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Use of Risk Insights to Optimize Aging Management Plan Implementation

2022 Top Innovative Practice Winner

Summary

Long-term operation (LTO) of nuclear power plants is being pursued by the majority of the industry. Most U.S. plants have already extended plant licenses up to 60 years. One has licenses that allow operation up to 80 years with more expected to follow. Nuclear power plants with an extended operating license implement Aging Management Programs (AMPs) to ensure critical infrastructure (e.g., concrete, piping and cables) are monitored for loss of intended function, and subsequent replacement, as they age. These passive components are critical to the long-term safe operation of these plants.

AMP testing and inspection tasks are often deterministic, and they are applied uniformly, without regard to the consequence of loss of intended function, to all systems, structures, and components (SSCs) that are "in-scope" of that AMP. Constellation and Ameren recognized that there are potential opportunities to apply a systematic, logical, risk-informed analysis to optimize AMP implementation. This could result in reduced burden while maintaining plant safety and reliability during LTO. Each utility member team, with support of EPRI, Enercon and Jensen-Hughes, developed and implemented the Framework that utilized existing risk tools, information, and operating experience to perform this evaluation. The initial framework and pilot applications are described in EPRI Technical Report 3002020713 – "Leveraging Risk Insights for Aging Management Program Implementation: 2022."

Current aging management implementation strategies have typically been focused on near-term obligations, which may need to be reconsidered for accomplishing longer-term reliability and sustainability objectives. Therefore, in the last year each team piloted the framework (Figures 1 and 2), which was the first of its kind to be based on risk insights, to optimize their AMP implementation for two specific AMPs (Ameren for medium-voltage cables and Constellation for pipe and valve selective leaching inspections). Each team confirmed that the framework could be implemented, and this resulted in a significant impact on optimizing AMP implementation over the life of their plants.

Constellation's and Ameren's work proved that the integrated framework is adaptable, and it may be applied to many other AMPs (Figure 3). The teams also demonstrated that it is flexible in that the likelihood ranking criteria can be used as is or with some adaptation at peer nuclear power plants and showed significant cost avoidance while improving safety. As this framework can be easily applied across the nuclear industry, it could result in hundreds of million dollars in overall savings.

Innovation

The Constellation and Ameren teams' efforts used an innovative and transformative integrated approach to apply and leverage available knowledge of SSC degradation mechanisms and existing risk tools to optimize AMP implementation. The framework takes elements of existing technical information on SSC degradation and existing risk tools to create a basis to modify the testing and inspection recommendations that were committed to by licensees to obtain their 20-year license extension. What's innovative in this case is the framework was developed using a component-specific approach versus using generalized risk analysis used in other applications in the industry. The results are a specialized evaluation basis to provide a clear picture of the risk of a particular SSC based on the degradation mechanisms specific to that type of component. This provides a much better technical justification for the resulting AMP actions. The output of a completed framework evaluation provides the technical basis.

Each team showed how their utilization of the Framework differs from the conventional deterministic method by providing the industry a flexible way to optimize a utility's existing resources associated with AMP implementation. These optimization benefits include reduced inherent risk of intrusive maintenance and reduced burden for low risk components with limited benefits while focusing the commensurate attention on higher risk components. It is unique that this effort has combined diverse expertise (e.g., risk experts, component experts) within each utility and from the respective industry partners in a way that facilitated the optimal use of existing resources, the sharing of risk insights common to aging management, and the utilization of the current state of knowledge.

Each team showed that the generic framework can be implemented on different types of aging mechanisms and different levels of quantitative and qualitative available plant resources. Since it was successfully applied to two types of AMPs (electrical and mechanical) and was evaluated using insights from different risk tools, the results also showed that existing risk tools and methods could be used without a need to create costly new ones. Additionally, many other plant processes (e.g., component overhauls, surveillance intervals, and inspection frequencies) whose requirements are deterministically applied can benefit from use of this framework.

Safety

Optimization of AMP implementation may lead to a reduction in low value maintenance. This may reduce plant risk and avoid inherent safety hazards associated with the eliminated maintenance tasks. Each team demonstrated (e.g., when performing cable diagnostic testing, or selective leaching inspections of piping) the plant configuration required to perform these tasks may cause an increase in risk associated with removing the equipment from service. The altered plant configuration could elevate the core damage frequency (CDF) or large early release frequency (LERF) while the associated equipment is out of service. Radiation exposure could be incurred by personnel performing the work on cable or piping if it is in the radiologically controlled areas.

Another example is that industrial/personnel safety is challenged when injecting high voltages for cable diagnostics, or excavation of piping to perform selective leaching inspections. There have been plant experiences where excavation for pipe inspections has caused damage to equipment, or near misses have occurred. Each reduction in the number of cable tests, or a pipe inspection reduces the associated risk. The result of each team's evaluation was a reduction in the number of electrical cable tests and selective leaching component inspections. The teams did not look into the specifics associated with the reduction in CDF/LERF, dose reduction, or personnel/industrial safety. However, it is reasonable to assume that significant safety improvements will be achieved while maintaining a focus on risk significant SSCs.

Cost Savings

Each team's results showed a reduction in the number of cable tests (Ameren) or component inspections

(Constellation). The cable pilot resulted in the number of cable tests that needed to be performed by extending test frequency of risk-informed cables from 6 to 10 years for 54 of 59 cable groups for the 20-year period of extended operation (PEO). A detailed cost analysis was done for each cable circuit to determine the avoided cost. The cable pilot evaluation only took credit for person-hours and materials required to plan, block out of service, test, evaluate the test results, and restore the circuits for service. Test cost varied based on complexity and can be as high as $16,790. The total estimated costs for cable testing resulted in the following range of estimated savings of $622,000 for a reduction of two tests per cable testing group (54 groups) during the 20-year PEO. These savings could roughly double if the plant extends its operating life out to 80 years. These savings are minimum savings due to the assumptions of person-hour costs (average versus actual). Additionally, these are best case scenarios and do not account for person-hour/dose related reductions, and risk reduction of human performance induced equipment damage caused during the disconnecting and reconnecting of the cable terminations. The current estimated savings from this effort are not the total savings expected. An evaluation for the low-voltage cables that need to be tested at a 6-year frequency will increase the total savings.

The team evaluating selective leaching inspections resulted in the reduction in pre-period of extended operation scope from 68 inspections to 16. The estimated total cost to complete 68 pre-PEO inspections, including potential sample expansion activities, is $4.67 million. With this risk insight strategy, the site would perform 16 inspections. Assuming potential sample expansion activities, the estimated total cost is $2.4 million. This risk insight evaluation aging management strategy results in an estimated cost savings of $2.27 million.

Total combined cost savings for the two pilots is $2.89 million dollars. If we conservatively assign avoided costs for scope expansion, risk reduction, dose reduction, outage delays, etc. of 120% that would result in a total savings of approximately $3.5 million dollars. It should be noted that this framework is transferrable and can easily be repeated by those that have similar AMP considerations like those evaluated for each team. The impacts will vary based on plant designs and the number of SSCs in-scope for a particular operating plant, but it is conservative to estimate that if these analyses were completed and implemented across all the operating units in the U.S. that the savings would be more than $200 million dollars.

Productivity/Efficiency

The implementation of the framework will optimize resources needed to implement the AMPs over the PEO. Using a risk-informed approach the scope of inspections (selective leaching) and the frequency of testing (cables) versus the deterministic recommendation of the AMPs will have a direct effect to reduce resources needed for those AMPs. The reduction in effort will result from reducing the number of tasks and the associated person-hours for performing work commensurate with the likelihood and risk of failure. The efficiency gains for each AMP will reduce the number of work orders to be planned, eliminate trenching required for pipe inspections, or scaffold building for cable testing. Additionally, operations will not have to remove and restore to service the SSCs, technicians' hours required to inspect the piping and test the cables will be reduced, and engineering time for test evaluation and documentation of the results will be reduced.

For cables, these efforts resulted in 128.9 person-months savings. In the case of the pilot for cables the productivity/efficiency gain would be $611,000 savings divided by the $60 person-hour rate used by the pilot site results in 10,183 person-hours which for a 30-day 8 hour-day person-month is 40.6 person-months reduction for the 108 work orders eliminated.

The selective leaching inspection reductions will also be in labor hours. A reduction from 68 to 16 work orders using the framework results in 22,700 person-hours less labor.

Using a person-hour rate of $100/hour, for an 8-hour day, 30-day person-month is 88.3 person-months that are eliminated. That equates to $2.27 million in savings.

This effort was also undertaken by a cross-functional team at Constellation and Ameren of engineering and risk analysis subject matter experts (SMEs). Each team's respective risk and SSC subject matter experts created a strong partnership to evaluate the effectiveness and limitations of the framework when applied to chosen AMP's implementation. They also worked with other industry technical and risk analysis SMEs to perform their respective evaluations. Each team was assisted as needed by other Constellation and Ameren site Operations, System Engineering, and outside industry SMEs in development and review of the likelihood and consequence of failure evaluations. Each team's evaluation was able to determine the likelihood of degradation and combine it with insights from existing risk tools including PRA methodology results to evaluate the consequence that an SSC's failure would cause. That evaluation was used to populate a risk matrix that can be used as a technical basis to apply a risk-informed approach.

Transferability

The teams showed that the framework is a robust and versatile process that can be applied independent of plant type (BWR or PWR). It is robust because it was demonstrated by both the Constellation and the Ameren efforts that the likelihood of the loss of intended function tables they developed could be used by any plant.

Similarly, the consequence of the loss of intended function evaluations did not require use of specific PRA tools (e.g., risk-informed ISI and 50.69. Additionally, the teams showed that the framework does not require new PRA models or analysis to be developed but can rely on already established risk thresholds (e.g., RAW importance measure and CCDP and CLERP) to set the consequence levels.

The revision of commitments associated with an AMP, in the case of the pilot cable test frequency and one-time selective leaching pre-PEO inspections, should be similar across the entire U.S. nuclear fleet of plants (BWR and PWR). That means that other nuclear plant operators can perform similar analysis to get the benefits of the framework, however cost savings will vary based on the specific license renewal scoping of each utility.

Additionally, the framework is transferrable to other AMPs with sizable SSC scope and deterministic requirements. NEI's License Renewal Task Force has a focus group that is evaluating other AMPs to which the framework may be applied, and how the framework can be applied beyond just AMP optimization (i.e., other deterministic requirements that could use this methodology to risk-inform regulatorily required actions).

Team Members

- Barry Thurston, Sr. Staff Engineer (Constellation)
- Jessica Bock, Inaccessible Cable AMP Owner (formerly of Ameren)
- Justin Hiller, Supervising Engineer, Risk Management (Ameren)
- Andrew Burgess, Project Manager, License Renewal (Ameren)
- Suzanne Loyd, Sr. Manager, Risk Management (Constellation)
- Nina Lacome, Risk Management Engineer (Constellation)
- Seth Rios, Sr. Staff Engineer (Constellation)
- Deven Strabala, Program Engineer (Constellation)

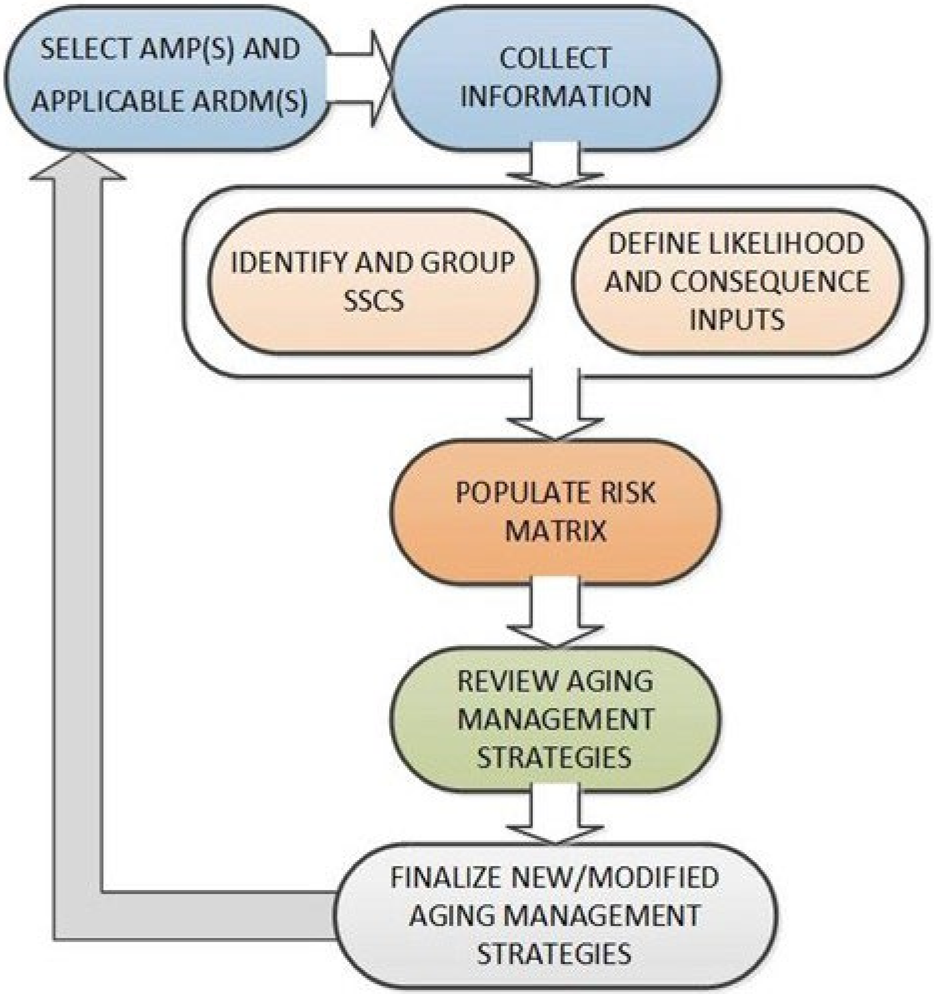


Figure 1 – Simplified Aging Management Program Risk Insights Framework

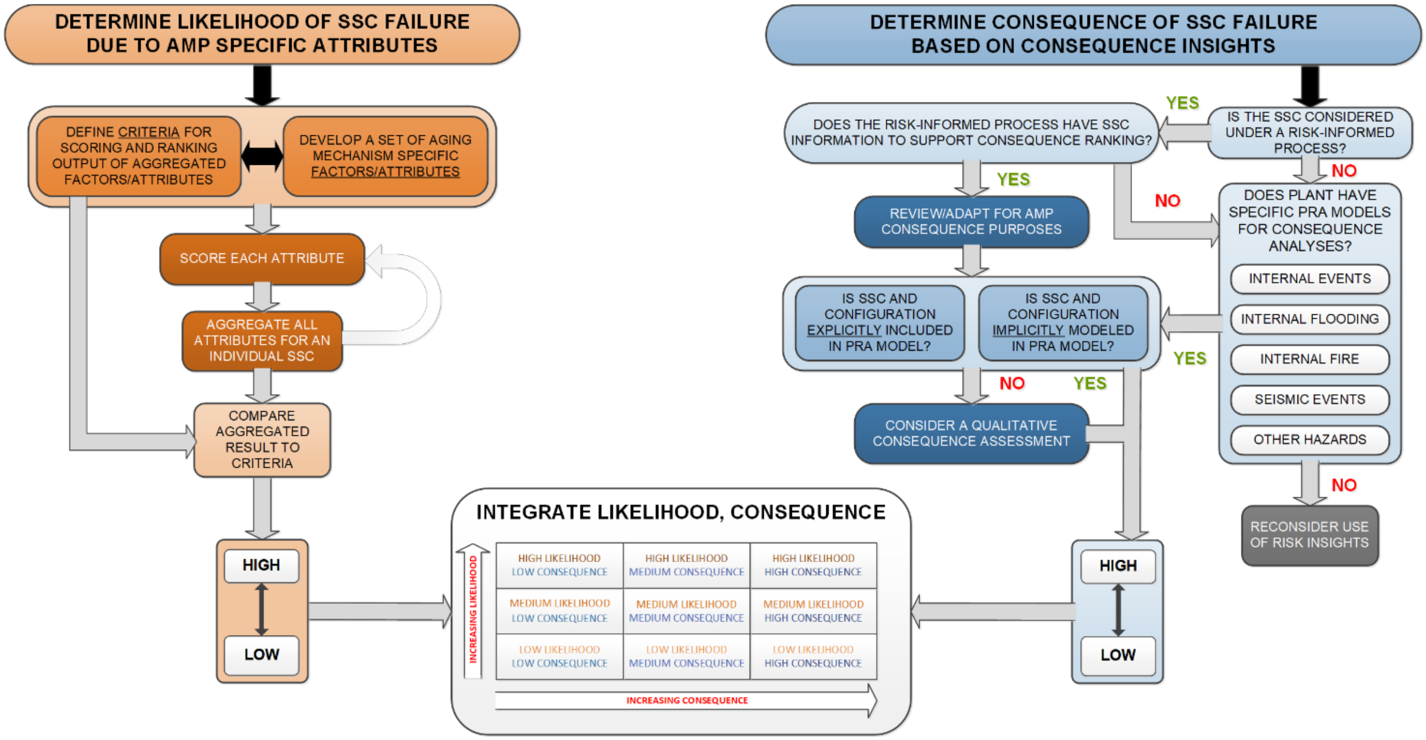
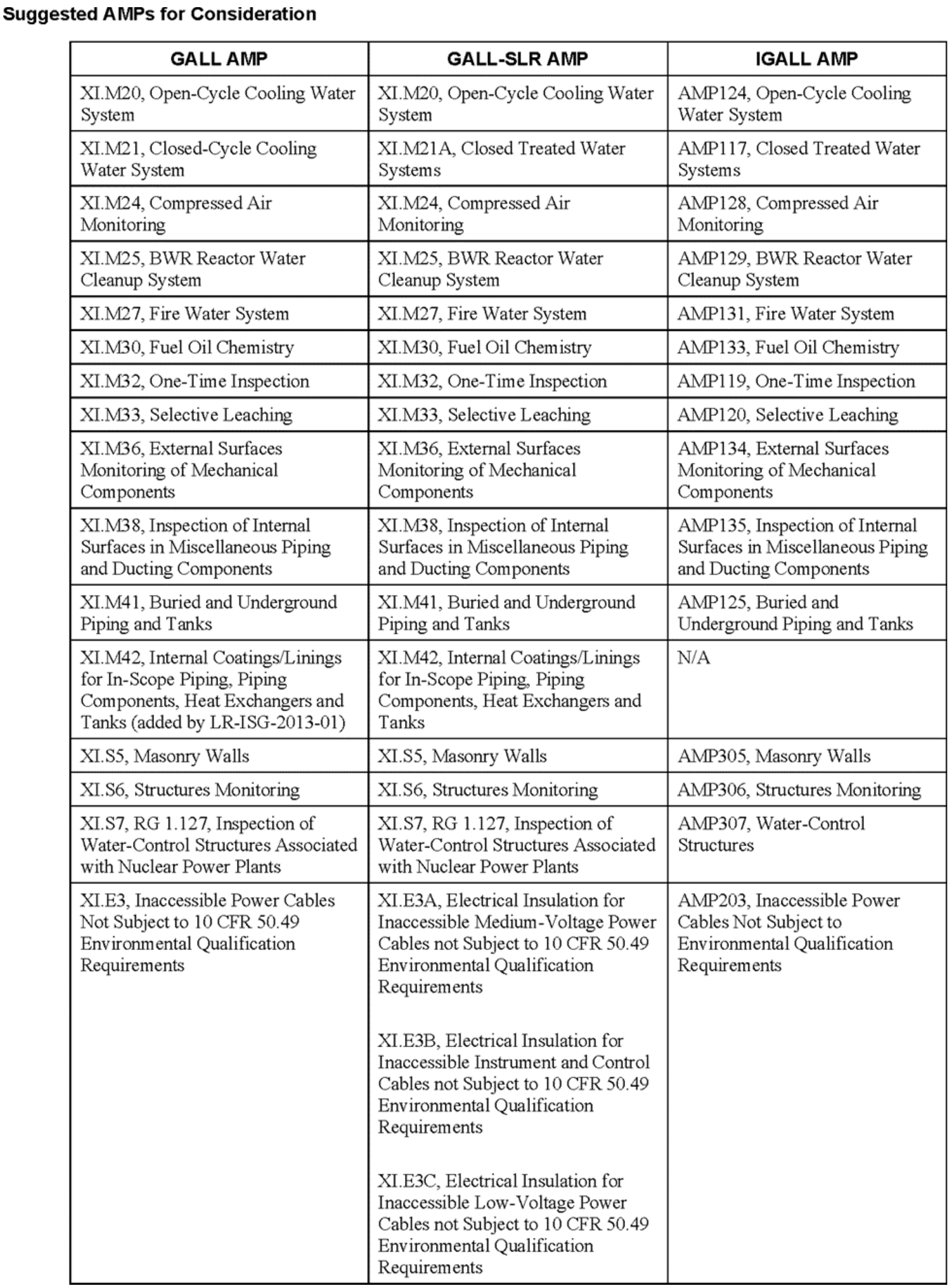


Figure 2- Generic RIAM Inputs to the Risk Matrix



Suggested AMPs for Consideration

GALL AMP	GALL-SLR AMP	IGALL AMP
XI.M20, Open-Cycle Cooling Water System	XI.M20, Open-Cycle Cooling Water System	AMP124, Open-Cycle Cooling Water System
XI.M21, Closed-Cycle Cooling Water System	XI.M21A, Closed Treated Water Systems	AMP117, Closed Treated Water Systems
XI.M24, Compressed Air Monitoring	XI.M24, Compressed Air Monitoring	AMP128, Compressed Air Monitoring
XI.M25, BWR Reactor Water Cleanup System	XI.M25, BWR Reactor Water Cleanup System	AMP129, BWR Reactor Water Cleanup System
XI.M27, Fire Water System	XI.M27, Fire Water System	AMP131, Fire Water System
XI.M30, Fuel Oil Chemistry	XI.M30, Fuel Oil Chemistry	AMP133, Fuel Oil Chemistry
XI.M32, One-Time Inspection	XI.M32, One-Time Inspection	AMP119, One-Time Inspection
XI.M33, Selective Leaching	XI.M33, Selective Leaching	AMP120, Selective Leaching
XI.M36, External Surfaces Monitoring of Mechanical Components	XI.M36, External Surfaces Monitoring of Mechanical Components	AMP134, External Surfaces Monitoring of Mechanical Components
XI.M38, Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components	XI.M38, Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components	AMP135, Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components
XI.M41, Buried and Underground Piping and Tanks	XI.M41, Buried and Underground Piping and Tanks	AMP125, Buried and Underground Piping and Tanks
XI.M42, Internal Coatings/Linings for In-Scope Piping, Piping Components, Heat Exchangers and Tanks (added by LR-ISG-2013-01)	XI.M42, Internal Coatings/Linings for In-Scope Piping, Piping Components, Heat Exchangers and Tanks	N/A
XI.S5, Masonry Walls	XI.S5, Masonry Walls	AMP305, Masonry Walls
XI.S6, Structures Monitoring	XI.S6, Structures Monitoring	AMP306, Structures Monitoring
XI.S7, RG 1.127, Inspection of Water-Control Structures Associated with Nuclear Power Plants	XI.S7, RG 1.127, Inspection of Water-Control Structures Associated with Nuclear Power Plants	AMP307, Water-Control Structures
XI.E3, Inaccessible Power Cables Not Subject to 10 CFR 50.49 Environmental Qualification Requirements	XI.E3A, Electrical Insulation for Inaccessible Medium-Voltage Power Cables not Subject to 10 CFR 50.49 Environmental Qualification Requirements XI.E3B, Electrical Insulation for Inaccessible Instrument and Control Cables not Subject to 10 CFR 50.49 Environmental Qualification Requirements XI.E3C, Electrical Insulation for Inaccessible Low-Voltage Power Cables not Subject to 10 CFR 50.49 Environmental Qualification Requirements	AMP203, Inaccessible Power Cables Not Subject to Environmental Qualification Requirements

Figure 3- Suggested AMPs for Consideration