

## **XI.E6 ELECTRICAL CABLE CONNECTIONS NOT SUBJECT TO 10 CFR 50.49 ENVIRONMENTAL QUALIFICATION REQUIREMENTS**

### **Program Description**

The purpose of the aging management program (AMP) described herein is to provide reasonable assurance that the intended functions of the metallic parts of electrical cable connections that are not subject to the environmental qualification requirements of 10 CFR 50.49 and susceptible to age-related degradation resulting in increased resistance of connection due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, or oxidation are maintained consistent with the current licensing basis through the period of extended operation.

Cable connections are used to connect cable conductors to other cable conductors or electrical devices. Connections associated with cables within the scope of license renewal are part of this AMP. The most common types of connections used in nuclear power plants are splices (butt or bolted), crimp-type ring lugs, connectors, and terminal blocks. Most connections involve insulating material and metallic parts. This AMP focuses on the metallic parts of the electrical cable connections. This AMP provides a one-time test, on a sampling basis, to ensure that either aging of metallic cable connections is not occurring and/or that the existing preventive maintenance program is effective such that a periodic inspection program is not required. The one-time test confirms the absence of age-related degradation of cable connections resulting in increased resistance of connection due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, or oxidation.

AMP XI.E1, "Insulation Material for Electrical Cables and Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements," manages the aging of insulating material but not the metallic parts of the electrical connections. AMP XI.E1 is based on a visual inspection of accessible cables and connections. Visual inspection may not be sufficient to detect the aging effects from thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, or oxidation on the metallic parts of cable connections.

Electrical cable connections exposed to appreciable ohmic or ambient heating during operation may experience increased resistance of connection caused by repeated cycling of connected loads or of the ambient temperature environment. Different materials used in various cable system components can produce situations where stresses between these components change with repeated thermal cycling. For example, under loaded conditions, ohmic heating may raise the temperature of a compression terminal and cable conductor well above the ambient temperature, thereby causing thermal expansion of both components. Thermal expansion coefficients of different materials may alter mechanical stresses between the components and may adversely impact the termination. When the current is reduced, the affected components cool and contract. Repeated cycling in this fashion can cause loosening of the termination and may lead to increased resistance of connection or eventual separation of compression-type terminations. Threaded connectors may loosen if subjected to significant thermally-induced stress and cycling.

Cable connections within the scope of license renewal should be tested at least once prior to the period of extended operation to provide an indication of the integrity of the cable connections. The specific type of test to be performed is a proven test for detecting increased resistance of connection, such as thermography, contact resistance testing, or another appropriate test. As an alternative to thermography or resistance measurement of cable

connections, for the accessible cable connections that are covered with insulation materials such as tape, the applicant may perform visual inspection of insulation material to detect aging effects for covered cable connections. When this alternative visual inspection is used to check cable connections, the applicant must use periodic inspections and cannot use a one-time test to confirm the absence of age-related degradation of cable connections. The basis for performing only a periodic visual inspection is documented.

This AMP, as described, is a sampling program. The following factors are considered for sampling: voltage level (medium and low voltage), circuit loading (high loading), connection type and location (high temperature, high humidity, vibration, etc.). The technical basis for the sample selections should be documented. If an unacceptable condition or situation is identified in the selected sample, a determination is made as to whether the same condition or situation is applicable to other connections not tested. The corrective action program is used to evaluate the condition and determine appropriate corrective action.

SAND96-0344, "Aging Management Guidelines for Electrical Cable and Terminations," indicated that loose terminations were identified by several plants. The major concern is failures of a deteriorated cable system (cables, connections including fuse holders, and penetrations) that could prevent it from performing its intended function. This AMP is not applicable to cable connections in harsh environments since they are already addressed by the requirements of 10 CFR 50.49. Even though cable connections may not be exposed to harsh environments, increased resistance of connection is a concern due to the aging mechanisms discussed above.

## **Evaluation and Technical Basis**

1. **Scope of Program:** Cable connections associated with cables within the scope of license renewal that are external connections terminating at active or passive devices, are in the scope of this AMP. Wiring connections internal to an active assembly are considered part of the active assembly and, therefore, are not within the scope of this AMP. This AMP does not include high-voltage (>35 kilovolts) switchyard connections. The cable connections covered under the Environmental Qualification (EQ) program are not included in the scope of this program.
2. **Preventive Actions:** This is a condition monitoring program, and no actions are taken as part of this program to prevent or mitigate aging degradation.
3. **Parameters Monitored/Inspected:** This AMP focuses on the metallic parts of the connection. The one-time testing verifies that increased resistance of connection due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, or oxidation is not an aging effect that requires periodic testing. A representative sample of electrical cable connections is tested. The following factors are considered for sampling: voltage level (medium and low voltage), circuit loading (high load), connection type, and location (high temperature, high humidity, vibration, etc.). The technical basis for the sample selection is documented.
4. **Detection of Aging Effects:** A representative sample of electrical connections within the scope of license renewal is tested at least once prior to the period of extended operation to confirm that there are no aging effects requiring management during the period of extended operation. Testing may include thermography, contact resistance testing, or other appropriate testing methods without removing the connection insulation, such as heat shrink tape, sleeving, insulating boots, etc. The one-time test provides additional confirmation to

support industry operating experience that shows that electrical connections have not experienced a high degree of failures, and that existing installation and maintenance practices are effective. Twenty percent of the population with a maximum sample of 25 constitutes a representative sample size. Otherwise a technical justification of the methodology and sample size used for selecting components for one-time test should be included as part of the AMP's site documentation.

As an alternative to thermography or measuring connection resistance of the cable connection sample, for accessible cable connections that are covered with heat shrink tape, sleeving, insulating boots, etc., the applicant may use visual inspection of insulation materials to detect surface anomalies, such as embrittlement, cracking, chipping, melting, discoloration, swelling or surface contamination. When this alternative visual inspection is used to check cable connections, the first inspection is completed prior to the period of extended operation and every 5 years thereafter. The basis for performing only a periodic visual inspection to monitor age-related degradation of cable connections is documented.

5. **Monitoring and Trending:** Trending actions are not included as part of this AMP because it is a one-time testing or, alternatively, a periodic visual inspection program where the ability to trend inspection results is limited. However, results that are trendable provide additional information on the rate of degradation.
6. **Acceptance Criteria:** Cable connections should not indicate abnormal temperature for the application when thermography is used; otherwise a low resistance value appropriate for the application when resistance measurement is used. When the visual inspection alternative for covered cable connections is used, the absence of embrittlement, cracking, chipping, melting, discoloration, swelling or surface contamination indicates that the covered cable connection components are not loose.
7. **Corrective Actions:** If acceptance criteria are not met, the corrective action program is used to perform an evaluation that considers the extent of the condition, the indications of aging effect, and changes to the one-time testing program or alternative inspection program. Corrective actions may include, but are not limited to, sample expansion, increased inspection frequency, and replacement or repair of the affected cable connection components. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the corrective actions.
8. **Confirmation Process:** As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.
9. **Administrative Controls:** The administrative controls for this AMP provide for a formal review and approval process. As discussed in the Appendix for GALL, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.
10. **Operating Experience:** Electrical cable connections exposed to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, or oxidation during operation may experience increased resistance of connection. There have been limited numbers of age-related failures of cable connections reported. An applicant's operating experience with detection of aging effects should be adequate to demonstrate that the program is capable of detecting the presence or noting the absence of aging effects for

electrical cable connections where a one-time inspection is used to confirm the effectiveness of another preventive or mitigative AMP.

This AMP considers the technical information and guidance provided in NUREG/CR-5643, SAND96-0344, IEEE Std. 1205-2000, EPRI 109619, EPRI 104213, NEI White Paper on AMP XI.E6, Final License Renewal Interim Staff Guidance LR-ISG-2007-02, Staff Response to the NEI White Paper on AMP XI.E6, Licensee Event Report (LER) 361 2007005, LER 3612007006 and LER 3612008006.

## References

- 10 CFR Part 50, Appendix B, *Quality Assurance Criteria for Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.
- EPRI 104213, *Bolted Joint Maintenance & Application Guide*, Electric Power Research Institute, Palo Alto, CA, December 1995.
- EPRI 109619, *Guideline for the Management of Adverse Localized Equipment Environments*, Electric Power Research Institute, Palo Alto, CA, June 1999.
- Final License Renewal Interim Staff Guidance LR-ISG-2007-02: Changes to Generic Aging Lesson Learned (GALL) Report Aging Management Program (AMP) XI.E6, *Electrical Cable Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements*, 74 FR 68287, U.S. Nuclear Regulatory Commission, December 23, 2009.
- IEEE Std. 1205-2000, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations*.
- Licensee Event Report 361 2007005, *San Onofre Unit 2, Loose Electrical Connection Results in Inoperable Pump Room Cooler*, U.S. Nuclear Regulatory Commission.
- Licensee Event Report 3612007006, *San Onofre Units 2 and 3, Loose Electrical Connection Results in One Train of Emergency Chilled Water (ECW) System Inoperable*, U.S. Nuclear Regulatory Commission.
- Licensee Event Report 3612008006, *San Onofre 2, Loose Connection Bolting Results in Inoperable Battery and TS Violation*, U.S. Nuclear Regulatory Commission.
- NEI White Paper, *GALL AMP XI.E6 (Electrical Cables)*, Nuclear Energy Institute, September 5, 2006. (ADAMS Accession Number ML062770105)
- NUREG/CR-5643, *Insights Gained From Aging Research*, U.S. Nuclear Regulatory Commission, March 1992.
- SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants – Electrical Cable and Terminations*, prepared by Sandia National Laboratories for the U.S. Department of Energy, September 1996.
- Staff's Response to the NEI White Paper on Generic Aging Lessons Learned (GALL) Report Aging Management Program (AMP) XI.E6, *Electrical Cable Connections Not Subject to*

*10 CFR 50.49 Environmental Qualification Requirements*, U.S. Nuclear Regulatory Commission, March 16, 2007. (ADAMS Accession Number ML070400349)