposed.

No.	Comment	Proposed Resolution	Staff Response
1-8	Page 2, 1st paragraph in Clarification: The statement "FAC is a pure corrosion process that does not have an erosion component" is not correct. While electrochemical conditions make the "window" where FAC will be operative very small, if there is no turbulence, there is no FAC and there is only minimal dissolution.	1. Revise the incorrect statement. 2. Define the (purely mechanical) erosion to the (purely electrochemical) corrosion continuum discussed above. Properly note where FAC lies in that continuum and why FAC only occurs for a single material class under special environmental conditions	The cited statement has been deleted and replaced with: "NSAC 202L-R3 states that FAC is sometimes, but incorrectly, called erosion corrosion and notes that erosion is not part of the FAC degradation mechanism."
1-9	Page 3, 2nd paragraph in Changes: The end of the second paragraph in the "Changes to FAC AMP" section, there is a reference to Callaway 1999; this is obviously a reference to the failure OE from Callaway. This OE event was attributed in part by both FAC and Erosion mechanisms. There is still a disagreement in the industry between the site, and EPRI, as to whether the report on this issue performed by an outside vendor is accurate.	Consider comments by EPRI, which have been communicated between the current Callaway site FAC Program Engineer, and EPRI experts on FAC and Wall Thinning mechanisms. They have extensively reviewed this OE, and are revisiting the incident to support the comments to this ISG.	The staff cannot consider comments that address future unknown actions of the industry. The LR-ISG is based on docketed correspondence in an LER from May 2000. The staff will consider changes to that information when a supplement to the LER is issued. No change was made to the LR-ISG in response to this comment.
1-10	Page 3, Clarifications to Definitions, last paragraph: This paragraph is completely correct, however, it does not offer a solution.	1. Clearly define erosion, erosion-corrosion, corrosion (and FAC) as noted above. 2. Note that erosion, in various forms (cavitation, particles, et al.) will cause metal loss. 3. Licensees must demonstrate that their programs address areas of "pure" erosion in terms of prediction, inspection, and resolution.	The staff understands the comment but disagrees with the proposed resolution. The LR-ISG currently states that erosion is a progressive loss of material. The definition cannot be limited to metal loss, since erosion is also associated with degradation of concrete, elastomers, and earthen structures. Regarding the "prediction, inspection, and resolution" of erosion, these aspects are addressed in the "detection of aging effects," "monitoring and trending," and "corrective actions" program elements of the revised AMP. Clarifications were added to each program element to clearly delineate between activities for FAC and activities for erosion mechanisms. No other changes were made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-11	Page 3, Changes to the FAC AMP, 3rd paragraph: "Lines that are being monitored for wall thinning due to erosion mechanisms may be included with these other non-modeled (per the FAC program) lines and treated in a comparable fashion."	Add a clearly worded sentence or paragraph that states that solutions to (pure) erosion conditions will be different than solutions to FAC, so the two degradation mechanisms must be addressed separately, but that the existing and well established FAC program and methodology provides a useful way to plan inspections, record and trend data, etc.	The staff agrees in part with the proposed resolution for erosion conditions. The staff believes that the paragraph above the one with the cited sentence provides sufficient guidance regarding different solutions to erosion from FAC. However, the staff added the following sentence in the LR-ISG to address using the existing FAC program: "However, the existing FAC program provides a useful methodology to plan and perform component inspections, and to record and trend inspection data." In addition, the staff changed the "corrective actions" program element of the AMP to clearly distinguish between actions for FAC and actions for erosion.
1-12	Page 3, 3rd full paragraph, last sentence. The operating experience at Callaway (in 1999) and Dresden (in 2007) are cited as examples of combined FAC and erosion. Callaway may have been an example but it is not clear from the lab analysis that it was. The Dresden operating experience could not have contained an FAC element since the material was FAC-resistant P11 chrome-moly steel.	Reword: The staff's review of operating experience has shown that, in some cases, wall thinning is **may be** caused by a combination of mechanisms, which includes FAC and some type of erosion ~~(Callawy 1999, Dresden 2007).~~	The staff disagrees with the comment and the proposed resolution. The Callaway event is discussed in comment 1-9. For the Dresden event, although the second failure in 2007 was not caused by FAC because of the material, the component initially failed in 1996 when it was carbon steel. The associated LER (237/1996-007) states that piping failed due to FAC as determined by an inspection. Based on the subsequent 2007 event, the problem was reasonably due a combination of mechanisms. No change was made to the LR-ISG in response to this comment, but see comment 1-32 for a related change to XI.M17.

No.	Comment	Proposed Resolution	Staff Response
1-13	Page 3, 3rd paragraph in "Changes to FAC AMP": While many FAC susceptible locations are modeled and wear predicted using software such as CHECWORKS, a very large portion of the program scope is included in the SNM (Non-modeled) evaluation. The value added by the new CHECWORKS erosion module which is soon to be released will be minimal and only useful in the SSE (modeled) scope. EPRI TR 1011231 and 112657 are discussed and compared as being used together for erosion monitoring.	Don't count on the use of any modifications to currently used program software, such as CHECWORKS, to greatly improve the industry's ability to predict or inspect for potential mechanical erosion induced wall thinning. Components which will be monitored for erosion thinning should not be treated similarly to SNM, as suggested in the ISG. SNM components inspections are strategically chosen at known likely problem areas based upon component geometry, and then generalities are made for the wall thinning of the components and lines. Choosing locations which are more likely to experience erosion and actually finding anything of value would be very unlikely.	The staff disagrees with the comment and the proposed resolution. The LR-ISG expects licensees to identify additional locations susceptible to erosion as part of the extent of condition following the identification of an erosion condition. The inclusion of components being monitored for erosion with SNM components should not change how licensees implement the SNM portion of the current program. The existing FAC program methodology provides a useful way to plan inspections, and record and trend data for managing loss of material due to wall thinning. No changes were made in response to this comment.
1-14	Page 3, 4th paragraph, last sentence: This sentence discusses lines being monitored for erosion damage. Most erosion mechanisms are caused by localized conditions. As such, they are component issues and not line issues. For example, cavitation may occur downstream of a flow control valve but it will not be a concern throughout the entire line.	Reword: Lines **or locations** that are being monitored for wall thinning due to erosion mechanisms may be included with these other non-modeled lines and treated in a comparable fashion.	The staff agrees with the comment and changed the LR-ISG as proposed.
1-15	Page 4, 1st paragraph, last sentence: Although this sentence does not specifically imply that mechanical erosion mechanisms should be covered in the FAC program it may lead to some expectations and these concerns have been noted in the general comments above.	Reword: Although every plant site may not encounter erosion mechanisms, if ongoing monitoring **activities** of wall thinning due to erosion **are occurring, they should be included in an AMP.** ~~is not included as part of any other AMP, then these monitoring activities should be included in the FAC program.~~	The staff disagrees with the comment and the proposed resolution. The staff feels that sufficient caveats have been added in the FAC AMP to highlight the differences between FAC and erosion mechanisms. No change was made to the LR-ISG in response to this comment.
1-16	Page 4, Action Bullet 2: The revised definition does not clarify the differences between FAC and (pure) erosion. The revised definition and continued ties to the FAC program, may actually add confusion.	See initial comment on clearly defining erosion through erosion-corrosion to corrosion and defining where FAC fits.	The staff disagrees with the comment and the proposed resolution. A number of licensees use the approach documented in the LR-ISG without apparent confusion. No change was made to the LR-ISG in response to this comment.
1-17	Page 4, Action Bullet 1 and 2: These bullets basically come out and say that erosion should be a separate AMP, but that industry and NRC don't want to make a separate AMP.	See Proposed Resolution for "Changes to the FAC AMP, third paragraph."	The staff disagrees with the comment and the proposed resolution. See staff response to comment 1-13. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-18	A-2, SRP Table 3.0-1: ISG states, "Where applicable, the program also manages wall thinning…." This change is unnecessary. The text does not define the mechanism except through reference to NSAC-202L, so stating that it also includes erosion mechanisms is unnecessary. NSAC-202L includes identifying loss of material based on OE regardless of whether due to erosion mechanisms or FAC. Managing loss of material due to erosion mechanisms is not precluded by the existing wording.	Delete the added phrase.	The staff disagrees with the comment and the proposed resolution. Although managing loss of material due to erosion is not precluded by the existing wording, the addition of the sentence as proposed by the NRC will clearly delineate when the FAC AMP manages mechanisms other than FAC. No change was made to the LR-ISG in response to this comment.
1-19	App B/D General: The FAC program implementation at PWRs addresses systems with carbon steel components. These are present in the secondary systems, and FAC is not used to manage primary (borated) systems. If site-specific OE indicates the need to manage additional aging effects in these systems, a different (or new) program would be chosen to provide that management.	Replace recommendations for assignment of FAC in tables IV.C2, V.D1, VII.C1, and VII.E1 with a plant-specific program for management of wall thinning due to erosion in these systems.	The staff disagrees with this comment and the proposed resolution. Regarding the proposal to create a plant-specific AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
1-20	App B/D General XI.M17, Scope: As above, the program implemented by NSAC-202L-R2 or R3 generally addresses systems with FAC-susceptible carbon steel components (less than 1.25% chromium) in single phase systems at or above 200F, or in two-phase systems. Allowance is provided to include additional non-modeled components that may have unknown or widely varying operating conditions that may prevent development of reasonably accurate analytical models. The inclusion of this allowance for scope expansion in NSAC-202L-R2/R3 was not intended to extend to additional systems and significantly different materials. If site-specific OE indicates the need to manage additional aging effects in these systems, a different (or new) program would be chosen to provide that management.	Revise last two sentences of Element 1. Scope of Program: to read: "The program may also include piping and components that are susceptible to erosion wall-thinning mechanisms such as cavitation, flashing, droplet impingement, or solid particle impingement in various water systems **that may be susceptible to FAC**. Since there are no known materials that are immune to wall thinning due to erosion, piping and components of any material may be included in the non-FAC portion of the program."	The staff disagrees with this comment and the proposed resolution. The proposed addition of the phrase limits the FAC program to only systems susceptible to FAC, which is counter to the approach being proffered by the staff. Regarding the comment to create a plant-specific AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-21	Page B-5 & D-5, Table IX.F: In the entry under Erosion, in the sentence that states, "Erosion is the progressive loss of material due to the mechanical interaction between a surface and a high-velocity fluid." This statement is incorrect. High-velocities are not required, especially for solid particle erosion as velocities ~ 5 feet per second have been shown to cause damage in raw water systems (e.g., Service Water Systems).	Reword: Erosion is the progressive loss of material due to the mechanical interaction between a surface and a ~~high-velocity~~ fluid.	The staff agrees with the comment, but instead of deleting "high velocity" replaced it with "moving."
1-22	Page B-5, GALL Table IX.F: The definition of erosion is correct and clear. The initial portion of the definition of FAC is also correct (and implies although not stated) that FAC is a special case of erosion-corrosion that only applies to carbon steel under very specific environmental conditions). The added items in brackets "[In previous versions of the GALL Report and past NRC generic communications, this type of corrosion has been incorrectly called erosion-corrosion, which is misleading since erosion implies a mechanical process instead of chemical dissolution.]" are not correct, as noted above in comments on Clarification and Definitions.	1. Remove the added items in brackets. 2. Add additional definitions of erosion-corrosion (an interaction between mechanical effects and electrochemical effects) and corrosion (a purely electrochemical process) and note that FAC is a special case of erosion-corrosion. 3. FAC Program. Note that FAC programs provide a useful and proven method for planning, executing, and recording inspections, and trending those results.	The staff agrees with the comment and deleted the sentence in brackets as suggested in item 1 of the proposed resolution. However, the staff does not believe that a new definition, as proposed in item 2 which notes that FAC is a special case of erosion-corrosion, should be added, since industry guidance documents do not support this point. See comment 1-36 for more information. No change was made to the LR-ISG in response to this portion of the comment. See comment 1-11 for changes made to the LR-ISG regarding the 3rd proposed resolution.
1-23	Page B-6, Program Description: Stating that the FAC program "may be used to manage wall thinning due to various erosion mechanisms" is good but also potentially asks for trouble (i.e., blindly using the FAC program will have licensees wonder why higher Cr carbon steel erodes (e.g., as shown in some of the OE).	Clearly state that the FAC program provides a useful format and methodology, however, the differences in the source, rates, solutions to degradation, etc. must be properly understood.	The staff understands the comment, but disagrees with the proposed resolution. The staff believes that it has included sufficient caveats regarding the limitations of using the FAC program for managing erosion mechanisms. Examples include the addition of "for FAC" and "for erosion mechanisms" in the "detection of aging effects," monitoring and trending," and "corrective action" program elements. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-24	Page B-6 (D-6) item 2: The noted conditions are effective in reducing or eliminating FAC but have minimal impact on erosion mechanisms.	Reword: However, it is noted that monitoring of water chemistry to control pH and dissolved oxygen content, and selection of appropriate piping material, geometry, and hydrodynamic conditions, are effective in reducing FAC and **but not** erosion mechanisms.	The staff partially agrees with the comment in that pH control and oxygen content will not affect erosion; however, the other cited conditions may be effective. GALL AMP XI.M17 was changed as follows: "…are effective in reducing FAC, and the selection of appropriate piping material, geometry, and hydrodynamic conditions can be effective in reducing both FAC and erosion mechanisms."
1-25	Page B-6 (D-6) item 1: Recommend revising "piping and components" to read "piping, piping components, and piping elements" since these are the only components listed in the marked up pages of the GALL included in the ISG. This would improve the clarity of the scope.	Reword: Revise "piping and components" to read "piping, piping components, and piping elements" to be consistent with other GALL component types.	The staff agrees with the comment and changed the LR-ISG as proposed.
1-26	Page B-7 (D-7) item 5, line 5: The sentence that begins, "It is recognized …" misrepresents the design and usage of CHECWORKS. CHECWORKSTM is a "best estimate" program and as such its predictions are adjusted by inspection data to pass through the center of the inspection data.	Reword: ~~It is recognized that CHECWORKSTM is not always conservative in predicting component thickness; therefore, when measurements show the predictions to be non-conservative, the model must be re-calibrated using the latest field data.~~ Inspection data from every refueling outage is input into CHECWORKSTM to ensure that the predictive model is properly re-calibrated.	The staff notes that the comment pertains to existing wording in the AMP that is not being changed by this LR-ISG. However, the staff agrees that the use of inspection data can be more clearly described in the AMP. The sentence in the proposed resolution was deleted and replaced with: "Data from each component inspection is used to calibrate the wear rates calculated in the predictive model with those observed in field data."
1-27	Page B-7 (D-7) element 4: It is uncertain at what level of wall thinning an extent of review is required. Element 4 states "If wall thinning due to an erosion mechanism (e.g., cavitation, flashing, droplet impingement, or solid particle impingement) is identified, then the applicant performs an extent-of-condition review to identify other components that are comparably susceptible to the same mechanism"	Include criteria to define when an extent of review is required.	The staff agrees with the comment, but disagrees with the proposed resolution. A licensee's corrective action program controls when an extent of condition is required, and guidance in that regard is not appropriate for an AMP. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-28	Page B-7 (D-7) element 5, 2nd paragraph: Element 5 does not identify a preferred methodology to be used to “predict the remaining service life of the component”	Identify the methodology preferred by the NRC to “predict the remaining service life to the component.”	The staff understands the comment but disagrees with the proposed resolution. NSAC-202L provides several methods to determine wear between two outages and remaining service life. Comparable to degradation due to FAC, the NRC allows licensees to determine the method that is used. No change was made to the LR-ISG in response to this comment.
1-29	Page B-7 (D-7) element 5, 2nd paragraph: Predictive tools are absent.	Identify the lack of predictive tools, meaning that the licensee must have some understanding of where susceptibilities could exist in the system and must act accordingly.	The staff agrees with the comment, but disagrees with the proposed resolution. The “detection of aging effects” program element provides several references that provide insights into understanding susceptibilities in the system. No change was made to the LR-ISG in response to this comment.
1-30	Page B-8 (D-8) element 7, 2nd sentence: The paragraph is accurate, but it would be clearer to modify the second sentence.	Reword: For FAC, long-term corrective actions could include adjusting operating parameters or selecting resistant materials.	The staff agrees with the comment and changed the LR-ISG as proposed.
1-31	Page B-8 (D-8) element 7, Corrective Actions: No guidance is given for evaluating the effectiveness of corrective actions for erosion mechanisms or “as part an AMP,” presumably, a different AMP.	As noted above, clearly state (and reiterate) that the FAC program (merely) provides a useful format and methodology, however, the differences in the sources, rates, solutions to degradation, etc. must be properly understood. That is, in the absence of a separate AMP to cover erosion mechanisms, the AMP format, etc. can be used; however, the differences between FAC and erosion must be clearly understood in terms of drivers and solutions.	The staff agrees with the comment and the proposed resolution. The associated portion of the “corrective action” program element was revised to clarify the corrective actions for erosion. Also, the “monitoring and trending” program element currently discusses continuing periodic wall thickness measurements as part of confirming the effectiveness of corrective actions for replacement components. With regard to differences between FAC and non-FAC “drivers and solutions,” several changes have been made to clearly distinguish between these mechanisms in response to this comment and comments 1-24, 1-30, 1-43, and 2-6.

No.	Comment	Proposed Resolution	Staff Response
1-32	Page B-8 (D-8) item 10: Five examples of operating experience are cited as "… other than FAC or a combination of mechanisms." Looking at the five: 1) Point Beach – FWH shell was due to FAC alone according to EPRI review. 2) Callaway - may have been an example but it is not clear from the lab analysis. 3) Peach Bottom – cavitation erosion, abrasive erosion (i.e., solid particle erosion), and water jet cutting 4) Dresden – liquid droplet impingement, 5) Quad Cities – "erosion." While wall thinning caused by a combination of mechanisms may occur, it is not common.	Reword: Observed wall thinning may be due to mechanisms other than FAC or, less commonly, due to a combination of mechanisms.	The staff agrees with the comment and changed the LR-ISG as proposed.
1-33	Page D-2, GALL IV-C2: It is hard to imagine that wall thinning is an issue in the RCS system of a PWR. Particulates are monitored, the only place two-phase coolant exists is next to the fuel rods and in the pressurizer, and the only place cavitation or flashing would occur is in the RCP or downstream of connecting valves or orifices, which may or may not be the RCS system. Based on review of EPRI 1011231 "Recommendations for Controlling Cavitation, Flashing, Liquid Droplet Impingement, and Solid Particle Erosion in Nuclear Power Plant Piping Systems," we do not understand the NRC concern for erosion in the RCS of PWRs. BWRs are mentioned in EPRI 1011231, but not PWRs.	Make line item specific to BWRs. In GALL, Rev 2, FAC is only applied to BWRs. I did not see any examples of wall thinning in the RCS system in the ISG, yet the revisions seem to focus on the RCS system. I know Palo Verde experienced cavitation issues related to the RCPs during start-up, but these were resolved. Add OE related to erosion to the AMP and provide the cause.	The staff agrees with the comment and deleted the new item in IV-C2 for wall thinning due to erosion in the reactor coolant system of PWRs. Regarding the proposed resolution to add erosion-related OE to the AMP, the staff believes sufficient operating experience relating to erosion is included in the current changes to the AMP.
1-34	Page D-3, VII C1: This line item is not needed as XI. M20 manages erosion in service water systems in accordance with [Generic Letter (GL)] 89-13 commitments. This new item confuses this issue. To do this would be contrary to the [GL] 89-13 commitment which is part of [XI.]M20.	Delete this line item as it is not needed. Revise [XI.]M20 to include wall thinning due to erosion as an aging effect. Do not credit a program that is not part of the [GL] 89-13 commitments.	The staff disagrees with the comment and the proposed resolution. Although GL 89-13 included routine inspections for erosion, it only considered erosion due to suspended particulates. If erosion due to causes other than solid particle erosion has been identified, then this degradation typically would not be included in GL 89-13 commitments. However, while XI.M20 relies on implementation of GL 89-13, this does not preclude a licensee from performing aging management activities through a different AMP by using a generic note E. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
1-35	Page D-5, Table IX.F::Says, "Different forms of erosion may include cavitation, flashing, droplet impingement, or solid particle impingement." Forms of erosion DO include the listed items.	Change to read, "Different forms of erosion include cavitation, flashing, droplet impingement, and solid particle impingement.	The staff agrees with the comment and changed the LR-ISG as proposed.
1-36	Page D-5, Table IX.F: Definition of FAC contains reference to previous definitions. This is unnecessary. Recommend just sticking with the new definition without apologizing for previous version.	Delete "[In previous versions of the GALL Report and past NRC generic communications, this type of corrosion has been incorrectly called erosion-corrosion, which is misleading since erosion implies a mechanical process instead of chemical dissolution]."	The staff agrees with the comment and changed the LR-ISG as proposed.
1-37	Page D-5, Table IX.F, FAC: This section was more correct before the modifications. That is, it did not define FAC as only being operative on piping. It did correctly state that FAC is a form of erosion-corrosion, and that the mechanism is well understood and well described.	1. Return to the original wording. 2. Add discussion as proposed in the comment for Discussion – General.	The staff agrees that the definition should not be restricted only to piping, and replaced "piping" with "components" in the definition. However, NSAC-202L states: *Flow-accelerated corrosion is sometimes, but incorrectly, called erosion-corrosion. Erosion, it should be noted, is not part of the degradation mechanism.* Based on the above, the staff disagrees that the previous definition was more correct before the modification, and thus retained the revision to the LR-ISG.
1-38	Page D-6, Program Description: The qualifier is unnecessary. Should limit the discussion to what the program does; not necessarily when you may choose to use it.	Delete "if the erosion mechanisms are not being managed by another program."	The staff agrees with the comment and changed the LR-ISG. Also see responses to comments 1-39 and 2-7.
1-39	Page D-6, Program Description: Added paragraph indicates that "an appropriate inspection program … should be developed." The FAC "program" may be that program and it is already "developed" as described in XI.M17.	Recommend modifying the first sentence to indicate that wall thinning may be caused by the listed mechanisms and reference the EPRI 1011231, and that this [XI.]M17 program may be used to manage such wall thinning. Perhaps combine the first sentence of the Program Description into this paragraph.	The staff agrees with the comment and changed the LR-ISG. Also see responses to comments 1-38 and 2-7.
1-40	Page D-6, Element 1: In added text, don't need to specify a "non-FAC portion of the program."	Delete from last sentence, "the non-FAC portion of."	The staff disagrees with the comment and the proposed resolution. However, for clarity the term "non-FAC" was changed to "erosion." The phrase "...erosion portion of..." is being retained to reinforce the distinction between components in scope for FAC and components in scope for erosion.

No.	Comment	Proposed Resolution	Staff Response
1-41	Page D-6, Element 3: In its basic form, wall thinning is still loss of material.	Recommend leaving loss of material as the relevant aging effect.	The staff agrees with the comment but disagrees with the proposed resolution. GALL Report Table IX.E currently defines the aging effect "wall thinning" as a specific type of loss of material attributed to FAC, and defines FAC and erosion as aging mechanisms. The AMP has been corrected because it previously ascribed an aging effect due to another aging effect instead of aging mechanisms. No change was made to the LR-ISG in response to this comment.
1-42	Page D-6, Element 4: The added discussion on performing extent of condition review is unnecessary and redundant. As stated on page 4 extent of condition is part of corrective action element and should remain only there. There is no need to include this review in element 4 as detection of aging effects is used to provide information on how the aging effects will be detected not corrective actions. It states in this element that the program includes identification of susceptible locations which is the same as an extent of condition review.	Delete the extent of condition review discussion.	The staff agrees that the extent-of-condition review is part of the corrective action element. However, since the prediction of susceptible locations for erosion mechanisms is not as defined as for FAC through CHECWORKS, the extent-of-condition review is the starting point for this aspect and needs to be discussed in the "detection of aging effects" program element. AMP XI.M17 "detection of aging effects" program element was revised to clarify that the extent-of-condition reviews are from corrective actions in response to operating experience.
1-43	Page D-7, Element 5: The first paragraph is modified to expand and update discussions of CHECWORKS, et al. but does not clearly state that those codes and associated chemistry and materials selection solutions are for FAC and FAC only.	The first paragraph must clearly state whenever possible that CHECWORKS, et al. are for FAC and FAC only. The (added) second paragraph on erosion should note that the methodology for inspection planning, execution of inspections, data recording, data trending, etc. provided in FAC programs can be useful for erosion evaluations, but that predictive methods for FAC or FAC solutions will not be applicable to erosion.	The staff agrees with the comment and notes that, although NSAC-202L and CHECWORKS training provides sufficient guidance regarding limitations for erosion mechanisms, the staff added additional clarifications in the AMP by re-wording the first sentence of element 5. Also, clarification between FAC and erosion were made in response to comments 1-24, 1-30, and 2-6.
1-44	Page D-8, Element 6: Acceptance criteria should not refer to inputting data into a predictive code or say you need to include corrective actions. The prediction may be a simple straight line projection from two measured points. Corrective actions are covered by element #7.	Revise the first part of first sentence to read, "Inspection results are used to calculate…". Change last sentence to say, "Calculations indicate that an area will not reach the minimum allowed wall thickness before the next scheduled inspection."	The staff agrees that the wording in the acceptance criteria program element should be revised. The staff replaced the existing program element with words from NSAC-202L Section 4.7 and 4.9.

No.	Comment	Proposed Resolution	Staff Response
1-45	Page D-8, Element 7: The statement, "The selection of replacement materials requires consideration of a number factors, because a material that is completely erosion resistant is not available." can be shortened. It could just say "A material that is completely erosion resistant is not available." Whenever replacement materials are evaluated a number of factors are normally considered.	Revise the wording to shorten the statement.	The staff agrees with the comment and changed XI.M17 "corrective action" program element as follows: "Periodic monitoring activities should continue for any components replaced with resistant material, since a material that is completely erosion resistant is not available."
2-1	Introduction: Erosion mechanisms are not "Aging Effects."	The erosion mechanisms discussed do result in wall thinning but are not aging effects similar to general corrosion, FAC, MIC, etc. Remove the reference to aging mechanisms and only refer to the wall thinning or wear attributes of the erosion mechanisms.	The staff disagrees with this comment and the proposed resolution. Wall thinning caused by erosion mechanisms is a time-dependent loss of material similar to FAC. EPRI 1010639 notes that cavitation erosion is not considered an applicable aging mechanism because "it is assumed that all conditions that could result in cavitation erosion were corrected during the current term of operation." EPRI 1010639 also notes that cavitation erosion may need to be considered during plant-specific aging management review in infrequently operated systems where loss of function may occur in the period of extended operation. This would similarly apply where cavitation erosion has been identified during the current term of operation, but has not been corrected. As stated in the LR-ISG, the Statement of Considerations for Part 54 notes that corrective actions should focus on prevention, elimination, or management of the effects caused by these mechanisms. Since some licensees have chosen to manage some erosion mechanisms rather than correct the conditions, the resulting loss of material is an aging effect that requires management.

No.	Comment	Proposed Resolution	Staff Response
2-2	General: The inclusion or addition of mechanical erosion mechanisms into the FAC AMP (XI.M17) would be confusing and possibly detrimental to the currently well bounded and structured industry FAC programs. The susceptibility bases of industry FAC programs are clearly defined and the inclusion of erosion mechanisms would cross many of those boundaries.	Create a separate AMP for mechanical erosion mechanisms.	The staff disagrees with this comment and the proposed resolution. Regarding the proposal to create a separate AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
2-3	Discussion: Erosion, similar to FAC, is a wall-thinning phenomenon related to fluid dynamics	FAC is a true aging mechanism due to corrosion; in this case, the degradation of the normally protective oxide layer of a carbon steel component. Fluid dynamics only accelerates the process. Remove "similar to FAC" from the statement.	The staff agrees with the comment but disagrees with the proposed resolution. Erosion and FAC cause a similar aging effect, loss of material, but through different mechanisms. The purpose of this LR-ISG is to ensure that wall thinning caused by erosion is being effectively managed. No change was made to the LR-ISG in response to this comment.
2-4	Discussion: Erosion mechanism such as cavitation, flashing and droplet impingement are not aging mechanisms but typically associated with improper operation and considered to be a design deficiency.	Remove the reference to aging mechanisms as related to cavitation, flashing and droplet impingement or clarify/reiterate that these are not aging mechanisms.	The staff disagrees with the comment and the proposed resolution. Cavitation, flashing, droplet impingement cause an aging effect, loss of material, similar to FAC, but through different mechanisms. While some erosion mechanisms may be considered design deficiencies, if licensees have chosen to manage the resulting loss of material through ongoing monitoring activities instead of through design or operational changes, then these monitoring activities need to be part of an AMP. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
2-5	Discussion: During recent license renewal reviews, the staff found instances where applicants continued to experience loss of material due to cavitation erosion because the design deficiency was not corrected. The industry guidelines also state that this deficiency will be corrected during the current term of operation. In that regard, the Statement of Considerations (60 FR 22461, 22469, May 8, 1995) for 10 CFR 54 notes that corrective actions that should be taken to address functional degradation logically include cause determinations other than aging (e.g., improper operation), but that corrective actions should focus on prevention, elimination or management of the effects caused by these mechanisms.	Revise or recall LR-ISG-2012-01. Erosion mechanisms are not aging effects and a few instances of improper management of these degradation mechanisms, is not sufficient cause for new industry guidance. Industry guidance has already been established for these degradation effects in the form of prevention and elimination. Industry guidelines also state that these types of deficiencies should be corrected when found, therefore in the current term of operation, and need not be carried into the extended period of operation. However, if these additional wear mechanisms are to be managed programmatically, then a new AMP should be created.	The staff agrees with the comment, but disagrees with the proposed resolution. A number of licensees have chosen not to follow industry guidelines and are managing the degradation caused by erosion through ongoing monitoring activities in lieu of correcting the cause of the problem. Regarding the proposal to create a new AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
2-6	Discussion: GALL Report AMP XI.M17, 'Flow-Accelerated Corrosion,' manages wall thinning due to FAC and is established and widely used by industry. However, the existing guidance in this program is not fully applicable to wall thinning due to erosion mechanisms. For example, the "monitoring and trending" program element of GALL Report AMP XI.M17 includes the use of software to identify locations susceptible to wall thinning due to FAC, but the software does not predict susceptible locations.	Erosion mechanisms should not be managed by "monitoring and trending." The industry guidelines also stated that this deficiency will be corrected during the current term of operation. In that regard, the Statement of Considerations (60 FR 22461, 22469; May 8, 1995) for 10 CFR Part 54 notes that corrective actions that should be taken to address functional degradation logically include cause determinations, which could involve mechanisms other than aging (e.g., improper operation), but that corrective actions should focus on prevention, elimination, or management of the effects caused by these mechanisms.	The staff agrees with the comment, but disagrees with the initial part of the proposed resolution. Although industry guidelines may state that erosion mechanisms will be corrected during the current term of operation, licensees have chosen not to follow industry guidelines by instead managing the aging effect (loss of material) caused by these mechanisms. Industry guidelines state that cavitation may need to be included in the AMR in certain circumstances. The Statement of Considerations for the 10 CFR Part 54 final rule (60 FR 22461, 22469; May 8, 1995) states that the proper approach for a license renewal was one that focuses on mitigating the detrimental effects of aging regardless of the mechanism, and notes that corrective actions should focus on prevention, elimination or management of the effects caused by the mechanism(s). This LR-ISG only addresses those situations where erosion mechanisms are being managed, since they have not been prevented or eliminated. However, in order to more clearly distinguish between activities for FAC and erosion mechanisms, see comment 1-43 for changes to AMP XI.M17 in the "monitoring and trending" program element.

No.	Comment	Proposed Resolution	Staff Response
2-7	Discussion: As noted in SRP-LR Section 2.1.3.2.2, "Long-Lived," passive components that are not replaced on the basis of a qualified life or specified time period require an aging management review (AMR) under 10 CFR 54.21(a)(1)(ii). SRP-LR Section 2.1.3.2.2 also states that components replaced on the basis of condition are not generically excluded from an AMR, and condition monitoring may be evaluated as a program to ensure functionality during the period of extended operation. If an applicant has implemented a replacement strategy for susceptible items, such as replacement frequency that utilizes actual wall thinning data from past plant-specific operating experience, then the staff recognizes these items do not meet the definition of long-lived, passive components and, therefore, they do not have to be managed for aging within the context of license renewal. However, if other strategies to manage the aging of the susceptible items are utilized, such as replacement based on periodic monitoring for loss of material by wall thickness measurements, then these items should be managed for aging, and this ISG is applicable.	Since most utilities address damaged areas caused by erosion mechanisms when identified and do not treat erosion as "long-lived" wear, the comments in this section should be heightened for awareness. Should a new AMP be processed strictly for erosion, this statement addressing AMP exclusion should be forefront in the discussion.	The staff agrees with the comments, and changed the program description to heighten the awareness of the applicability of the AMP to erosion. Also see responses to comments 1-38 and 1-39. The staff also notes that the LR-ISG currently addresses situations where licensees correct the cause(s) of erosion degradation, and states that this LR-ISG would not apply. However, a number of licensees have chosen to manage the degradation caused by erosion through ongoing monitoring activities in lieu of correcting the cause of the problem. The prevalence of this approach by licensees prompted the staff to issue this LR-ISG, which reflects one approach to manage erosion mechanisms that is acceptable to the staff. No change was made to the LR-ISG in response to this comment.
2-8	Discussion: GALL Report AMP XI.M17, "Flow-Accelerated Corrosion," manages wall thinning due to FAC and is well established and widely used by industry. However, the existing guidance in this program is not fully applicable to wall thinning due to erosion mechanisms. For example, the "monitoring and trending" program element of GALL Report AMP XI.M17 includes the use of software to identify locations susceptible to wall thinning due to FAC, but the software does not predict susceptible locations related to erosion. Also, the "corrective actions" program element includes the replacement of susceptible components with FAC-resistant material, such as high chromium steel, which does not necessarily prevent wall thinning due to erosion mechanisms. As such, additional consideration is needed to address wall thinning due to erosion mechanisms.	Additional wall thinning due to erosion mechanisms should be addressed in a new and separate AMP.	The staff agrees with the comment, but disagrees with the proposed resolution. See responses to comments 1-24, 1-30, 1-43, and 2-6 regarding changes to clarify the applicability of the each element for FAC or erosion mechanisms. Regarding the proposal to create a new or separate AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
2-9	[Same section quoted as 2-8]	The additional consideration noted should be in the form [of] a new AMP and not incorporated into [XI.]M17.	The staff agrees with the comment, but disagrees with the proposed resolution. Regarding the proposal to create a new AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
2-10	Discussion – Clarifications to Definitions: Section IX.E, "Aging Effects," of the GALL Report currently includes "erosion," and "flow accelerated corrosion," in its definition of "loss of material," but only includes "cavitation" for concrete structures. Section IX.F, "Significant Aging Mechanisms," of the GALL Report defines "erosion" as the "loss of material from a solid surface…due to mechanical interaction between that surface and a fluid." In addition, it defines "flow-accelerated corrosion" as the "co-joint activity involving corrosion and erosion in the presence of a moving corrosive fluid leading to the accelerated loss of material." Although the GALL Report definition associates flow-accelerated corrosion with erosion, EPRI Report 106611, "Flow-Accelerated Corrosion in Power Plants," states that FAC is "a pure corrosion process that does not have an erosion component." Since erosion is not involved in the FAC process, as the GALL Report definition suggests, this may lead to some confusion and inconsistencies in how NRC guidance is applied. In addition, Section IX.E of the GALL Report currently defines "wall thinning" as an aging effect that "is a specific type of loss of material attributed to general corrosion or flow-accelerated corrosion." In light of this discussion, the definitions of these aging effects and their associated mechanisms need to be revised to include additional mechanisms associated with erosion.	Erosion is not an aging mechanism in piping systems. Erosion in piping systems is the result of design deficiencies, malfunctioning components or abnormal system operation. The definitions in the GALL Report should be revised to disconnect FAC and erosion as similar wear mechanisms.	The staff notes that the EPRI report cited in the draft has been changed in the final LR-ISG. The staff agrees with the comment, but disagrees with the proposed resolution. The NRC modified 10 CFR Part 54 in 1995 to change the form of the AMR to manage the effects of aging on functionality instead of managing aging mechanisms. In that regard, erosion and FAC cause a similar aging effect, loss of material, but through different mechanisms. While some erosion mechanisms may be caused by a design deficiency, if licensees have chosen to manage this degradation through ongoing monitoring activities instead of through design or operational changes, then these monitoring activities need to be part of an AMP. No change was made to the LR-ISG in response to this comment; however, the LR-ISG specifically changed the definition of FAC to remove the term erosion due to the potential for confusion.

No.	Comment	Proposed Resolution	Staff Response
2-11	Discussion – Clarifications to Definitions: Erosion in piping is caused by fluid motion that can involve cavitation, flashing, liquid droplet impingement, and solid particle impingement, which are found in many water systems. Erosion mechanisms are sometimes perceived as being comparable to wall thinning due to FAC; however, these other mechanisms are not addressed in the prediction methodology for FAC programs. Based on staff reviews of industry-wide operating experience, these additional mechanisms require further consideration to ensure that passive components are being maintained consistent with the current licensing basis.	Erosion is not FAC and is not addressed in FAC programs. If required, a new AMP should be created for erosion and not included in [XI.]M17.	The staff agrees with the comment, but disagrees with the proposed resolution. The LR-ISG states that erosion is not FAC and is not addressed in specific aspects of the FAC program. Regarding the proposal to create a new AMP, see the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
2-12	Discussion: Changes to the FAC Aging Management Program.	[XI.]M17 should not be revised to address erosion mechanisms. If required a new AMP should be developed. All references to FAC programs managing the effects of erosion mechanisms should be removed.	The staff disagrees with the proposed resolution. Regarding a new AMP, refer to the staff response to comment 1-1. No change was made in response to this comment.
2-13	General: AMP 17.	AMP M17 should not be revised to include erosion mechanisms except to reference a new AMP for Erosion Mechanisms. In the ISG's tables where the Aging Management Program for Wall Thinning due to Erosion is references as Chapter XI.M17, "Flow-Accelerated Corrosion," replace with a reference to a new AMP for Erosion.	The staff disagrees with the proposed resolution. Regarding a new AMP, refer to the staff response to comment 1-1. No change was made to the LR-ISG in response to this comment.
2-14	General: Raw Water, Service Water, Closed Cooling Water and other water systems ([less than] 200F) are covered by other AMPs.	Reference/revise AMPs [XI.M20] and [XI.]M21A to address erosion in these systems.	The staff agrees with the comment, but disagrees with the proposed resolution. The LR-ISG currently discusses XI.M20, but clarifies that the AMP only addresses erosion due to solid particles in raw water systems and does not include other forms of erosion. This LR-ISG reflects one approach to manage erosion mechanisms that is acceptable to the staff, and it does not preclude an applicant from citing generic note E to indicate that a different AMP is credited. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
2-15	Appendix A: The following table[s] in Appendix A all begin to discuss additional scoping for the FAC AMP. Many of these locations, systems, structures, components are monitored by other programs, and should not be duplicated, for example buried piping, or raw water. Scope of this ISG doesn't limit itself to piping/components.	The current industry programs are set up that the primary focus is piping and pressure retaining components. Adding structures such as vessel internals etc. would not be appropriate as there are more specific and advanced monitoring techniques used.	The staff disagrees with the comment and the proposed resolution. The new items being added to the SRP-LR and the GALL Report only cite "piping, piping components, and piping elements." However, the staff notes that NSAC-202L currently includes inspections of feedwater heaters, which are not piping, piping components, or piping elements. No change was made to the LR-ISG in response to this comment.
2-16	Appendix A, Table 3.1-1: This section mentions the AMP for reactor vessel, internals, and RCS. If this table is suggesting adding these locations to the susceptibility, or SNM portion of the FAC program, this is just one example of how greatly this ISG could impact the scope of the program expanding it significantly and necessitating a significant expense to reconsider and re-evaluate all susceptible locations. These areas would otherwise be completely excluded by the program due to materials, system conditions, etc.	Provide more information into what this Table is actually suggesting or implying. If it is implying that erosion may be possible in these systems and locations, and that it needs to be monitored by the FAC AMP, which could be a problem programmatically.	The staff disagrees with the comment and the proposed resolution. The introduction of new AMR items does not change the identification of aging effects requiring management, since the SRP-LR and the GALL Report are not to be used for scoping and screening. NEI 95-10 states that aging effects requiring management are identified using guidance from various industry documents and operating experience reviews, and that if there is no corresponding GALL Report item, then a plant-specific aging evaluation is required. If monitoring wall thickness for erosion mechanisms is not needed at a facility, then the AMR items can be treated as "not applicable," similar to other AMR items. However, in response to comments 1-33, the staff deleted the new item in IV-C2 for wall thinning due to erosion in the reactor coolant system of PWRs.
2-17	Appendix A, Table 3.2-1: AMP for Engineered Safety Features evaluated in Chapter V of GALL. Including areas in these systems or locations would greatly increase the scope of the program, many areas that would have otherwise and previously been excluded.	This ISG appears to have the potential to have a completely open possibility for scope expansion as it seems to argue that any and all locations are susceptible to erosion.	The staff disagrees with the comment and the proposed resolution. See the staff response to comment 2-16. No changes were made to the LR-ISG in response to this comment.
2-18	Appendix A, Table 3.3-1; AMP for Auxiliary Systems evaluated in Chapter VII of GALL. Including areas in these systems/locations would greatly increase the scope of the program, many areas that would have otherwise and previously been excluded.	This ISG appears to have the potential to have a completely open possibility for scope expansion as it seems to argue that any and all locations are susceptible to erosion.	The staff disagrees with the comment and the proposed resolution. See the staff response to comment 2-16. No change was made to the LR-ISG in response to this comment.

No.	Comment	Proposed Resolution	Staff Response
2-19	Appendix A, Table 3.4-1: AMP for Steam and Power Conversion System evaluated in Chapter VIII of GALL. Including areas in these systems/locations would greatly increase the scope of the program, many areas that would have otherwise and previously been excluded.	This ISG appears to have the potential to have a completely open possibility for scope expansion as it seems to argue that any and all locations are susceptible to erosion. This seems most appropriate in this area, as many locations in the Steam and Power Systems are already part of the FAC program, and continuing to monitor locations which are known to degrade, even after replacement with more [resistant] materials seems more appropriate than significantly increasing program scope as suggested by the three sections above.	The staff disagrees with the comment and the proposed resolution. See the staff response to comment 2-16. No change was made to the LR-ISG in response to this comment.
2-20	Appendix B, IV-C2, V-D1, VII-C1, VII-E1, VII-E3: This ISG is proposing a number of RCS, ECCS, Open-Cycle Cooling, Service Water, CVCS, and Reactor Water Cleanup systems to be added to the program (wall thinning) SNM, which would greatly increase the scope of the monitoring program.	It would be more appropriate to look at industry OE for problem areas where there are known erosive mechanisms degrading systems and components [in order to] limit the scope increase.	The staff disagrees with the comment and the proposed resolution. The introduction of new AMR items does not change the identification of aging effects, since the SRP-LR and the GALL Report should not to be used for scoping and screening. Because erosion mechanisms are not currently included in the GALL Report, the introduction of new AMR items will eliminate the need for citing generic note H, for an aging effect not in the GALL Report. No change was made to the LR-ISG in response to this comment.
2-21	All: The addition of mechanical erosion mechanisms to the FAC AMP would be detrimental to the well bounded and structured industry FAC programs. The susceptibility bases of industry FAC programs are clearly defined and the inclusion of erosion mechanisms would cross many of those boundaries.	Create a separate AMP for mechanical erosion mechanisms.	The staff disagrees with this comment and the proposed resolution. Regarding the proposal to create a separate AMP, see the staff response to comment 1-1 No change was made to the LR-ISG in response to this comment.