NUCLEAR ENERGY INSTITUTE

Douglas J. Walters
SR. PROJECT MANAGER, LICENSING
NUCLEAR GENERATION

April 24, 2000

Mr. Christopher I. Grimes
Chief, License Renewal and Standardization Branch
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Mail Stop O-12 G15
Washington, DC 20555-0001

SUBJECT: Generic Aging Lessons Learned Report Comments

PROJECT NUMBER: 690

Dear Mr. Grimes:

In our letter dated March 27, 2000 we provided comments on GALL Chapter VI, Electrical Components. We met with the NRC staff March 29 to discuss our comments. Enclosed is a revised copy of GALL Chapter VI that reflects the NRC staff feedback provided in that meeting.

In our original comments we provided a "clean copy" of GALL to reflect how it would read with our comments incorporated. The enclosure to this letter includes a mark-up of that clean copy and a new clean copy to reflect the feedback provided in the March 29 meeting.

We understand that no additional meeting are scheduled to discuss Chapter VI; however, we are available to answer questions should any arise.

Sincerely,

Douglas J. Walters

Douglas J. Walters

c: Mr. Sam Lee
Mr. P.T.Kuo

D042

1776 I STREET, NW SUITE 400 WASHINGTON, DC 20006-3708 PHONE 202.739.8000 FAX 202.785.4019 www.nei.org

CHAPTER VI

ELECTRICAL COMPONENTS

Major Electrical Components

A. ~~Insulated~~ Electrical Cables and Connections

A. Electrical ~~Insulated~~ Cables and Connections

A.1 Conductor Insulation

A.1.1 ~~Accessible Insulated~~ Electrical cables and connections exposed to an adverse localized environment caused by heat or radiation

A.1.2 Electrical cables used in instrumentation circuits that are sensitive to reduction in conductor insulation resistance (IR) exposed to an adverse localized environment caused by heat or radiation

A.1.3 Inaccessible medium-voltage (2 kV to 15 kV) cables (e.g., installed in conduit or direct buried) exposed to an adverse localized environment caused by exposure to moisture and voltage

A.2 Connector Contacts

A.2.1 Electrical connectors exposed to borated water leakage

Systems, Structures and Components

This review table addresses electrical ~~insulated~~ cables and connections installed in power and instrumentation and control (I&C) applications. The power cables addressed are low-voltage (<1000 V) and medium-voltage (2 kV to 15 kV). High voltage power cables (>15 kV) are not normally used at nuclear power plants, have unique, specialized constructions and must be evaluated on an application specific basis.

Electrical ~~Insulated~~ cables and their required terminations (i.e., connections) are reviewed as a single commodity. The types of connections included in this review are splices, mechanical connectors, and terminal blocks. This common review is translated into program actions, which treat cables and connections in the same manner.

Electrical ~~Insulated~~ cables and connections that are in the plant's environmental qualification (EQ) program are not included in this section. Components in the EQ program have a qualified life and the components ~~is~~ are replaced at the end of that qualified life. The qualified life may be extended by methods such as refurbishment ~~of specific parts~~ or ~~by~~ reanalyzing the aging assessment ~~qualified life evaluation~~, but the plant is required by the EQ regulation (10 CFR 50.49) to replace the component when its qualified life has expired. This makes all EQ components replacement items under § 54.21(a)(1)(ii) and no EQ components are required to be included in the aging management review. ~~Compliance with § 50.49 is adequate to ensure maintenance of the intended functions of the insulated cables and connections included in the plant's EQ program.~~

System Interfaces

~~Insulated~~ Electrical cables and connections functionally interface with all plant systems that rely on electric power and/or instrumentation and control. ~~Insulated~~ Electrical cables and connections also interface with and are supported by structural commodities (e.g., cable trays, conduit, cable trenches, cable troughs, duct banks, cable vaults and manholes) which are reviewed, as appropriate, in the Structures and Components Supports section.

VI. ELECTRICAL COMPONENTS
A. ~~Insulated~~ Electrical Cables and Connections

Item	Structure and Component	Region of Interest	Material	Environment	Aging Effect	References
A.1.1	~~Accessible Insulated~~ Electrical Cables and Connections	Conductor insulation	Various organic polymers (e.g., EPR, SR, EPDM, XLPE)	Adverse localized environment caused by heat or radiation in the presence of oxygen	Embrittlement, cracking, melting, discoloration, leading to reduced insulation resistance, electrical failure, caused by thermal/ thermoxidative degradation of organics, radiolysis and photolysis (UV sensitive materials only) of organics; radiation-induced oxidation	~~NUREG-1705~~ NUREG-1723 NUREG/CR-5643 IEEE Std. P1205 SAND96-0344 ~~EPRI TR-109619~~
A.1.2	Electrical cables used in instrumentation circuits that are sensitive to reduction in conductor insulation resistance (IR)	Conductor insulation	Various organic polymers (e.g., EPR, SR, EPDM, XLPE)	Adverse localized environment caused by heat or radiation in the presence of oxygen	Embrittlement, cracking, melting, discoloration, leading to reduced insulation resistance, electrical failure, caused by thermal/ thermoxidative degradation of organics, radiation-induced oxidation	NUREG-1705 NUREG/CR-5643 IEEE Std. P1205 SAND96-0344
A.1.3	Inaccessible Medium-Voltage (2 kV to 15 kV) Cables (e.g. installed in conduit or direct buried)	Conductor insulation	Various organic polymers (e.g., EPR, SR, EPDM, XLPE)	Adverse localized environment caused by exposure to moisture and voltage	Formation of water trees, localized damage, leading to electrical failure (breakdown of insulation), caused by moisture intrusion, water trees	~~NUREG-1705~~ NUREG-1723 IEEE Std. P1205 SAND96-0344 ~~EPRI TR-109619~~

VI. ELECTRICAL COMPONENTS
A. ~~Insulated~~ Electrical Cables and Connections

Existing Aging Management Program (AMP)	Evaluation and Technical Basis	Further Evaluation
Aging Management Program for ~~Insulated~~ Electrical Cables and Connections Exposed to an Adverse Localized Environment caused by Heat or Radiation	See Chapter XI program A.1 for a description.	No
Aging Management Program for Electrical Cables Used in Instrumentation Circuits that are Sensitive to Reduction in Conductor Insulation Resistance (IR) Exposed to an Adverse Localized Environment Caused by Heat or Radiation	See Chapter XI program A.2 for a description.	No
Aging Management Program For Inaccessible Medium-Voltage Cables Exposed to an Adverse Localized Environment caused by Moisture and Voltage Exposure	See Chapter XI program A.3 for a description.	No

VI. ELECTRICAL COMPONENTS

A. ~~Insulated~~ Electrical Cables and Connections

Item	Structure and Component	Region of Interest	Material	Environment	Aging Effect	References
A.2.1	Electrical Connectors Exposed to Borated Water Leakage	Connector contacts	Various metals used for electrical contacts	Exposure to borated water leakage	Corrosion of connector contact surfaces caused by intrusion of borated water	NUREG-1723 IEEE Std. P1205 SAND96-0344

VI. ELECTRICAL COMPONENTS

A. ~~Insulated~~ Electrical Cables and Connections

Existing Aging Management Program (AMP)	Evaluation and Technical Basis	Further Evaluation
Borated Water Leakage Surveillance Program for Electrical Connectors	See Chapter XI program A.4 for a description.	No

References

NUREG-1705, *Safety Evaluation Report Related to the License Renewal of Calvert Cliffs Nuclear Power Plant, Units 1 and 2*, December 1999

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

~~EPRI TR-109619, *Guideline or the Management of Adverse Localized Equipment Environments*, June 1999~~

CHAPTER X

TIME-LIMITED AGING ANALYSES

A.1 ~~Qualified Life Analyses~~ Aging Assessments for Electrical ~~Components~~ Equipment Included in the Plant's Environmental Qualification (EQ) Program

A.1 Aging Assessments for Electrical Equipment Included in the Plant's Environmental Qualification (EQ) Program

The Nuclear Regulatory Commission (NRC) has established nuclear station environmental qualification (EQ) requirements in 10 CFR 50 Appendix A, Criterion 4, and in 10 CFR 50.49. 10 CFR 50.49 specifically requires that an EQ program be established to demonstrate that certain electrical components located in "harsh" plant environments (i.e., those areas of the plant that could be subject to the harsh environmental effects of a loss of coolant accident (LOCA), high energy line breaks (HELBs) or post-LOCA radiation) are qualified to perform their safety function in those harsh environments after the effects of inservice aging. 10 CFR 50.49 requires that the effects of significant aging mechanisms be addressed as part of environmental qualification.

All operating plants must meet the requirements of ~~10 CFR 50.49 (EQ Rule)~~ § 50.49 for certain electrical equipment important-to-safety. ~~The EQ rule~~ § 50.49 defines the scope of equipment to be included, requires the preparation and maintenance of a list of in-scope equipment, and requires the preparation and maintenance of a qualification file that includes equipment performance specifications, electrical characteristics and environmental conditions. ~~The aging provisions are contained in~~ § 50.49(e)(5) contains aging provisions that require ~~which requires~~, in part, consideration of all significant types of aging degradation that can affect equipment functional capability. § 50.49(e) also requires equipment replacement or refurbishment prior to the end of designated life unless additional life is established through ongoing qualification. § 50.49(f) establishes four methods of demonstrating qualification for aging and accident conditions. §§ 50.49(k) and (l) ~~permits~~ permit different qualification criteria to apply based on plant and equipment vintage. Supplemental EQ regulatory guidance for compliance with these different qualification criteria is provided in the DOR Guidelines, *Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors*, June 1979, NUREG-0588, *Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment*, July 1981, and Regulatory Guide 1.89, Rev. 1, *Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants*, June 1984. Compliance with ~~the EQ rule~~ § 50.49 provides evidence that the equipment will perform its intended functions during accident conditions after ~~considering~~ experiencing the detrimental effects of in-service aging.

Generic safety issue (GSI) 168 is related to low-voltage EQ ~~components~~ instrumentation and control cables and is currently an open generic issue ~~related to~~ for license renewal. NRC research is ongoing to provide information to resolve it. Specific issues being addressed in this research are presented in NUREG/CR-6384. Once this generic issue is resolved, guidance will be provided as to the impact on license renewal. In the interim, NRC letter dated June 2, 1998, "*Guidance on Addressing GSI-168 for License Renewal*," (C. Grimes, NRC to D. Walters, NEI) provides guidance on addressing GSI-168 in license renewal applications. It states that, until the generic issue is resolved, "*...an acceptable approach described in the SOC is to provide a*

technical rationale demonstrating that the current licensing basis for EQ, pursuant to 10 CFR 50.49 will be maintained in the period of extended operation."

~~The EQ process manages component intended functions through the use of qualification analyses.~~ EQ programs manage component thermal, radiation and cyclical aging through the use of equipment aging assessments based on § 50.49(f) qualification methods. ~~As required by the EQ Rule, an installed EQ component must always be qualified. Before the qualification for a component expires, the qualification must be extended analytically or through refurbishment or additional qualification testing, or the component must be replaced.~~ As required by § 50.49, EQ equipment must be refurbished, replaced, or its qualification extended prior to reaching the aging limits established in the equipment aging assessment. ~~Analyses~~ Aging assessments for EQ equipment ~~which~~ that specify a qualification of at least 40 years are considered time limited aging analyses (TLAA) for license renewal.

EQ TLAA DEMONSTRATION OPTIONS

~~There are~~ Three TLAA demonstration ~~methods~~ options are provided in § 54.21(c)(1) ~~that can be used for evaluating TLAA~~:

(i) the analysis remains valid for the period of extended operation,
(ii) the analysis is projected to the end of the period of extended operation, or
(iii) the effects of aging on the intended functions will be adequately managed during the period of extended operation.

For ~~demonstration method~~ option (i), the ~~qualification~~ equipment aging assessment existing at the time of the renewal application ~~extends~~ qualifies the equipment through the period of extended operation and no further evaluation is necessary.

For ~~demonstration method~~ option (ii), a reanalysis of the equipment aging assessment was performed in order to extend the qualification of the component through the period of extended operation. Important attributes of an equipment aging assessment reanalysis include analytical methods, data collection and reduction methods, underlying assumptions, acceptance criteria and corrective actions (if acceptance criteria are not met). These attributes are discussed in the **EQ Equipment Aging Assessment Reanalysis Attributes** section.

~~For demonstration method (iii), since these components are regulated under § 50.49 which requires that a qualified component be installed to perform the intended functions, at some time in the future before the component's qualification expires, the component's qualification must be extended analytically or through refurbishment or additional qualification testing, or the component must be replaced.~~ Option (iii) would be used in cases (a) where the equipment aging assessment does not extend the qualification into, or extends the qualification into but not through, the period of extended operation, or (b) where aging management actions such as

periodic maintenance, inspection, testing, or parts replacement are required to maintain the qualification through the period of extended operation. In light of this option EQ programs, which implement the requirements of § 50.49 (as further defined and clarified by the DOR Guidelines, NUREG-0588, and Regulatory Guide 1.89, Rev. 1.), at plants are viewed as aging management programs for license renewal. The evaluation and technical basis for EQ programs as acceptable aging management programs is provided in the **EQ Program Evaluation and Technical Basis** section. Reanalysis of an aging assessment to extend the qualifications of equipment is performed on a routine basis as part of an EQ program. Important attributes of an equipment aging assessment reanalysis include analytical methods, data collection and reduction methods, underlying assumptions, acceptance criteria and corrective actions (if acceptance criteria are not met). These attributes are discussed in the **EQ Equipment Aging Assessment Reanalysis Attributes** section.

~~An acceptable approach found during license renewal applications is to examine the reanalysis method performed for demonstration methods (ii) and (iii). The technical rationale attributes applicable to reanalysis should include analytical methods, data collection and reduction methods, acceptance criteria and corrective actions (if acceptance criteria are not met), and underlying assumptions. The following attribute descriptions have been found acceptable and should be used as a review guide.~~

EQ PROGRAM EVALUATION AND TECHNICAL BASIS

(1) Scope of Program: EQ programs include certain electrical equipment that is important to safety and could be exposed to harsh environment accident conditions, as defined in 10 CFR 50.49.

(2) Preventive Actions: § 50.49 does not require actions that prevent aging effects. EQ program actions that could be viewed as preventive actions include (a) establishing the equipment service condition tolerance and aging limits (e.g., qualified life or condition limit), (b) refurbishment, replacement, or requalification of installed equipment prior to reaching these aging limits, and (c) where applicable, requiring specific installation, inspection, monitoring, or periodic maintenance actions to maintain equipment aging effects within the qualification.

(3) Parameters Monitored/Inspected: EQ equipment aging limits are not typically based on condition or performance monitoring. However, per Regulatory Guide 1.89 Rev. 1, such monitoring programs are an acceptable basis to modify aging limits. Monitoring or inspection of certain environmental, condition or equipment parameters may be used to ensure that the equipment is within its qualification or as a means to modify the qualification.

(4) Detection of Aging Effects: § 50.49 does not require the detection of aging effects for in-service equipment. Monitoring of aging effects may be used as a means to modify equipment aging limits.

(5) Monitoring and Trending: § 50.49 does not require monitoring and trending of equipment condition or performance parameters of in-service equipment to manage the effects of aging. EQ program actions that could be viewed as monitoring include monitoring how long qualified equipment has been installed. Monitoring or inspection of certain environmental, condition or

equipment parameters may be used to ensure that the equipment is within its qualification or as a means to modify the qualification.

(6) Acceptance Criteria: § 50.49 acceptance criteria is that in-service EQ equipment is maintained within its qualification including (a) its established aging limits and (b) continued qualification for the projected accident conditions. § 50.49 requires refurbishment, replacement, or requalification prior to exceeding the aging limits of each installed device. When monitoring is used to modify an equipment aging limit, plant-specific acceptance criteria are established based on applicable § 50.49(f) qualification methods.

(7 & 8) Corrective Actions & Confirmation Process: If EQ equipment is found to be outside its qualification, corrective actions are implemented in accordance with the station's corrective action program. When unexpected adverse conditions are identified during operational or maintenance activities that affect the environment or qualified equipment, affected EQ equipment is evaluated and appropriate corrective actions are taken, which may include changes to the qualification bases and conclusions. When emerging industry aging issues are identified that affect the qualification of EQ equipment, affected equipment is evaluated and appropriate corrective actions are taken, which may include changes to the qualification bases and conclusions. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.

(9) Administrative Controls: EQ programs are implemented through the use of station policy, directives and procedures. EQ programs will continue to comply with § 50.49 throughout the renewal period including development and maintenance of qualification documentation demonstrating equipment will perform required functions during harsh accident conditions. EQ program documents identify the applicable environmental conditions for the equipment locations. EQ program qualification files are maintained at the plant site in an auditable form for the duration of the installed life of the equipment. EQ program documentation is controlled under the station's quality assurance program.

(10) Operating Experience: EQ programs include consideration of operating experience to modify qualification bases and conclusions, including aging limits. Compliance with § 50.49 provides evidence that the equipment will perform its intended functions during accident conditions after experiencing the detrimental effects of in-service aging.

~~REANALYSIS OF A QUALIFICATION~~
EQ EQUIPMENT AGING ASSESSMENT REANALYSIS ATTRIBUTES

The reanalysis of an equipment aging assessment is normally performed ~~for a specific application~~ to extend the qualification ~~if excess conservatism exists in the original analysis~~ by reducing excess conservatisms incorporated in the prior aging assessment. Reanalysis of an aging assessment to extend the qualifications of equipment is performed on a routine basis as part of an EQ program. ~~The qualified life may be limited by~~ An equipment life limiting condition may be due to thermal, radiation, or cyclical aging; the vast majority of ~~qualified life values~~ equipment aging limits are based on thermal ~~limits~~ conditions. Conservatisms may exist in aging assessment parameters such as the assumed ambient temperature of the equipment, an unrealistically low activation energy, or in the application of equipment (de-energized versus

energized). ~~The~~ An equipment aging assessment reanalysis is documented according to the ~~plant's~~ station's quality assurance program requirements, which requires the verification of assumptions and conclusions. ~~Specific~~ Important attributes of an equipment aging assessment reanalysis include analytical methods, data collection and reduction methods, underlying assumptions, acceptance criteria and corrective actions (if acceptance criteria are not met). These attributes are discussed below.

Analytical Methods: The analytical models use in an equipment aging assessment reanalysis should be the same as those previously applied during the prior aging assessment. The Arrhenius methodology is an acceptable thermal model ~~used to~~ for performing a thermal ~~reanalysis~~ aging assessment. The analytical method used for a radiation ~~reanalysis~~ aging assessment is to demonstrate qualification for the total integrated dose (i.e., normal radiation dose for ~~60 years~~ the projected installed life plus accident radiation dose). For ~~radiation~~ license renewal, one acceptable method of establishing the 60 year ~~aging~~ normal radiation dose is to multiply the 40 year normal radiation dose ~~applicable to the equipment~~ by 1.5 (i.e., 60 years/40 years)~~the ratio of the evaluation period and divide by 40 years (e.g., for license renewal 60 years/40 years = 1.5)~~. ~~This value~~ The result is added to the ~~applicable~~ accident radiation dose to obtain the total integrated dose for the equipment. For cyclical aging a similar approach may be used. Other models may be justified on a case-by-case basis.

Data Collection & Reduction Methods: Reducing excess conservatisms in the equipment service conditions (e.g., temperature, radiation, cycles) used in ~~existing analyses~~ the prior aging assessment is the chief method used for a reanalysis. Temperature data used in ~~a reanalysis shall be conservatively based~~ an equipment aging assessment should be conservative and based on plant design temperatures or on actual plant temperature data ~~measurements in the area around the equipment being reanalyzed~~. When used, plant temperature data ~~measurements~~ can be obtained in several ways, ~~examples of which are through~~ including monitors used for technical specification compliance, other installed monitors, measurements made by plant operators during rounds, and temperature sensors on large motors (while the motor is not running). A representative number of temperature measurements are ~~mathematically reduced to arrive at a~~ conservatively evaluated to establish the temperatures used in an equipment aging assessment ~~a reanalysis~~. ~~Temperatures~~ Plant temperature data may be used in an equipment aging assessment in different ~~several~~ ways ~~in a reanalysis~~ such as (a) ~~using the actual calculated~~ directly applying the plant temperature data in the aging assessment, or (b) using the plant ~~calculated~~ temperature data to ~~validate or show~~ demonstrate conservatism when using ~~a~~ plant design temperatures for an aging assessment ~~a reanalysis~~. Any changes to material activation energy values as part of an equipment aging assessment reanalysis should be justified. ~~Other~~ Similar methods of reducing excess conservatisms in the equipment service conditions used in prior aging assessments can be used for ~~establishing~~ radiation and cyclical aging ~~parameters, including parameters conservatively based on operational data, may also be used when justified~~.

X. TIME-LIMITED AGING ANALYSES

A.1 ~~Qualified Life Analyses~~ Aging Assessments for Electrical ~~Components~~ Equipment Included in the Plant's Environmental Qualification (EQ) Program

Underlying Assumptions: ~~Conservatisms in the~~ EQ equipment ~~qualification analyses are~~ aging assessments contain sufficient conservatisms to account for most environmental changes occurring due to plant modifications and events. When unexpected adverse conditions are identified during operational or maintenance activities that affect the environment or qualified equipment, affected EQ equipment is evaluated and appropriate corrective actions are taken, which may include changes to the qualification bases and conclusions. ~~Plant environmental zones are identified in the EQ documentation. The EQ documentation identifies the harsh environmental areas of the plant for loss of coolant accidents (LOCAs), high energy line breaks (HELBs) and radiation. The EQ documentation is a Quality Assurance controlled document.~~

~~Changes in environmental parameters are reviewed by the EQ responsible engineer to address affected EQ equipment on a generic basis. If the changes cannot be dispositioned on a generic basis, the station corrective action process would be initiated to resolve the specific equipment concerns. Adverse environmental changes are addressed on an ongoing basis.~~

~~When a significant environmental change is identified, a review of the qualification of affected EQ equipment is performed and applicable changes are made to the equipment qualification. In addition, when a reanalysis is performed for the purposes of extending the qualification, the environmental parameters for the equipment are verified. When environmental data used in an equipment reanalysis is confirmed to be accurate, the EQ documentation, if appropriate, is revised to reflect the new operating conditions. Equipment reanalyses are performed under calculations whose assumptions and environmental data are reviewed periodically for continued validity.~~

Acceptance Criteria & Corrective Actions: ~~The~~ An aging assessment reanalysis shall extend the ~~equipment's~~ qualification of the equipment. If the qualification cannot be extended by reanalysis, the equipment ~~is~~ must be refurbished, replaced, or requalified prior to ~~the expiration of~~ exceeding the ~~existing~~ current qualification. An equipment aging assessment reanalysis should be performed in a timely manner (i.e., sufficient time is available to refurbish, replace or requalify the equipment if the reanalysis is unsuccessful).

References

Code of Federal Regulations, Title 10, Part 50, Section 49, *Environmental Qualification of electric Equipment Important to Safety for Nuclear Power Plants.*

NRC Bulletin 79-01B, Environmental Qualification of Class 1E Equipment, January 14, 1980.

NRC Regulatory Guide 1.89, *Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants*, June 1984.

DOR Guidelines, *Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors*, June 1979

NUREG-0588, *Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment,* December 1979.

NUREG/CR-6384,

IEEE Std. 317, *IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.*

IEEE Std. 323, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.*

IEEE Std. 383, *IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.*

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

NRC letter from C. Grimes, NRC, to D. Walters, NEI, "*Guidance on Addressing GSI-168 for License Renewal,*" June 2, 1998

NUREG-1705, *Safety Evaluation Report Related to the License Renewal of Calvert Cliffs Nuclear Power Plant, Units 1 and 2*, December 1999

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

CHAPTER XI

EXISTING AGING MANAGEMENT PROGRAMS (AMP) AND ACTIVITIES

Existing Aging Management Programs (AMP) and Activities

A.1 Aging Management Program for Electrical Cables and Connections Exposed to an Adverse Localized Environment Caused by Heat or Radiation

A.2 Aging Management Program for Electrical Cables Used in Instrumentation Circuits that are Sensitive to Reduction in Conductor Insulation Resistance (IR) Exposed to an Adverse Localized Environment Caused by Heat or Radiation

A.3 Aging Management Program for Inaccessible Medium-Voltage Cables Exposed to an Adverse Localized Environment Caused by Moisture and Voltage Exposure

A.4 Borated Water Leakage Surveillance Program for Electrical Connectors

A.1 Aging Management Program for ~~Insulated~~ Electrical Cables and Connections Exposed to an Adverse Localized Environment Caused by Heat or Radiation

In most areas within a nuclear power plant, the actual ambient environments are less severe than the design environments. However, in a limited number of localized areas, the actual environments may be more severe than the design environments. Conductor insulation materials used in cables and connections may degrade more rapidly than expected in these adverse localized environments. The purpose of this aging management program is to provide reasonable assurance that the intended functions of ~~insulated~~ electrical cables and connections exposed to adverse localized environments caused by heat or radiation will be maintained consistent with the current licensing basis through the period of extended operation.

As stated in NUREG/CR-5643, "*The major concern with cables, is the performance of aged cable when it is exposed to accident conditions.*" The statement of considerations for the final license renewal rule (60FR22477) states, "*The major concern is that failures of deteriorated cable systems (cables, connections, and penetrations) might be induced during accident conditions.*" The ~~insulated~~ electrical cables and connections covered by this aging management program, being non-EQ, are either not exposed to harsh accident conditions or are not required to remain functional during or following an accident to which they are exposed. Although the ~~insulated~~ electrical cables and connections included in this program are important to overall plant safety, their capability to perform their intended functions during or following a design basis event is not a major concern.

(1) Scope: The inspection program includes accessible ~~insulated~~ electrical cables and connections within the scope of license renewal that are installed in adverse localized environments caused by heat or radiation in the presence of oxygen. An adverse localized environment is a condition in a limited plant area that is significantly more severe than the specified service condition for the ~~insulated~~ electrical cable or connection.
(2) Preventive Actions: No actions are taken as part of this program to prevent or mitigate aging degradation.
(3) Parameters Monitored/Inspected: Accessible ~~insulated~~ electrical cables and connections installed in adverse localized environments are visually inspected for cable and connection jacket surface anomalies such as embrittlement, discoloration, cracking or surface contamination.
(4) Detection of Aging Effects: Cable and connection jacket surface anomalies are precursor indications of conductor insulation aging degradation from heat or radiation in the presence of oxygen. Accessible ~~insulated~~ electrical cables and connections installed in adverse localized environments are visually inspected at least once every 10 years, which is an adequate period to preclude failures of the conductor insulation.
(5) Monitoring and Trending: No actions are taken as part of this program to trend inspection results.

(6) Acceptance Criteria: No unacceptable, visual indications of cable and connection jacket surface anomalies, which suggest that conductor insulation degradation exists, as determined by engineering evaluation. An unacceptable indication is defined as a noted condition or situation that, if left unmanaged, could lead to a loss of the intended function.
(7 & 8) Corrective Actions & Confirmatory Process: Further investigation is performed on ~~insulated~~ electrical cables and connections when the acceptance criteria are not met in order to ensure that the intended functions will be maintained consistent with the current licensing basis. Corrective actions may include, but are not limited to, testing, shielding or otherwise changing the environment, relocation or replacement of the affected cable or connection. Specific corrective actions are implemented in accordance with the station's corrective action program. When an unacceptable condition or situation is identified, a determination is made as to whether the same condition or situation is applicable to other accessible or inaccessible cables or connections. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Controls: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Operating experience has shown that adverse localized environments caused by heat or radiation for ~~insulated~~ electrical cables and connections may exist next to or above (within three feet of) steam generators, pressurizers, or hot process pipes such as feedwater lines.

References

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

A.2 Aging Management Program for Electrical Cables Used in Instrumentation Circuits that are Sensitive to Reduction in Conductor Insulation Resistance (IR) Exposed to an Adverse Localized Environment Caused by Heat or Radiation

In most areas within a nuclear power plant, the actual ambient environments are less severe than the design environments. However, in a limited number of localized areas, the actual environments may be significantly more severe than the design environments. Conductor insulation materials used in electrical cables may degrade more rapidly than expected in these adverse localized environments. Exposure of electrical cables to adverse localized environments caused by heat or radiation can result in reduced insulation resistance (IR). Reduced IR causes an increase in leakage currents between conductors, and from individual conductors to ground. A reduction in IR can be a concern for circuits with sensitive, low-level signals such as radiation monitoring and nuclear instrumentation since it may contribute to inaccuracies in the instrument loop. When an instrumentation loop is found to be out of calibration during routine preventative maintenance, trouble shooting is preformed which includes the instrumentation cable. The purpose of this aging management program is to provide reasonable assurance that the intended functions of electrical cables used in circuits with sensitive, low-level signals exposed to adverse localized environments caused by heat or radiation will be maintained consistent with the current licensing basis through the period of extended operation.

As stated in NUREG/CR-5643, "*The major concern with cables, is the performance of aged cable when it is exposed to accident conditions.*" The statement of considerations for the final license renewal rule (60FR22477) states, "*The major concern is that failures of deteriorated cable systems (cables, connections, and penetrations) might be induced during accident conditions.*" The electrical cables covered by this aging management program, being non-EQ, are either not exposed to harsh accident conditions or are not required to remain functional during or following an accident to which they are exposed. Although the electrical cables and connections included in this program are important to overall plant safety, their capability to perform their intended functions during or following a design basis event is not a major concern.

(1) Scope of Program: This program includes electrical cables used in circuits with sensitive, low-level signals such as radiation monitoring and nuclear instrumentation that are within the scope of license renewal.
(2) Preventive Actions: No actions are taken as part of this program to prevent or mitigate aging degradation.
(3) Parameters Monitored/Inspected: The parameters monitored are specific to the instrumentation loop being calibrated as documented in the preventive maintenance procedure.
(4) Detection or Aging Effects: Calibration provides sufficient indication of the need for corrective actions by monitoring key parameters and providing trending data based on acceptance criteria related to instrumentation loop performance. The normal calibration

frequency provides reasonable assurance that severe aging degradation will be detected prior to loss of the cable intended function.
(5) Monitoring and Trending: No actions are taken as part of this program to trend the test results.
(6) Acceptance Criteria: Calibration readings within the loop specific acceptance criteria as set out in the preventive maintenance procedure.
(7 & 8) Corrective Actions & Confirmatory Process: Corrective actions such as recalibration and circuit trouble-shooting are implemented when an instrument loop is found to be out of calibration. Specific corrective actions are implemented in accordance with the station's corrective action program. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Controls: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Operating experience has shown that a significant number of cable failures are identified through routine calibration testing.

References

NUREG-1705, *Safety Evaluation Report Related to the License Renewal of Calvert Cliffs Nuclear Power Plant, Units 1 and 2*, December 1999

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

A.3 Aging Management Program for Inaccessible Medium-Voltage Cables Exposed to an Adverse Localized Environment Caused by Moisture and Voltage Exposure

Most ~~insulated~~ electrical cables in nuclear power plants are located in dry environments. However, some cables may be exposed to condensation and wetting in inaccessible locations such as conduits, cable trenches, cable troughs, duct banks, underground vaults, or direct buried installations. When an energized cable is exposed to but not designed for these conditions, water treeing or a decrease in the dielectric strength of the conductor insulation can occur, which can lead to electrical failure. The purpose of this aging management program is to provide reasonable assurance that the intended functions of inaccessible medium-voltage cables exposed to adverse localized environments caused by moisture and voltage exposure will be maintained consistent with the current licensing basis through the period of extended operation.

(1) Scope of Program: The program includes inaccessible (e.g., in conduit or direct buried) medium-voltage cables within the scope of license renewal that are exposed to significant moisture and significant voltage. Significant moisture is defined as periodic exposures to moisture that last more than a few days (e.g., cable in standing water). Periodic exposures to moisture that last less than a few days (i.e., normal rain and drain) are not significant. Significant voltage exposure is defined as being subjected to system voltage for more than twenty-five percent of the time. The moisture and voltage exposures described as significant in these definitions are not significant for medium-voltage cables that are designed for these conditions (e.g., continuous wetting and continuous energization is not significant for submarine cables).
(2) Preventive Actions: No actions are taken as part of this program to prevent or mitigate aging degradation.
(3) Parameters Monitored/Inspected: In-scope, medium-voltage cables exposed to significant moisture and significant voltage are tested to provide an indication of the condition of the conductor insulation. The specific type of test performed will be determined prior to each test.
(4) Detection of Aging Effects: In-scope, medium-voltage cables exposed to significant moisture and significant voltage are tested at least once every 10 years, which is an adequate period to preclude failures of the conductor insulation.
(5) Monitoring and Trending: No actions are taken as part of this program to trend the test results.
(6) Acceptance Criteria: The acceptance criteria for each test is defined by the specific type of test performed and the specific cable tested.
(7 & 8) Corrective Actions & Confirmatory Process: Further investigation is performed when the test acceptance criteria are not met in order to ensure that the intended functions of the ~~insulated~~ electrical cables and connections will be maintained consistent with the current licensing basis. Specific corrective actions are implemented in accordance with the station's corrective action program. When an unacceptable condition or situation is identified, a determination is made as to whether the same condition or situation is applicable to other

inaccessible, in-scope, medium-voltage cables. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Control: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Operating experience has shown that XLPE or high molecular weight polyethlene (HMWPE) insulation materials are most susceptible to water tree formation. The formation and growth of water trees varies directly with operating voltage. Treeing is much less prevalent in 4kV cables than those operated at 13 or 33kV. ~~Due to the low dielectric stress, water trees do not occur in low-voltage cables.~~

References

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

A.4 Borated Water Leakage Surveillance Program for Electrical Connectors

Ingress of borated water into electrical connectors, if not found and corrected, can lead to corrosion and connector failure. NRC Generic Letter (GL) 88-05 "*Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants,*" March 17, 1988 mandates that PWR licensees monitor the condition of the reactor coolant pressure boundary for occurrences of borated water leakage. Refer to the *Generic Letter 88-05 Program* for specific information. This program is an augmentation of the *Generic Letter 88-05 Program* and has the purpose of preventing or eliminating aging effects related to corrosion of electrical connector contact surfaces caused by intrusion of borated water.

(1) Scope of Program: This program includes electrical connectors located in proximity to borated water systems; inside or outside containment.
(2) Preventive Actions: Visual inspections are performed of electrical connector and enclosure external surfaces for evidence of borated water leakage such as discoloration or accumulated boric acid residue. Boric acid residue is removed and a determination is made as to the possible intrusion of borated water into the electrical connector or enclosure.
(3) Parameters Monitored/Inspected: Once any boric acid residue is removed from the external surfaces, the external areas where connector parts have mating surfaces or are sealed are inspected for evidence of borated water intrusion.
(4) Detection of Aging Effects: Inspections are performed each refueling outage. Operating experience supports this frequency as adequate for preventing loss of component intended function.
(5) Monitoring and Trending: No actions are taken as part of this program to trend the inspection results.
(6) Acceptance Criteria: No corrective action is necessary if borated water from leaks is determined not to have intruded into electrical connectors and enclosures.
(7 & 8) Corrective Action & Confirmatory Process: Corrective actions are implemented upon a determination of the possible intrusion of borated water into an electrical connector or enclosure. Corrective actions may include, but are not limited to, removing contaminants or corrosion from electrical connector contact surfaces, testing, and sealing the electrical connector or enclosure to prevent future water intrusion. Specific corrective actions are implemented in accordance with the station's corrective action program. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Controls: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Based on industry wide and plant specific operating experience, augmenting the GL 88-05 program as described in this program for electrical connectors is adequate to detect and prevent aging effects caused by borated water leakage before there is a loss of component intended function.

References

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NRC Generic Letter 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants," March 17, 1988.

CHAPTER VI

ELECTRICAL COMPONENTS

Major Electrical Components

A. Electrical Cables and Connections

A. Electrical Cables and Connections

A.1 Conductor Insulation

A.1.1 Electrical cables and connections exposed to an adverse localized environment caused by heat or radiation

A.1.2 Electrical cables used in instrumentation circuits that are sensitive to reduction in conductor insulation resistance (IR) exposed to an adverse localized environment caused by heat or radiation

A.1.3 Inaccessible medium-voltage (2 kV to 15 kV) cables (e.g., installed in conduit or direct buried) exposed to an adverse localized environment caused by exposure to moisture and voltage

A.2 Connector Contacts

A.2.1 Electrical connectors exposed to borated water leakage

Systems, Structures and Components

This review table addresses electrical cables and connections installed in power and instrumentation and control (I&C) applications. The power cables addressed are low-voltage (<1000 V) and medium-voltage (2 kV to 15 kV). High voltage power cables (>15 kV) are not normally used at nuclear power plants, have unique, specialized constructions and must be evaluated on an application specific basis.

Electrical cables and their required terminations (i.e., connections) are reviewed as a single commodity. The types of connections included in this review are splices, mechanical connectors, and terminal blocks. This common review is translated into program actions, which treat cables and connections in the same manner.

Electrical cables and connections that are in the plant's environmental qualification (EQ) program are not included in this section. Components in the EQ program have a qualified life and the components are replaced at the end of that qualified life. The qualified life may be extended by methods such as refurbishment or reanalyzing the aging assessment, but the plant is required by the EQ regulation (10 CFR 50.49) to replace the component when its qualified life has expired. This makes all EQ components replacement items under § 54.21(a)(1)(ii) and no EQ components are required to be included in the aging management review.

System Interfaces

Electrical cables and connections functionally interface with all plant systems that rely on electric power and/or instrumentation and control. Electrical cables and connections also interface with and are supported by structural commodities (e.g., cable trays, conduit, cable trenches, cable troughs, duct banks, cable vaults and manholes) which are reviewed, as appropriate, in the Structures and Components Supports section.

VI. ELECTRICAL COMPONENTS
A. Electrical Cables and Connections

Item	Structure and Component	Region of Interest	Material	Environment	Aging Effect	References
A.1.1	Electrical Cables and Connections	Conductor insulation	Various organic polymers (e.g., EPR, SR, EPDM, XLPE)	Adverse localized environment caused by heat or radiation in the presence of oxygen	Embrittlement, cracking, melting, discoloration, leading to reduced insulation resistance, electrical failure, caused by thermal/ thermoxidative degradation of organics, radiolysis and photolysis (UV sensitive materials only) of organics; radiation-induced oxidation	NUREG-1723 NUREG/CR-5643 IEEE Std. P1205 SAND96-0344
A.1.2	Electrical cables used in instrumentation circuits that are sensitive to reduction in conductor insulation resistance (IR)	Conductor insulation	Various organic polymers (e.g., EPR, SR, EPDM, XLPE)	Adverse localized environment caused by heat or radiation in the presence of oxygen	Embrittlement, cracking, melting, discoloration, leading to reduced insulation resistance, electrical failure, caused by thermal/ thermoxidative degradation of organics, radiation-induced oxidation	NUREG-1705 NUREG/CR-5643 IEEE Std. P1205 SAND96-0344
A.1.3	Inaccessible Medium-Voltage (2 kV to 15 kV) Cables (e.g., installed in conduit or direct buried)	Conductor insulation	Various organic polymers (e.g., EPR, SR, EPDM, XLPE)	Adverse localized environment caused by exposure to moisture and voltage	Formation of water trees, localized damage, leading to electrical failure (breakdown of insulation), caused by moisture intrusion, water trees	NUREG-1723 IEEE Std. P1205 SAND96-0344

VI. ELECTRICAL COMPONENTS
A. Electrical Cables and Connections

Existing Aging Management Program (AMP)	Evaluation and Technical Basis	Further Evaluation
Aging Management Program for Electrical Cables and Connections Exposed to an Adverse Localized Environment caused by Heat or Radiation	See Chapter XI program A.1 for a description.	No
Aging Management Program for Electrical Cables Used in Instrumentation Circuits that are Sensitive to Reduction in Conductor Insulation Resistance (IR) Exposed to an Adverse Localized Environment Caused by Heat or Radiation	See Chapter XI program A.2 for a description.	No
Aging Management Program For Inaccessible Medium-Voltage Cables Exposed to an Adverse Localized Environment caused by Moisture and Voltage Exposure	See Chapter XI program A.3 for a description.	No

VI. ELECTRICAL COMPONENTS
A. Electrical Cables and Connections

Item	Structure and Component	Region of Interest	Material	Environment	Aging Effect	References
A.2.1	Electrical Connectors Exposed to Borated Water Leakage	Connector contacts	Various metals used for electrical contacts	Exposure to borated water leakage	Corrosion of connector contact surfaces caused by intrusion of borated water	NUREG-1723 IEEE Std. P1205 SAND96-0344

VI. ELECTRICAL COMPONENTS
A. Electrical Cables and Connections

Existing Aging Management Program (AMP)	Evaluation and Technical Basis	Further Evaluation
Borated Water Leakage Surveillance Program for Electrical Connectors	See Chapter XI program A.4 for a description.	No

References

NUREG-1705, *Safety Evaluation Report Related to the License Renewal of Calvert Cliffs Nuclear Power Plant, Units 1 and 2*, December 1999

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

CHAPTER X

TIME-LIMITED AGING ANALYSES

A.1 Aging Assessments for Electrical Equipment Included in the Plant's Environmental Qualification (EQ) Program

A.1 Aging Assessments for Electrical Equipment Included in the Plant's Environmental Qualification (EQ) Program

The Nuclear Regulatory Commission (NRC) has established nuclear station environmental qualification (EQ) requirements in 10 CFR 50 Appendix A, Criterion 4, and in 10 CFR 50.49. 10 CFR 50.49 specifically requires that an EQ program be established to demonstrate that certain electrical components located in "harsh" plant environments (i.e., those areas of the plant that could be subject to the harsh environmental effects of a loss of coolant accident (LOCA), high energy line breaks (HELBs) or post-LOCA radiation) are qualified to perform their safety function in those harsh environments after the effects of inservice aging. 10 CFR 50.49 requires that the effects of significant aging mechanisms be addressed as part of environmental qualification.

All operating plants must meet the requirements of § 50.49 for certain electrical equipment important-to-safety. § 50.49 defines the scope of equipment to be included, requires the preparation and maintenance of a list of in-scope equipment, and requires the preparation and maintenance of a qualification file that includes equipment performance specifications, electrical characteristics and environmental conditions. § 50.49(e)(5) contains aging provisions that require , in part, consideration of all significant types of aging degradation that can affect equipment functional capability. § 50.49(e) also requires equipment replacement or refurbishment prior to the end of designated life unless additional life is established through ongoing qualification. § 50.49(f) establishes four methods of demonstrating qualification for aging and accident conditions. §§ 50.49(k) and (l) permit different qualification criteria to apply based on plant and equipment vintage. Supplemental EQ regulatory guidance for compliance with these different qualification criteria is provided in the DOR Guidelines, *Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors*; June 1979, NUREG-0588, *Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment;* July 1981, and Regulatory Guide 1.89, Rev. 1, *Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants*, June 1984. Compliance with § 50.49 provides evidence that the equipment will perform its intended functions during accident conditions after experiencing the detrimental effects of in-service aging.

Generic safety issue (GSI) 168 is related to low-voltage EQ instrumentation and control cables and is currently an open generic issue for license renewal. NRC research is ongoing to provide information to resolve it. Specific issues being addressed in this research are presented in NUREG/CR-6384. Once this generic issue is resolved, guidance will be provided as to the impact on license renewal. In the interim, NRC letter dated June 2, 1998, "*Guidance on Addressing GSI-168 for License Renewal*," (C. Grimes, NRC to D. Walters, NEI) provides guidance on addressing GSI-168 in license renewal applications. It states that, until the generic issue is resolved, "*...an acceptable approach described in the SOC is to provide a technical*

rationale demonstrating that the current licensing basis for EQ, pursuant to 10 CFR 50.49 will be maintained in the period of extended operation."

EQ programs manage component thermal, radiation and cyclical aging through the use of equipment aging assessments based on § 50.49(f) qualification methods. As required by § 50.49, EQ equipment must be refurbished, replaced, or its qualification extended prior to reaching the aging limits established in the equipment aging assessment. Aging assessments for EQ equipment that specify a qualification of at least 40 years are considered time limited aging analyses (TLAA) for license renewal.

EQ TLAA DEMONSTRATION OPTIONS

Three TLAA demonstration options are provided in § 54.21(c)(1):

(i) the analysis remains valid for the period of extended operation,
(ii) the analysis is projected to the end of the period of extended operation, or
(iii) the effects of aging on the intended functions will be adequately managed during the period of extended operation.

For option (i), the equipment aging assessment existing at the time of the renewal application qualifies the equipment through the period of extended operation and no further evaluation is necessary.

For option (ii), a reanalysis of the equipment aging assessment was performed in order to extend the qualification of the component through the period of extended operation. Important attributes of an equipment aging assessment reanalysis include analytical methods, data collection and reduction methods, underlying assumptions, acceptance criteria and corrective actions (if acceptance criteria are not met). These attributes are discussed in the **EQ Equipment Aging Assessment Reanalysis Attributes** section.

Option (iii) would be used in cases (a) where the equipment aging assessment does not extend the qualification into, or extends the qualification into but not through, the period of extended operation, or (b) where aging management actions such as periodic maintenance, inspection, testing, or parts replacement are required to maintain the qualification through the period of extended operation. In light of this option EQ programs, which implement the requirements of § 50.49 (as further defined and clarified by the DOR Guidelines, NUREG-0588, and Regulatory Guide 1.89, Rev. 1.), at plants are viewed as aging management programs for license renewal. The evaluation and technical basis for EQ programs as acceptable aging management programs is provided in the **EQ Program Evaluation and Technical Basis** section. Reanalysis of an aging assessment to extend the qualifications of equipment is performed on a routine basis as part of an EQ program. Important attributes of an equipment aging assessment reanalysis include analytical methods, data collection and reduction methods, underlying assumptions,

acceptance criteria and corrective actions (if acceptance criteria are not met). These attributes are discussed in the **EQ Equipment Aging Assessment Reanalysis Attributes** section.

EQ PROGRAM EVALUATION AND TECHNICAL BASIS

(1) Scope of Program: EQ programs include certain electrical equipment that is important to safety and could be exposed to harsh environment accident conditions, as defined in 10 CFR 50.49.

(2) Preventive Actions: § 50.49 does not require actions that prevent aging effects. EQ program actions that could be viewed as preventive actions include (a) establishing the equipment service condition tolerance and aging limits (e.g., qualified life or condition limit), (b) refurbishment, replacement, or requalification of installed equipment prior to reaching these aging limits, and (c) where applicable, requiring specific installation, inspection, monitoring, or periodic maintenance actions to maintain equipment aging effects within the qualification.

(3) Parameters Monitored/Inspected: EQ equipment aging limits are not typically based on condition or performance monitoring. However, per Regulatory Guide 1.89 Rev. 1, such monitoring programs are an acceptable basis to modify aging limits. Monitoring or inspection of certain environmental, condition or equipment parameters may be used to ensure that the equipment is within its qualification or as a means to modify the qualification.

(4) Detection of Aging Effects: § 50.49 does not require the detection of aging effects for in-service equipment. Monitoring of aging effects may be used as a means to modify equipment aging limits.

(5) Monitoring and Trending: § 50.49 does not require monitoring and trending of equipment condition or performance parameters of in-service equipment to manage the effects of aging. EQ program actions that could be viewed as monitoring include monitoring how long qualified equipment has been installed. Monitoring or inspection of certain environmental, condition or equipment parameters may be used to ensure that the equipment is within its qualification or as a means to modify the qualification.

(6) Acceptance Criteria: § 50.49 acceptance criteria is that in-service EQ equipment is maintained within its qualification including (a) its established aging limits and (b) continued qualification for the projected accident conditions. § 50.49 requires refurbishment, replacement, or requalification prior to exceeding the aging limits of each installed device. When monitoring is used to modify an equipment aging limit, plant-specific acceptance criteria are established based on applicable § 50.49(f) qualification methods.

(7 & 8) Corrective Actions & Confirmation Process: If EQ equipment is found to be outside its qualification, corrective actions are implemented in accordance with the station's corrective action program. When unexpected adverse conditions are identified during operational or maintenance activities that affect the environment or qualified equipment, affected EQ equipment is evaluated and appropriate corrective actions are taken, which may include changes to the qualification bases and conclusions. When emerging industry aging issues are identified that affect the qualification of EQ equipment, affected equipment is evaluated and appropriate

corrective actions are taken, which may include changes to the qualification bases and conclusions. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.

(9) Administrative Controls: EQ programs are implemented through the use of station policy, directives and procedures. EQ programs will continue to comply with § 50.49 throughout the renewal period including development and maintenance of qualification documentation demonstrating equipment will perform required functions during harsh accident conditions. EQ program documents identify the applicable environmental conditions for the equipment locations. EQ program qualification files are maintained at the plant site in an auditable form for the duration of the installed life of the equipment. EQ program documentation is controlled under the station's quality assurance program.

(10) Operating Experience: EQ programs include consideration of operating experience to modify qualification bases and conclusions, including aging limits. Compliance with § 50.49 provides evidence that the equipment will perform its intended functions during accident conditions after experiencing the detrimental effects of in-service aging.

EQ EQUIPMENT AGING ASSESSMENT REANALYSIS ATTRIBUTES

The reanalysis of an equipment aging assessment is normally performed to extend the qualification by reducing excess conservatisms incorporated in the prior aging assessment. Reanalysis of an aging assessment to extend the qualifications of equipment is performed on a routine basis as part of an EQ program. An equipment life limiting condition may be due to thermal, radiation, or cyclical aging; the vast majority of equipment aging limits are based on thermal conditions. Conservatisms may exist in aging assessment parameters such as the assumed ambient temperature of the equipment, an unrealistically low activation energy, or in the application of equipment (de-energized versus energized). An equipment aging assessment reanalysis is documented according to the station's quality assurance program requirements, which requires the verification of assumptions and conclusions. Important attributes of an equipment aging assessment reanalysis include analytical methods, data collection and reduction methods, underlying assumptions, acceptance criteria and corrective actions (if acceptance criteria are not met). These attributes are discussed below.

Analytical Methods: The analytical models use in an equipment aging assessment reanalysis should be the same as those previously applied during the prior aging assessment. The Arrhenius methodology is an acceptable thermal model for performing a thermal aging assessment. The analytical method used for a radiation aging assessment is to demonstrate qualification for the total integrated dose (i.e., normal radiation dose for the projected installed life plus accident radiation dose). For license renewal, one acceptable method of establishing the 60 year normal radiation dose is to multiply the 40 year normal radiation dose by 1.5 (i.e., 60 years/40 years). The result is added to the accident radiation dose to obtain the total integrated dose for the equipment. For cyclical aging a similar approach may be used. Other models may be justified on a case-by-case basis.

Data Collection & Reduction Methods: Reducing excess conservatisms in the equipment service conditions (e.g., temperature, radiation, cycles) used in the prior aging assessment is the chief method used for a reanalysis. Temperature data used in an equipment aging assessment should be conservative and based on plant design temperatures or on actual plant temperature data. When used, plant temperature data can be obtained in several ways, including monitors used for technical specification compliance, other installed monitors, measurements made by plant operators during rounds, and temperature sensors on large motors (while the motor is not running). A representative number of temperature measurements are conservatively evaluated to establish the temperatures used in an equipment aging assessment. Plant temperature data may be used in an equipment aging assessment in different ways such as (a) directly applying the plant temperature data in the aging assessment, or (b) using the plant temperature data to demonstrate conservatism when using plant design temperatures for an aging assessment. Any changes to material activation energy values as part of an equipment aging assessment reanalysis should be justified. Similar methods of reducing excess conservatisms in the equipment service conditions used in prior aging assessments can be used for radiation and cyclical aging.

Underlying Assumptions: EQ equipment aging assessments contain sufficient conservatisms to account for most environmental changes occurring due to plant modifications and events. When unexpected adverse conditions are identified during operational or maintenance activities that affect the environment or qualified equipment, affected EQ equipment is evaluated and appropriate corrective actions are taken, which may include changes to the qualification bases and conclusions.

Acceptance Criteria & Corrective Actions: An aging assessment reanalysis shall extend the qualification of the equipment. If the qualification cannot be extended by reanalysis, the equipment must be refurbished, replaced, or requalified prior to exceeding the current qualification. An equipment aging assessment reanalysis should be performed in a timely manner (i.e., sufficient time is available to refurbish, replace or requalify the equipment if the reanalysis is unsuccessful).

References

Code of Federal Regulations, Title 10, Part 50, Section 49, *Environmental Qualification of electric Equipment Important to Safety for Nuclear Power Plants.*

NRC Bulletin 79-01B, Environmental Qualification of Class 1E Equipment, January 14, 1980.

NRC Regulatory Guide 1.89, *Environmental Qualification of Certain Electric Equipment Important to Safety for Nuclear Power Plants*, June 1984.

DOR Guidelines, *Guidelines for Evaluating Environmental Qualification of Class 1E Electrical Equipment in Operating Reactors*; June 1979

NUREG-0588, *Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment,* December 1979.

NUREG/CR-6384,

IEEE Std. 317, *IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.*

IEEE Std. 323, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.*

IEEE Std. 383, *IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.*

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

NRC letter from C. Grimes, NRC, to D. Walters, NEI, "*Guidance on Addressing GSI-168 for License Renewal,*" June 2, 1998

NUREG-1705, *Safety Evaluation Report Related to the License Renewal of Calvert Cliffs Nuclear Power Plant, Units 1 and 2*, December 1999

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

CHAPTER XI

EXISTING
AGING MANAGEMENT PROGRAMS (AMP)
AND ACTIVITIES

Existing Aging Management Programs (AMP) and Activities

A.1 Aging Management Program for Electrical Cables and Connections Exposed to an Adverse Localized Environment Caused by Heat or Radiation

A.2 Aging Management Program for Electrical Cables Used in Instrumentation Circuits that are Sensitive to Reduction in Conductor Insulation Resistance (IR) Exposed to an Adverse Localized Environment Caused by Heat or Radiation

A.3 Aging Management Program for Inaccessible Medium-Voltage Cables Exposed to an Adverse Localized Environment Caused by Moisture and Voltage Exposure

A.4 Borated Water Leakage Surveillance Program for Electrical Connectors

A.1 Aging Management Program for Electrical Cables and Connections Exposed to an Adverse Localized Environment Caused by Heat or Radiation

In most areas within a nuclear power plant, the actual ambient environments are less severe than the design environments. However, in a limited number of localized areas, the actual environments may be more severe than the design environments. Conductor insulation materials used in cables and connections may degrade more rapidly than expected in these adverse localized environments. The purpose of this aging management program is to provide reasonable assurance that the intended functions of electrical cables and connections exposed to adverse localized environments caused by heat or radiation will be maintained consistent with the current licensing basis through the period of extended operation.

As stated in NUREG/CR-5643, "*The major concern with cables, is the performance of aged cable when it is exposed to accident conditions.*" The statement of considerations for the final license renewal rule (60FR22477) states, "*The major concern is that failures of deteriorated cable systems (cables, connections, and penetrations) might be induced during accident conditions.*" The electrical cables and connections covered by this aging management program, being non-EQ, are either not exposed to harsh accident conditions or are not required to remain functional during or following an accident to which they are exposed. Although the electrical cables and connections included in this program are important to overall plant safety, their capability to perform their intended functions during or following a design basis event is not a major concern.

(1) Scope: The inspection program includes accessible electrical cables and connections within the scope of license renewal that are installed in adverse localized environments caused by heat or radiation in the presence of oxygen. An adverse localized environment is a condition in a limited plant area that is significantly more severe than the specified service condition for the electrical cable or connection.
(2) Preventive Actions: No actions are taken as part of this program to prevent or mitigate aging degradation.
(3) Parameters Monitored/Inspected: Accessible electrical cables and connections installed in adverse localized environments are visually inspected for cable and connection jacket surface anomalies such as embrittlement, discoloration, cracking or surface contamination.
(4) Detection of Aging Effects: Cable and connection jacket surface anomalies are precursor indications of conductor insulation aging degradation from heat or radiation in the presence of oxygen. Accessible electrical cables and connections installed in adverse localized environments are visually inspected at least once every 10 years, which is an adequate period to preclude failures of the conductor insulation.
(5) Monitoring and Trending: No actions are taken as part of this program to trend inspection results.

(6) Acceptance Criteria: No unacceptable, visual indications of cable and connection jacket surface anomalies, which suggest that conductor insulation degradation exists, as determined by engineering evaluation. An unacceptable indication is defined as a noted condition or situation that, if left unmanaged, could lead to a loss of the intended function.
(7 & 8) Corrective Actions & Confirmatory Process: Further investigation is performed on electrical cables and connections when the acceptance criteria are not met in order to ensure that the intended functions will be maintained consistent with the current licensing basis. Corrective actions may include, but are not limited to, testing, shielding or otherwise changing the environment, relocation or replacement of the affected cable or connection. Specific corrective actions are implemented in accordance with the station's corrective action program. When an unacceptable condition or situation is identified, a determination is made as to whether the same condition or situation is applicable to other accessible or inaccessible cables or connections. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Controls: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Operating experience has shown that adverse localized environments caused by heat or radiation for electrical cables and connections may exist next to or above (within three feet of) steam generators, pressurizers, or hot process pipes such as feedwater lines.

References

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

A.2 Aging Management Program for Electrical Cables Used in Instrumentation Circuits that are Sensitive to Reduction in Conductor Insulation Resistance (IR) Exposed to an Adverse Localized Environment Caused by Heat or Radiation

In most areas within a nuclear power plant, the actual ambient environments are less severe than the design environments. However, in a limited number of localized areas, the actual environments may be significantly more severe than the design environments. Conductor insulation materials used in electrical cables may degrade more rapidly than expected in these adverse localized environments. Exposure of electrical cables to adverse localized environments caused by heat or radiation can result in reduced insulation resistance (IR). Reduced IR causes an increase in leakage currents between conductors, and from individual conductors to ground. A reduction in IR can be a concern for circuits with sensitive, low-level signals such as radiation monitoring and nuclear instrumentation since it may contribute to inaccuracies in the instrument loop. When an instrumentation loop is found to be out of calibration during routine preventative maintenance, trouble shooting is preformed which includes the instrumentation cable. The purpose of this aging management program is to provide reasonable assurance that the intended functions of electrical cables used in circuits with sensitive, low-level signals exposed to adverse localized environments caused by heat or radiation will be maintained consistent with the current licensing basis through the period of extended operation.

As stated in NUREG/CR-5643, "*The major concern with cables, is the performance of aged cable when it is exposed to accident conditions.*" The statement of considerations for the final license renewal rule (60FR22477) states, "*The major concern is that failures of deteriorated cable systems (cables, connections, and penetrations) might be induced during accident conditions.*" The electrical cables covered by this aging management program, being non-EQ, are either not exposed to harsh accident conditions or are not required to remain functional during or following an accident to which they are exposed. Although the electrical cables and connections included in this program are important to overall plant safety, their capability to perform their intended functions during or following a design basis event is not a major concern.

(1) Scope of Program: This program includes electrical cables used in circuits with sensitive, low-level signals such as radiation monitoring and nuclear instrumentation that are within the scope of license renewal.
(2) Preventive Actions: No actions are taken as part of this program to prevent or mitigate aging degradation.
(3) Parameters Monitored/Inspected: The parameters monitored are specific to the instrumentation loop being calibrated as documented in the preventive maintenance procedure.
(4) Detection or Aging Effects: Calibration provides sufficient indication of the need for corrective actions by monitoring key parameters and providing trending data based on acceptance criteria related to instrumentation loop performance. The normal calibration

frequency provides reasonable assurance that severe aging degradation will be detected prior to loss of the cable intended function.
(5) Monitoring and Trending: No actions are taken as part of this program to trend the test results.
(6) Acceptance Criteria: Calibration readings within the loop specific acceptance criteria as set out in the preventive maintenance procedure.
(7 & 8) Corrective Actions & Confirmatory Process: Corrective actions such as recalibration and circuit trouble-shooting are implemented when an instrument loop is found to be out of calibration. Specific corrective actions are implemented in accordance with the station's corrective action program. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Controls: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Operating experience has shown that a significant number of cable failures are identified through routine calibration testing.

References

NUREG-1705, *Safety Evaluation Report Related to the License Renewal of Calvert Cliffs Nuclear Power Plant, Units 1 and 2*, December 1999

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

A.3 Aging Management Program for Inaccessible Medium-Voltage Cables Exposed to an Adverse Localized Environment Caused by Moisture and Voltage Exposure

Most electrical cables in nuclear power plants are located in dry environments. However, some cables may be exposed to condensation and wetting in inaccessible locations such as conduits, cable trenches, cable troughs, duct banks, underground vaults, or direct buried installations. When an energized cable is exposed to but not designed for these conditions, water treeing or a decrease in the dielectric strength of the conductor insulation can occur, which can lead to electrical failure. The purpose of this aging management program is to provide reasonable assurance that the intended functions of inaccessible medium-voltage cables exposed to adverse localized environments caused by moisture and voltage exposure will be maintained consistent with the current licensing basis through the period of extended operation.

(1) Scope of Program: The program includes inaccessible (e.g., in conduit or direct buried) medium-voltage cables within the scope of license renewal that are exposed to significant moisture and significant voltage. Significant moisture is defined as periodic exposures to moisture that last more than a few days (e.g., cable in standing water). Periodic exposures to moisture that last less than a few days (i.e., normal rain and drain) are not significant. Significant voltage exposure is defined as being subjected to system voltage for more than twenty-five percent of the time. The moisture and voltage exposures described as significant in these definitions are not significant for medium-voltage cables that are designed for these conditions (e.g., continuous wetting and continuous energization is not significant for submarine cables).
(2) Preventive Actions: No actions are taken as part of this program to prevent or mitigate aging degradation.
(3) Parameters Monitored/Inspected: In-scope, medium-voltage cables exposed to significant moisture and significant voltage are tested to provide an indication of the condition of the conductor insulation. The specific type of test performed will be determined prior to each test.
(4) Detection of Aging Effects: In-scope, medium-voltage cables exposed to significant moisture and significant voltage are tested at least once every 10 years, which is an adequate period to preclude failures of the conductor insulation.
(5) Monitoring and Trending: No actions are taken as part of this program to trend the test results.
(6) Acceptance Criteria: The acceptance criteria for each test is defined by the specific type of test performed and the specific cable tested.
(7 & 8) Corrective Actions & Confirmatory Process: Further investigation is performed when the test acceptance criteria are not met in order to ensure that the intended functions of the electrical cables and connections will be maintained consistent with the current licensing basis. Specific corrective actions are implemented in accordance with the station's corrective action program. When an unacceptable condition or situation is identified, a determination is made as to whether the same condition or situation is applicable to other inaccessible, in-scope, medium-

voltage cables. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.

(9) Administrative Control: The implementation of this program is controlled by plant procedures.

(10) Operating Experience: Operating experience has shown that XLPE or high molecular weight polyethlene (HMWPE) insulation materials are most susceptible to water tree formation. The formation and growth of water trees varies directly with operating voltage. Treeing is much less prevalent in 4kV cables than those operated at 13 or 33kV.

References

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NUREG/CR-5643, *Insights Gained From Aging Research*, March 1992

IEEE Std. P1205, *IEEE Guide for Assessing, Monitoring and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations.*

SAND96-0344, *Aging Management Guideline for Commercial Nuclear Power Plants - Electrical Cable and Terminations*, September 1996, prepared by Sandia National Laboratories for the U.S. Department of Energy.

A.4 Borated Water Leakage Surveillance Program for Electrical Connectors

Ingress of borated water into electrical connectors, if not found and corrected, can lead to corrosion and connector failure. NRC Generic Letter (GL) 88-05 "*Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants*," March 17, 1988 mandates that PWR licensees monitor the condition of the reactor coolant pressure boundary for occurrences of borated water leakage. Refer to the *Generic Letter 88-05 Program* for specific information. This program is an augmentation of the *Generic Letter 88-05 Program* and has the purpose of preventing or eliminating aging effects related to corrosion of electrical connector contact surfaces caused by intrusion of borated water.

(1) Scope of Program: This program includes electrical connectors located in proximity to borated water systems; inside or outside containment.
(2) Preventive Actions: Visual inspections are performed of electrical connector and enclosure external surfaces for evidence of borated water leakage such as discoloration or accumulated boric acid residue. Boric acid residue is removed and a determination is made as to the possible intrusion of borated water into the electrical connector or enclosure.
(3) Parameters Monitored/Inspected: Once any boric acid residue is removed from the external surfaces, the external areas where connector parts have mating surfaces or are sealed are inspected for evidence of borated water intrusion.
(4) Detection of Aging Effects: Inspections are performed each refueling outage. Operating experience supports this frequency as adequate for preventing loss of component intended function.
(5) Monitoring and Trending: No actions are taken as part of this program to trend the inspection results.
(6) Acceptance Criteria: No corrective action is necessary if borated water from leaks is determined not to have intruded into electrical connectors and enclosures.
(7 & 8) Corrective Action & Confirmatory Process: Corrective actions are implemented upon a determination of the possible intrusion of borated water into an electrical connector or enclosure. Corrective actions may include, but are not limited to, removing contaminants or corrosion from electrical connector contact surfaces, testing, and sealing the electrical connector or enclosure to prevent future water intrusion. Specific corrective actions are implemented in accordance with the station's corrective action program. Confirmatory actions, as needed, are implemented as part of the station's corrective action program.
(9) Administrative Controls: The implementation of this program is controlled by plant procedures.
(10) Operating Experience: Based on industry wide and plant specific operating experience, augmenting the GL 88-05 program as described in this program for electrical connectors is adequate to detect and prevent aging effects caused by borated water leakage before there is a loss of component intended function.

References

NUREG-1723, *Safety Evaluation Report Related to the License Renewal of Oconee Nuclear Station, Units 1, 2 and 3*, February 2000

NRC Generic Letter 88-05, "Boric Acid Corrosion of Carbon Steel Reactor Pressure Boundary Components in PWR Plants," March 17, 1988.