

**FINAL LICENSE RENEWAL INTERIM STAFF GUIDANCE
LR-ISG-2007-02**

**CHANGES TO 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"**

INTRODUCTION

This final license renewal interim staff guidance (LR-ISG) LR-ISG-2007-02 provides interim guidance as to one approach acceptable to the U.S. Nuclear Regulatory Commission staff (NRC or the staff) for managing the effects of aging during the period of extended operation for certain electrical cable connections within the scope of the license renewal rule (Title 10 of the *Code of Federal Regulations*, Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants" (10 CFR Part 54)), and which are not otherwise subject to the environmental qualification requirements of Section 49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," of Part 50, "Domestic Licensing of Production and Utilization Facilities" of 10 CFR (10 CFR 50.49). This LR-ISG changes the staff's aging management recommendations in Generic Aging Lessons Learned (GALL) Report (NRC, 2005), Chapter XI, aging management program (AMP) XI.E6, "Electrical Cable Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements."

DISCUSSION

Consistent with the requirements of 10 CFR 54.4, electrical cable connections not otherwise subject to the requirements of 10 CFR 50.49 are within the scope of license renewal if they perform safety-related intended functions (10 CFR 54.4(a)(1)), they are nonsafety-related and their failure could prevent satisfactory accomplishment of a safety-related function (10 CFR 54.4(a)(2)), or they are relied upon to perform a function that demonstrates compliance with the Commission's regulations for certain regulated events (10 CFR 54.4(a)(3)). Further, because these in-scope electrical cable connections perform intended functions without moving parts or without a change in configuration or properties and are not subject to replacement based on a qualified life or specified time period, in accordance with 10 CFR 54.21(a)(3), a license renewal applicant is required to include technical information in the license renewal application to demonstrate that the effects of aging on the electrical cable connections will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation.

Loosening of electrical cable connections is an aging effect requiring management during the period of extended operation. Electrical cable connections exposed to appreciable ohmic or ambient heating during operation may experience loosening 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 so that the termination may be impacted. 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 high electrical resistance or eventual separation of

compression-type terminations. Threaded connectors may loosen if subjected to significant thermally induced stress and cycling.

Due to the potential loosening of bolted cable connections, the staff included aging management recommendations for these components in GALL Report AMP XI.E6. By letter dated September 5, 2006 (Nuclear Energy Institute (NEI), 2006a), the NEI submitted a white paper on this AMP (NEI, 2006b). NEI stated that there was not sufficient operating experience to support a conclusion that cable connections are a significant aging concern and that the recommended program elements of AMP XI.E6 duplicate aging management activities already defined and accepted in other AMPs. NEI also stated that the expanded scope of the program includes all voltage ranges regardless of the amount of evidence from operating experience. In addition, NEI identified wording in AMP XI.E6 that includes connections in active components. NEI requested that the staff review its white paper to eliminate AMP XI.E6 or minimize its scope and redundancy so that plants would not be burdened with activities that have no actual aging management benefit. On November 30, 2006, the staff met with NEI representatives to discuss the white paper (NRC, 2007a). In a letter dated March 16, 2007 (NRC, 2007b), the staff provided responses to each of the industry's concerns identified in the white paper. By letter dated May 25, 2007 (NEI, 2007a), NEI submitted comments on the staff's responses.

The staff reviewed the industry's white paper and comments and determined that, although AMP XI.E6 is based on the technical bases of Electric Power Research Institute documents and a Sandia National Laboratories report (SNL, 1996), operating experience reflects few instances related to failed connections due to aging. Most of the operating experience related to failed connections is due to human errors or maintenance practices. Therefore, the staff determined that current operating experience does not support the periodic inspections recommended in GALL Report AMP XI.E6. Instead, the staff believes that a one-time inspection of the metallic portion of electrical cable connections is warranted to demonstrate, in part, that the effects of aging on these components will be adequately managed so that the intended function(s) will be maintained consistent with the current licensing basis for the period of extended operation, in accordance with 10 CFR 54.21(a)(3).

To reflect the above determinations, the staff developed an interim revision to GALL Report AMP XI.E6 in the draft LR-ISG-2007-02. On September 6, 2007, the staff issued a *Federal Register* notice (NRC, 2007c) to request public comments on the draft LR-ISG. The staff proposed changes to AMP XI.E6 to clarify and recommend a one-time inspection, on a representative sample basis, to ensure that either aging of metallic cable connections is not occurring or that an existing preventative maintenance program is effective, such that a periodic inspection is not required. In a letter dated October 18, 2007 (NEI, 2007b), NEI provided comments on the draft LR-ISG. In summary, the NEI stated that the revised program should provide options, where appropriate, for the use of visual inspection to detect aging effects on covered connections.

The staff has determined that an interim revision to AMP XI.E6 is necessary to reduce the inspection frequency from that in GALL Report AMP XI.E6. Prior to the period of extended operation, a one-time inspection on a representative sample basis is adequate 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 inspection verifies that loosening and/or high resistance of cable connections due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination,

corrosion, or oxidation are not occurring and, therefore, periodic inspections are not required. The one-time inspection should include testing of a representative sample of the electrical cable connection population subject to an aging effect. The sample should include each type of electrical cable connection. The following factors should be considered for sampling: voltage level (medium and low voltage), circuit loading (high load), and location (high temperature, high humidity, vibration, etc.). The technical basis for the sample selection should be documented. The one-time inspection will confirm that there are no aging effects that require management during the period of extended operation.

The specific type of test to be performed will be a proven test for detecting loose connections such as thermography or contact resistance testing. The staff determined that resistance measurement or thermography is a preferred method for testing loose cable connections. However, if resistance measurement cannot be performed with the insulation in place, and for reasons of personnel safety energized equipment cannot be accessed to perform thermography, then visual inspection is an acceptable alternate inspection method for cable connections covered with insulation material. The staff has previously permitted visual inspection for covered bus connections in GALL Report AMP XI.E4, "Metal Enclosed Bus."

If a visual inspection is chosen as an alternative to thermography or resistance measurement of cable connections covered with insulating materials (heat shrink tapes, sleeving, insulation boots, etc.), then a one-time inspection cannot be used and periodic visual inspections would need to be performed. Periodic visual inspections can effectively detect loosening of cable connections by inspecting insulation materials for discoloration, cracking, chipping, or surface contamination.

Corrective actions should be taken when acceptance criteria are not met. Corrective actions may include, but are not limited to: sample expansion, increased inspection frequency, and replacement or repair of the affected cable connection components.

When performing periodic preventive maintenance that includes inspection and testing of cable connections, this maintenance activity can be credited towards AMP XI.E6. The applicant may also revise its preventive maintenance procedures to cover the inspection of cable connections to take credit for AMP XI.E6.

Based on the above discussion, the staff has determined that implementation of the guidance in this LR-ISG is adequate for compliance with the requirements of 10 CFR 54.21(a)(3) to demonstrate that the effects of aging for certain electrical cable connections not otherwise subject to the requirements of 10 CFR 50.49 will be adequately managed during the period of extended operation. Compliance with 10 CFR 54.21(a)(3) ensures adequate protection of the public health and safety and the common defense and security. In addition, implementation of this guidance results in a cost savings while still maintaining an adequate level of protection. This cost savings is attributed to the reduction in the number of inspections of certain electrical cable connections during the period of extended operation. It is also estimated that the costs of NRC oversight and inspection could decrease corresponding to the decrease in licensee-performed inspections.

ACTION

This final LR-ISG provides an interim revision to GALL Report AMP XI.E6. The revised AMP is available in Appendix A, "Revised Generic Aging Lessons Learned Report Aging Management Program XI.E6," and Appendix B, "Mark-Up of Changes to Generic Aging Lessons Learned Report Aging Management Program XI.E6," shows the changes to AMP XI.E6 from the GALL Report. The guidance in this LR-ISG is approved for use by the staff and stakeholders.

BACKFITTING DISCUSSION

This LR-ISG contains guidance as to one acceptable approach for managing the effects of aging during the period of extended operation for certain electrical cable connections within the scope of license renewal, which are not otherwise subject to the environmental qualification requirements of 10 CFR 50.49. Set forth below is the staff's discussion on: (i) whether this LR-ISG addresses "newly identified" systems, structures, or components (SSCs) subject to aging management under 10 CFR 54.37(b), and (ii) compliance with the requirements of the Backfit Rule, 10 CFR 50.109.

Newly Identified SSCs under 10 CFR 54.37(b)

The NRC is not proposing to include certain electrical cable connections as "newly identified" SSCs under 10 CFR 54.37(b). Therefore, any additional action on such connections 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).

Compliance with the Backfit Rule

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.

Current operating license holders who have not applied for renewed licenses – This LR-ISG is not directed at holders of (original) operating licenses. As such, issuance of this LR-ISG does not constitute backfitting as applied to holders of (original) operating licenses. Current operating license holders should continue to implement existing maintenance and inspection activities to ensure that electrical cable connections will perform their intended functions. Current operating license holders wishing to apply this guidance to their existing maintenance programs must follow the appropriate provisions under 10 CFR Part 50.

Licensees who are currently in the license renewal process – This LR-ISG is directed to current applicants for license renewal. However, this LR-ISG is not backfitting as defined in 10 CFR 50.109(a)(1). This guidance is non-binding and provides one approach acceptable to the NRC staff for managing the effects of aging of certain electrical cable connections in accordance with the requirements of 10 CFR Part 54. License renewal applicants are not required to use this guidance. Applicants may elect to propose an alternative approach for managing the aging of certain electrical cable connections during the period of extended operation. In addition, the Backfit Rule does not protect license renewal applicants voluntarily requesting renewed licenses from changes in NRC requirements or guidance on license renewal prior to or during the pendency of their renewal application (NRC, 2008). Therefore,

issuance of this LR-ISG does not constitute backfitting as applied to current applicants for license renewal.

Licensees who already hold a renewed license – This guidance is also directed to licensees who already hold a renewed license. However, 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 certain electrical cable connections). However, the NRC encourages licensees to consider the information in this LR-ISG and implement voluntary actions consistent with this guidance as they deem appropriate. Renewed license holders may follow the provisions under 10 CFR Part 50 if they choose to implement this LR-ISG into their appropriate AMPs.

REFERENCES

- 10 CFR Part 54, *Requirements for Renewal of Operating Licenses for Nuclear Power Plants*, Office of the Federal Register, National Archives and Records Administration, 2009.
- 10 CFR Part 50, *Domestic Licensing of Production and Utilization Facilities*, Office of the Federal Register, National Archives and Records Administration, 2009.
- Nuclear Energy Institute (NEI). 2006a. Letter from James H. Riley, NEI, to U.S. Nuclear Regulatory Commission Document Control Desk, “NEI White Paper on GALL AMP XI E6 (Electrical Cables).” (September 5, 2006). ADAMS No. ML062770105.
- Nuclear Energy Institute (NEI). 2006b. “NEI E6 Electrical Connections Program White Paper.” (September 2006). ADAMS No. ML062770111.
- Nuclear Energy Institute (NEI). 2007a. Letter from James H. Riley, NEI, to P.T. Kuo, NRC, “Nuclear Energy Institute (NEI) Comments on Staff Response to 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.’” (May 25, 2007). ADAMS Nos. ML071590175 and ML071590182.
- Nuclear Energy Institute (NEI). 2007b. Letter from John C. Butler, NEI, to Chief, Rulemaking Directives, and Editing Branch, NRC, “Proposed License Renewal Interim Staff Guidance LR-ISG-2007-02: Changes to Generic Aging Lesson Learned (GALL) Aging Management Program (AMP) XI.E6, Electrical Cable Connections Not Subject to 10 CFR 50.49 Environmental Qualification Requirements.” (October 18, 2007). ADAMS No. ML072960480.
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- U.S. Nuclear Regulatory Commission (NRC). 2007a. “Summary of the License Renewal Meeting between the U.S. Nuclear Regulatory Commission Staff and the Nuclear Energy Institute Regarding Generic Aging Lessons Learned Aging Management Program XI.E6.” (January 26, 2007). ADAMS No. ML063600004.

- U.S. Nuclear Regulatory Commission (NRC). 2007b. Letter from Pao-Tsin Kuo, NRC, to Alexander Marion, NEI, "Staff Response to the Nuclear Energy Institute (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 Requirement.'" (March 16, 2007). ADAMS No. ML070400349.
- U.S. Nuclear Regulatory Commission (NRC). 2007c. "Proposed 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' Solicitation of Public Comment," *Federal Register*. Washington, D.C. Vol. 72, No. 172, pp. 51256–51259. (September 6, 2007).
- U.S. Nuclear Regulatory Commission (NRC). 2008. Memorandum from Dale E. Klein, Chairman, to Hubert T. Bell, Office of the Inspector General, "Response to Recommendation 8 of 9/6/07 Audit Report on NRC's License Renewal Program." (April 1, 2008). ADAMS No. ML080870286.
- Sandia National Laboratories (SNL). 1996. "Aging Management Guideline for Commercial Nuclear Power Plants – Electrical Cable and Terminations." SAND 96-0344. (September 1996).

APPENDIX A

**REVISED GENERIC AGING LESSONS LEARNED REPORT AGING MANAGEMENT
PROGRAM XI.E6**

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

Program Description

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 program. 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 aging management program (AMP) focuses on the metallic parts of the electrical cable connections. This program provides a one-time inspection, on a sampling basis, to confirm the absence of age-related degradation of cable connections due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, and oxidation.

GALL XI.E1, "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. GALL XI.E1 is based on only 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, and oxidation on the metallic parts of cable connections.

Electrical cable connections exposed to appreciable ohmic or ambient heating during operation may experience loosening 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 so that the termination may be impacted. 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 high electrical resistance or eventual separation. 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 will be a proven test for detecting loose connections, such as thermography, contact resistance testing, or another appropriate test justified in the application. As an alternative to thermography or resistance measurement of cable connections, for the accessible cable connections that are covered with insulation materials, 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 cannot use a one-time inspection.

This program, as described, can be thought of as a sampling program. The following factors should be considered for sampling: voltage level (medium and low voltage), circuit loading (high loading), 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 will be used to evaluate the condition and determine appropriate corrective action.

SAND 96-0344, "Aging Management Guidelines for Electrical Cable and Terminations," indicated loose terminations were identified by several plants. The major concern is that the failures of a deteriorated cable system (cables, connections including fuse holders, and penetrations) could prevent it from performing its intended function. This program is not applicable to cable connections in harsh environment since they are already addressed by the requirements of 10 CFR 50.49. Even though cable connections may not be exposed to harsh environments, loosening or high resistance of connection is a concern due to aging mechanisms discussed above.

Evaluation and Technical Basis

- 1. *Scope of Program:*** Cable connections associated with cables within the scope of license renewal, which are external connections terminating at active or passive devices, are in the scope of this program. Wiring connections internal to an active assembly are considered part of the active assembly and therefore are not within the scope of this program. This program does not include high-voltage (>35 kV) switchyard connections. The cable connections covered under the Environmental Qualification (EQ) program are not included in the scope of this program.
- 2. *Preventive Actions:*** No actions are taken as part of this program to prevent or mitigate aging degradation.
- 3. *Parameters Monitored/Inspected:*** This program will focus on the metallic parts of the connection. The one time testing verifies that loosening of bolted connections or high resistance of cable connections due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, and oxidation is not an aging effect that requires a periodic testing program. 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), and location (high temperature, high humidity, vibration, etc.). The technical basis for the sample selection is to be documented.
- 4. *Detection of Aging Effects:*** A representative sample of electrical connections within the scope of license renewal will be 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 inspection provides additional confirmation to support industry operating experience that shows electrical connections have not experienced a high degree of failures, and that existing installation and maintenance practices are effective.

As an alternative to thermography or measuring connection resistance of cable connections, for the accessible cable connection 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 discoloration, cracking, chipping, or surface

contamination. When this alternative visual inspection is used to check cable connections, the first inspection will be completed before the period of extended operation and every five years thereafter.

5. **Monitoring and Trending:** Trending actions are not included as part of this program because it is a one-time inspection program.
6. **Acceptance Criteria:** Bolted connections shall not indicate abnormal temperature for the application when thermography is used. A low resistance value appropriate for the application when resistance measurement is used. When the visual inspection alternative for covered bolted connection is used, the absence of discoloration, cracking, chipping or surface contamination will provide positive indication that the covered bolted connections are not loose.
7. **Corrective Actions:** If acceptance criteria are not met, the corrective action program will be used to perform an evaluation that will consider the extent of the condition, the indications of aging effect, and changes to the one-time 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 to this report, 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 to this report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.
9. **Administrative Controls:** As discussed in the appendix to this report, 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 appreciable ohmic or ambient heating during operation may experience loosening caused by repeated cycling of connected loads or of the ambient temperature environment. There have been limited numbers of age related failures of cable connections reported. This one-time inspection confirms the absence of aging degradation of metallic cable connections.

References

- EPRI TR-109619, *Guideline for the Management of Adverse Localized Equipment Environments*, Electric Power Research Institute, Palo Alto, CA, June 1999.
- IEEE Std. P1205-2000, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations*.
- NUREG/CR-5643, *Insights Gained From Aging Research*, U.S. Nuclear Regulatory Commission, March 1992.

SAND 96-0344, *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.

EPRI TR - 104213, *Bolted Joint Maintenance & Application Guide*, Electric Power Research Institute, Palo Alto, CA, December 1995.

APPENDIX B

**MARK-UP OF CHANGES TO GENERIC AGING LESSONS LEARNED REPORT AGING
MANAGEMENT PROGRAM XI.E6**

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

Program Description

Cable connections are used to connect cable conductors to other ~~cables~~ cable conductors or electrical devices. Connections associated with cables within the scope of license renewal are part of this program. 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 aging management program ~~for (AMP)~~ focuses on the metallic parts of the electrical cable connections ~~(metallic parts) account for the following aging stressors:-~~ This program provides a one-time inspection, on a sampling basis, to confirm the absence of age-related degradation of cable connections due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, and oxidation.

GALL XI.E1, "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. GALL XI.E1 is based on only a visual inspection of accessible cables and connections. Visual inspection ~~is~~ may not be sufficient to detect the aging effects from thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, and oxidation on the metallic parts of cable connections.

~~Circuits~~ Electrical cable connections exposed to appreciable ohmic or ambient heating during operation may experience loosening ~~related to~~ 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 ~~existing~~ between these components change with repeated thermal cycling. For example, under loaded conditions, ~~appreciable~~ ohmic heating may raise the temperature of a compression ~~termination~~ terminal and cable conductor well above the ambient temperature, thereby causing thermal expansion of both components. ~~Different thermal~~ Thermal expansion coefficients of different materials may alter mechanical stresses between the components so that the termination may ~~tighten on the conductor~~ be impacted. When the ~~load or~~ current is reduced, the affected components cool and contract. Repeated cycling in this fashion can ~~produce~~ cause loosening of the termination ~~under ambient conditions~~, and may lead to high electrical resistance ~~joints~~ or eventual separation ~~to compression type terminations~~. Threaded connectors, ~~splices, and terminal blocks~~ 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 will be ~~determined prior to the initial test, and is to be~~ a proven test for detecting loose connections, such as thermography, contact resistance testing, or ~~an~~ other appropriate ~~testing test~~ justified in the application. As an alternative to thermography or resistance measurement of cable connections, for the accessible cable connections that are covered with insulation materials, 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 cannot use a one-time inspection.

This program, as described, can be thought of as a sampling program. The following factors ~~are~~ should be considered for sampling: ~~application (high,~~ voltage level (medium and low voltage), circuit loading (high loading), and location (high temperature, high humidity, vibration, etc.). The

technical basis for the sample selections ~~is~~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 will be used to evaluate the condition and determine appropriate corrective action.

~~SAND SAND 96-0344, "Aging Management Guidelines for Electrical Cable and Terminations," indicated loose terminations were identified by several plants. The major concern is that the failures of a deteriorated cable system (cables, connections including fuse holders, and penetrations) might be induced during accident conditions. Since the connections are not subject to the environmental qualification requirements of 10 CFR 50.49, an aging management program is required to manage the aging effects. This program will ensure that electrical cable connections will perform their intended function for the period of extended operation could prevent it from performing its intended function. This program is not applicable to cable connections in harsh environment since they are already addressed by the requirements of 10 CFR 50.49. Even though cable connections may not be exposed to harsh environments, loosening or high resistance of connection is a concern due to aging mechanisms discussed above.~~

Evaluation and Technical Basis

- 1. Scope of Program:** ~~Connections~~Cable connections associated with cables ~~in~~within the scope of license renewal, which are ~~part of this program, regardless of their association with external connections terminating at active or passive components.~~devices, are in the scope of this program. Wiring connections internal to an active assembly are considered part of the active assembly and therefore are not within the scope of this program. This program does not include high-voltage (>35 kV) switchyard connections. The cable connections covered under the Environmental Qualification (EQ) program are not included in the scope of this program.
- 2. Preventive Actions:** No actions are taken as part of this program to prevent or mitigate aging degradation.
- 3. Parameters Monitored/Inspected:** This program will focus on the metallic parts of the connection. The ~~monitoring includes one time testing verifies that~~ loosening of bolted connections or high resistance of cable connections due to thermal cycling, ohmic heating, electrical transients, vibration, chemical contamination, corrosion, and oxidation is not an aging effect that requires a periodic testing program. A representative sample of electrical cable connections is tested. The following factors are ~~to be~~ considered for sampling: ~~application (high, voltage level~~ (medium and low voltage), circuit loading (high load), and location (high temperature, high humidity, vibration, etc.). The technical basis for the sample ~~selected~~selection is to be documented.
- 4. Detection of Aging Effects:** ~~Electrical~~A representative sample of electrical connections within the scope of license renewal will be tested at least once ~~every 10 years.~~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. ~~This is an adequate period to preclude failures of the electrical connections since experience has shown that aging degradation is a slow process. A 10-year testing interval will provide two data points during a 20-year period, which can be used to characterize the degradation rate. The first tests for license renewal are to be completed before the period of extended operation.~~ without

removing the connection insulation such as heat shrink tape, sleeving, insulating boots, etc. The one-time inspection provides additional confirmation to support industry operating experience that shows electrical connections have not experienced a high degree of failures, and that existing installation and maintenance practices are effective.

As an alternative to thermography or measuring connection resistance of cable connections, for the accessible cable connection 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 discoloration, cracking, chipping, or surface contamination. When this alternative visual inspection is used to check cable connections, the first inspection will be completed before the period of extended operation and every five years thereafter.

5. **Monitoring and Trending:** Trending actions are not included as part of this program because ~~the ability to trend test results is dependent on the specific type of test chosen. However, test results that are trendable provide additional information on the rate of degradation~~a one-time inspection program.
6. ~~**Acceptance Criteria:** The acceptance criteria for each test are defined by the specific type of test performed and the specific type of cable connections tested~~**Acceptance Criteria:** Bolted connections shall not indicate abnormal temperature for the application when thermography is used. A low resistance value appropriate for the application when resistance measurement is used. When the visual inspection alternative for covered bolted connection is used, the absence of discoloration, cracking, chipping or surface contamination will provide positive indication that the covered bolted connections are not loose.
7. ~~**Corrective Actions:** An engineering evaluation is performed when the test acceptance criteria are not met in order to ensure that the intended functions of the cable connections can be maintained consistent with the current licensing basis. Such an evaluation is to consider the significance of the test results, the operability of the component, the reportability of the event, the extent of the concern, the potential root causes for not meeting the test acceptance criteria, the corrective action necessary, and the likelihood of recurrence. When an unacceptable condition or situation is identified, a determination is made on whether the same condition or situation is applicable to other in scope cable connections not tested.~~**Corrective Actions:** If acceptance criteria are not met, the corrective action program will be used to perform an evaluation that will consider the extent of the condition, the indications of aging effect, and changes to the one-time 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 to this report, 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 to this report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the confirmation process.
9. **Administrative Controls:** As discussed in the appendix to this report, the staff finds the requirements of 10 CFR Part 50, Appendix B, acceptable to address the administrative controls.

10. ~~Operating Experience: Operating experience has shown that loosening of connections and corrosion of connections are aging mechanisms that, if left unmanaged, could lead to a loss of electrical continuity and potential arcing or fire~~ Operating Experience: Electrical cable connections exposed to appreciable ohmic or ambient heating during operation may experience loosening caused by repeated cycling of connected loads or of the ambient temperature environment. There have been limited numbers of age related failures of cable connections reported. This one-time inspection confirms the absence of aging degradation of metallic cable connections.

References

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