**U.S. NUCLEAR REGULATORY COMMISSION**
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Division 1

# DRAFT REGULATORY GUIDE

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## DRAFT REGULATORY GUIDE DG-1240

*(Proposed new regulatory guide)*

## CONDITION MONITORING PROGRAM FOR ELECTRIC CABLES USED IN NUCLEAR POWER PLANTS

## A. INTRODUCTION

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for condition monitoring for electric cables for nuclear power plants, for those licensees choosing to use monitoring to meet the requirements of Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities" of the *Code of Federal Regulations* (10 CFR Part 50) (Ref. 1), Section 50.65, "Requirements for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants."

Paragraph (a)(1) of 10 CFR 50.65, states that "Each holder of an operating license for a nuclear power plant...shall monitor the performance or condition of structures, systems, or components...in a manner sufficient to provide reasonable assurance that these structures, systems, and components...are capable of fulfilling their intended functions." Licensees may, as an alternative to compliance with paragraph (a)(1) of the Maintenance Rule, comply with the requirements of paragraph (a)(2). That paragraph allows a licensee to avoid monitoring if it can demonstrate that the condition or performance of a SCC within the scope of the rule is being effectively controlled through preventative maintenance.

Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," (Ref. 2) provides general guidelines for complying with 50.65(a)(1). This Regulatory Guide provides specific guidance for condition monitoring of cables to provide reasonable assurance that the cables are capable of performing their intended function(s) during their installed life. In particular, this regulatory guide describes a programmatic approach to condition monitoring of electric cable systems and their operating environments and acceptable condition monitoring techniques. The programmatic approach and condition monitoring may be used to demonstrate compliance with either paragraphs (a)(1) or (a)(2) of the Maintenance Rule.

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This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received final staff review or approval and does not represent an official NRC final staff position.

Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules, Announcements, and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; submitted through the NRC's interactive rulemaking Web page at http://www.nrc.gov; or faxed to (301) 492-3446. Copies of comments received may be examined at the NRC's Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by August 13, 2010.

Electronic copies of this draft regulatory guide are available through the NRC's interactive rulemaking Web page (see above); the NRC's public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/; and the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession No. ML100760364. The regulatory analysis may be found in ADAMS under Accession No. ML101530476.

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

# B. DISCUSSION

## Background

Electric cables are one of the most important components in a nuclear plant since they provide the power needed to operate electrical equipment, and they transmit signals to and from the various controllers used to perform safety functions and accident mitigation in a nuclear power plant. Despite their importance, cables typically receive little attention since they are considered passive, long-lived components that have been very reliable over the years when subjected to the environmental conditions they were designed and qualified for.

The integrity of electric cables is monitored, to some extent, through periodic inservice testing of the equipment to which they are attached; however, this testing does not specifically focus on the cables and may not be sufficient to detect all of the aging and other degradation mechanisms to which a particular cable is susceptible. While these tests can demonstrate the function of the cables under test conditions, they do not verify the continued successful performance of cables when called upon to operate fully loaded for extended periods, as they would under anticipated normal service operating conditions or under design-basis conditions. Nor does inservice testing of a cable provide specific information on the status of aging degradation processes or the physical integrity and dielectric strength of its insulation and jacket materials. Consequently, a cable circuit with undetected damaged or degraded insulation could pass an inservice functional test but still fail unexpectedly when called upon to operate under anticipated environmental conditions or the more severe stresses encountered in emergency operation during a design-basis event (i.e., fully loaded equipment, more extreme environmental conditions, extended operation in a heavily loaded state). Recent operating experience indicates inservice failures of several power cables.

Longer cable circuits may pass through several different operating environments over the length of their routing throughout the plant. Portions of such a cable circuit may pass through areas experiencing harsh environmental conditions, such as high temperature, high radiation, high humidity, wetting (i.e., an operating environment in which a cable is exposed to moisture or high humidity for extended periods of time, with intermittent brief periods of complete submergence in water), or submersion (i.e., an operating environment in which a cable is completely submerged in water continuously or for extended periods of time). There has been concern that such local adverse environmental stressors can cause excessive aging and degradation in the exposed sections of a cable that could significantly shorten its qualified life and cause unexpected early failures.

It should be emphasized that the occurrence of cable system operating environments or locally adverse conditions that are unanticipated or more severe than the original plant design may constitute a design deficiency of the cable system. A cable system must be designed to meet applicable regulations and to perform its intended function in the plant environment under all anticipated operational occurrences and design-basis events.

Special consideration should be given to the problem of monitoring the operating environment for cable circuits routed through inaccessible underground cable ducts and conduits, covered cable distribution trenches, bunkers, and manhole vaults. Since most of these underground distribution systems are largely inaccessible, wetted and flooding conditions remain undetected for extended periods of time. Eventually, power and control cables that are not designed to operate in a submerged state will experience early failures, often resulting in significant safety consequences. The NRC has described several of these incidents in Information Notice 2002-12, "Submerged Safety-Related Cables," dated April 21, 2002 (Ref. 3), Information Notice 1989-63, "Possible Submergence of Electric Circuits Located Above the Flood Level Because of Water Intrusion and Lack of Drainage," dated September 5, 1989 (Ref. 4), and Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients," dated February 7, 2007 (Ref. 5). Generic Letter 2007-01 observed that cable insulation degradation as a result of continuous wetting or submergence could affect multiple underground power cable circuits at a plant site; should one of these medium-voltage cables fail, the resulting high-level fault currents and transient voltages would propagate onto the immediate power distribution system and potentially fail other systems with degraded power cable insulation.

Operating experience reveals that the number of cable failures is increasing with plant age, and that cable failures are occurring within the plants' 40-year licensing periods. These cable failures have resulted in plant transients and shutdowns, loss of safety functions and redundancy, entries into limiting conditions for operation, and challenges to plant operators. While in many cases the failed cables were identified through current testing practices, some of the failures may have occurred before the failed condition was identified (i.e., on cables that are not normally energized or tested). Therefore, it is necessary to monitor the condition of electric cables throughout their installed life through the implementation of a cable condition monitoring program.

Condition monitoring involves the observation, measurement, and trending of one or more condition indicators that can be correlated to the physical condition or functional performance of the cable. An "ideal" condition monitoring technique should have the following desired attributes:

a. nondestructive and nonintrusive,
b. capable of measuring property changes or indicators that are trendable and can be consistently correlated to functional performance during normal service,
c. applicable to cable types and materials commonly used in nuclear power plants,
d. provides reproducible results that are not affected by the test environment or, if they are so affected, the results can be corrected for those effects,
e. able to identify the location of any defects in the cable,
f. allows the establishment of a well-defined end condition, and
g. provides sufficient time before incipient failure to allow corrective actions.

## Cable Monitoring Methods/Techniques

Electric cable condition monitoring tests may generally be grouped by whether the inspection or test is performed in situ on electric cables in the plant or whether it is a laboratory-type test performed on representative material specimens in a controlled laboratory setting. These condition monitoring test techniques may be performed to measure and assess the following:

a. electrical properties (such as insulation resistance/polarization index, voltage withstand, dielectric loss/dissipation factor, time domain reflectometry, partial discharge),
b. mechanical properties (such as hardness, elongation at break, compressive modulus/polymer indenter test),
c. chemical/physical properties (such as density, oxidation induction time, oxidation induction temperature, and Fourier Transform Infrared Spectroscopy),
d. physical condition/appearance, or
e. functional performance (technical specification related calibration and functional surveillance tests, system/component operating tests, preventive maintenance functional tests).

Research and experience have shown that no single, nonintrusive, currently available condition monitoring method can be used alone to predict the survivability of electric cables under accident conditions. Many condition monitoring techniques (e.g., elongation at break, compressive modulus, density) are localized indicators of the condition at the specific place along a cable circuit where the measurement is made; cable properties measured at multiple points may show the cable to be in sound condition, but a measurement made only inches away at a more severely stressed section could show otherwise. Furthermore, the criteria used to define cable functional condition or accident survivability for a particular circuit are application specific. Consequently, the use of absolute acceptance criteria for a single specific condition monitoring technique is neither meaningful nor practical. It would be more effective to set administrative quantitative or qualitative acceptance criteria for screening-type cable condition monitoring inspections and tests (e.g., visual inspection, bulk electrical properties tests, or functional tests) that, when exceeded, could then administratively trigger more detailed inspection and retesting, or further testing using additional condition monitoring techniques to provide an expanded characterization of cable condition and degree of insulation degradation. The results of the expanded inspection and testing could then provide sufficient information to conduct a formal assessment of the cable's condition and initiate appropriate corrective actions.

Based on the operating parameters, cable insulation and jacket materials, cable construction (e.g., solid/extruded versus laminated, shielded versus unshielded), and environmental and operating stressors for each cable system application, licensees select condition monitoring inspection and testing techniques to detect, quantify, and monitor the status of the aging mechanisms that are causing the degradation of the cable system. By selecting the condition monitoring techniques that are best suited to the detection and monitoring of the anticipated stressors and associated aging and degradation mechanisms identified, licensees can more accurately monitor the condition of critical plant cables, assess their operating condition, and implement corrective actions to manage aging and degradation in those cables that are found to be experiencing stressors and aging/degradation rates beyond specified design conditions. The realistic and timely assessment of cable condition is the best means for managing cable degradation and avoiding unexpected early cable failures. Sections 3 and 4.5 of NUREG/CR-7000, "Essential Elements of an Electric Cable Condition Monitoring Program," issued January 2010 (Ref. 6), provide guidance on the selection of electric cable condition monitoring techniques.

Licensees can use a number of monitoring techniques to evaluate cable condition. A combination of monitoring techniques may be needed to validate cable performance. Some of the typical condition monitoring techniques and inspection methods that have been or are being used for cable condition monitoring include those described below, which are recommended for use when appropriate.

*1. Direct Current High-Potential Test (dc High Voltage)*

The direct current (dc) high-potential test (HPT) is a pass/fail test applicable to medium-voltage power cables and all insulation and jacket materials. Aging mechanisms detected by the HPT comprise thermally induced embrittlement and cracking, radiation-induced embrittlement and cracking, mechanical damage, water treeing, moisture intrusion, and surface contamination.

Advantages associated with the HPT test are that it is relatively easy to perform, it does not require access to the entire length of the cable, and the test can potentially detect degradation sites before failure in service. The disadvantages of HPT are that the cable must be disconnected to perform the test and the high voltages involved during testing may damage the cable insulation.

Recent research by the Electric Power Research Institute (EPRI) on medium-voltage cross-linked polyethylene (XLPE)- and ethylene propylene rubber (EPR)-insulated cables has shown that a dc HPT of field-aged cables could potentially damage or cause extruded cables, especially field-aged XLPE-insulated cable, to fail prematurely. Among the conclusions reached in the EPRI study are that dc HPTs of field-aged cables can reduce cable life, dc HPTs of field-aged cables generally increases water tree growth, and pre-energization dc HPTs of new medium-voltage cable does not significantly reduce in cable life.

*2. Step Voltage Test (dc High Voltage)*

The step voltage test (SVT) is a diagnostic test that can be applied to low- and medium-voltage cable and all insulation and jacket material. The SVT is capable of detecting aging mechanisms such as thermally induced embrittlement and cracking, radiation-induced embrittlement and cracking, mechanical damage, water treeing, moisture intrusion, and surface contamination.

The advantages of SVT are that it is relatively easy to perform, it provides trendable data on commonly used cable insulation materials, and it does not require access to the entire length of the cable. The disadvantages of SVT are that the cable must be disconnected to perform the test, and the high voltages involved during testing may damage the cable insulation. The potential problems with the dc HPT identified by the recent EPRI research study are also applicable to the SVT.

*3. Illuminated Borescope*

The illuminated borescope (IB) inspection technique is a screening method that can be applied to inaccessible low-voltage cables, de-energized medium-voltage cables, and all types of cable insulation and jacket materials. The IB inspection technique is essentially an optically enhanced visual inspection using the IB tool to visually access cables in otherwise inaccessible conduits and ducts to assess their physical appearance and condition and to identify and locate water intrusion or contamination in the conduits or cable ducts. The IB test is capable of detecting aging mechanisms such as mechanical damage, potential for moisture intrusion, and surface contamination.

Advantages of the IB test are that the test is relatively easy to implement and can be performed on inaccessible cables to detect the presence of stressors or cable damage and degradation. The disadvantage of the IB test is that it does not provide quantitative data that can be trended.

*4. Visual Inspection*

The visual inspection technique for accessible cables is a very simple yet extremely powerful cable condition monitoring technique for evaluating cable system aging because physical damage and many degradation mechanisms are readily detectable through sight. Visual inspection can be used to identify changes in physical/visual appearance, surface texture, and damage. Flashlights or magnifiers can aid visual inspection.

The advantages of visual inspection are that it is easy to perform, it is minimally intrusive and nondestructive, and it can easily detect degradation because of locally adverse conditions. The disadvantages are that the cables to be inspected must be visible and accessible; results are not quantitative, making trending very difficult; and appearance is subjective and observations can vary from inspector to inspector.

*5. Compressive Modulus (Polymer Indenter)*

This technique is a mechanical properties (hardness) technique that is applicable to polymer jacket and insulation materials, such as polyethylene, EPR, chlorosulphonated polyethylene, and neoprene, used for low-voltage cables. The compressive modulus technique is most effective at detecting thermally induced embrittlement and radiation-induced embrittlement. The technique can detect and monitor the stressor effects of elevated temperature and radiation exposure.

Advantages of the compressive modulus test are that it is relatively easy to perform, it provides trendable data on commonly used cable insulation materials, and results can be correlated to known measures of cable condition. This technique is suitable for assessing short segments of the insulation. The disadvantages are that the cables must be accessible for in situ measurements; measurements are made on the outer surface so the condition of underlying insulation must be inferred; the underlying cable construction, cable geometry, temperature, and humidity affect the results; aging-related changes in the compressive modulus are very small for some polymers until the end of life; the compressive modulus does not give direct correlation to changes in electrical properties (such as insulation resistance and dielectric strength); and the test is not effective for XLPE cables that do not have a polyethylene jacket.

*6. Dielectric Loss-Dissipation Factor/Power Factor*

The dielectric loss-dissipation factor or power factor test (tan δ test) can be used to diagnose problems in low- and medium-voltage cables. The dielectric loss-dissipation factor test has the ability to detect thermally induced cracking, radiation-induced cracking, mechanical damage, water treeing, moisture intrusion, and surface contamination.

Advantages associated with the dielectric loss-dissipation factor technique are that it is relatively easy to perform, it provides trendable data on commonly used cable insulation materials, it does not require access to the entire cable, and the results can be correlated to known measures of cable condition. Disadvantages include that the end terminations of the cable must be disconnected to perform the test, the test is applicable to cables that have shielded or sheath construction because it requires a defined ground return path of the loss (leakage) current back to the test set (supply source), the test should not be performed on low-voltage (600 volt) and 5,000 volt unshielded cables because of safety concerns and unreliable test results resulting from an undefined ground return path, and the amount of capacitance in the cable circuit limits the test such that standard test equipment cannot test very long and larger conductor cables.

*7. Insulation Resistance/Polarization Index*

The insulation resistance/polarization index test is a diagnostic test that is relatively effective with low- and medium-voltage cables and all insulation and jacket materials. The insulation resistance test is a standard test used to measure the dielectric integrity of cable insulation; because of its sensitivity to temperature and humidity, it frequently is used as a pass/fail test because of the difficulties in obtaining an accurate and consistent absolute insulation resistance measurement. The polarization index test, which is the ratio of the insulation resistance measured at 10 minutes to the insulation resistance measured at

1 minute, successfully detects aging mechanisms such as thermally induced cracking and radiation-induced cracking in the presence of moisture, moisture intrusion, and surface contamination.

Advantages of the test are that it is relatively easy to perform, it does not require access to the entire cable, it does not need to be corrected for temperature effects, and it can provide trendable data. The disadvantages are that the end terminations of the cable must be disconnected to perform the test, the test is not as sensitive to insulation degradation as other electrical properties techniques, and leakage currents are very small and sensitive to surrounding environmental conditions, making it difficult to measure accurately.

*8. Partial Discharge Test*

The partial discharge test (PDT) is a diagnostic test that applies to medium-voltage shielded cables and all types of cable insulation and jacket materials. Aging mechanisms detected by the PDT include thermally induced embrittlement and cracking, mechanical damage, radiation-induced embrittlement and cracking, and water treeing.

Advantages of the PDT are that it does not require access to the entire length of the cable, it identifies the significant partial discharge sites in an insulation system, it provides information on the severity of the insulation defects, and it gives information on the location of each of the significant partial discharge sites (and insulation defects). Disadvantages are that the end terminations of the cable must be disconnected to perform the test, performance of the PDT is complex and requires a high skill level, the interpretation of PDT results requires a very high skill level and training, and the high testing voltage applied during the PDT has the potential to weaken and permanently damage the cable insulation. Also, nearby operating electrical equipment in a plant environment could cause noise interfere with the test, so this test is most successful on shielded cables.

*9. Time Domain Reflectometry*

The time domain reflectometry (TDR) test is a diagnostic test that can be implemented on low- and medium-voltage cables and all types of cable insulation and jacket materials. The TDR test is able to detect aging mechanisms such as thermally induced cracking, radiation-induced cracking, and severe mechanical damage. The TDR test can also identify the presence of water and its location along a cable run, the location and severity of electrical faults, and the location and severity of insulation damage.

Advantages of the TDR test are that it provides useful information for identifying and locating potential defects and discontinuities in a cable that may indicate severe insulation degradation or impending cable fault, it is nondestructive, it can be performed in situ from one end of a cable, and data can be trended against a baseline reflectogram. Disadvantages are that the end terminations of the cable must be disconnected to perform the test; training and experience are required for best results; and transient conditions, such as immersion, are only detectable when present during the TDR test.

*10. Line Resonance Analysis*

The line resonance analysis (LIRA) test is a diagnostic test that is applicable to low- and medium-voltage cables and all types of cable insulation and jacket materials. The LIRA test can detect aging mechanisms such as thermally induced embrittlement and cracking, radiation-induced embrittlement and cracking, and severe mechanical damage.

Advantages of the LIRA test are that it can be performed in situ without disconnecting the cable, the test requires only a single access point, the analysis of results can account for the effects of loads attached to the cable, and it can accurately identify the site of localized degradation. Disadvantages are that the test is not simple to perform or interpret, and training and experience are needed to obtain meaningful results.

*11. Infrared Imaging Thermography*

The infrared imaging thermography technique is a nondestructive, noncontact, electronically enhanced visual inspection technique for electrical equipment that is simple to perform and valuable in identifying potentially damaging service conditions where elevated temperatures are present. This technique is applicable to low- and medium-voltage cables or higher and all types of cable insulation and jacket materials. The infrared imaging test is able to detect aging mechanisms such as thermally induced embrittlement and cracking. Infrared imaging provides a useful tool for identifying temperature hotspots that could lead to accelerated degradation of electric cable systems or that indicate high-resistance electrical joints in electrical connectors and splices because of loosening, dirt or contamination, or corrosion. The instrument's high-resolution temperature detection capabilities combined with image storage and analysis software make it possible to trend the thermal data obtained.

Advantages of the infrared imaging thermography technique are that it is relatively easy to perform, properly corrected data identify the temperatures and location of hotspots, measurements can be made when the circuit is operating with a full load, data may be stored and trended with appropriate software, the test is nondestructive and nonintrusive, and it does not require the cable system under test to be disconnected. Disadvantages are that it requires training and experience for best results, measurements made when the circuit is operating at load can lead to safety concerns, high-end imagers and analysis software are expensive, and the cables and accessories to be monitored must be visually accessible.

Further information describing the selection and performance of many different types of cable condition monitoring techniques, including in situ methods and laboratory tests, appears in Section 3 of NUREG/CR-6704, "Assessment of Environmental Qualification Practices and Condition Monitoring Techniques for Low-Voltage Electric Cables," Volume 2, "Condition Monitoring Test Results," issued February 2001 (Ref. 7); Section 5 of SAND96-0344, "Aging Management Guideline for Commercial Nuclear Power Plants—Electric Cable Terminations" (Ref. 8); Institute of Electrical and Electronics Engineers (IEEE) Standard (Std.) 400-2001, "IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems," dated January 29, 2002 (Ref. 9); IEEE Std. 400.1-2007, "IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above with High Direct Current Voltage," dated September 21, 2007 (Ref. 10); IEEE Std. 400.2-2004, "IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)," dated March 8, 2005 (Ref. 11); IEEE Std. 400.3-2006, "IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment," dated February 5, 2007 (Ref. 12); and Section 6 and Annexes A, C, and D.4 of IEEE Std 1205-2000, "IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations," dated March 20, 2000 (Ref. 13).

## C. REGULATORY POSITION

1. The NRC staff considers the following elements, which consolidate a core program of periodic inspections and tests, together with the results of inservice testing, environmental monitoring and management activities, the incorporation of cable-related operating experience, periodic formal cable

condition assessment review and trending, and problem identification and corrective action, to constitute an effective cable condition monitoring program:

a. Select cables to be monitored.
b. Develop database for monitored cables.
c. Characterize and monitor service environments.
d. Identify stressors and expected aging mechanisms.
e. Select condition monitoring techniques suitable to monitored cables.
f. Establish baseline condition of monitored cables.
g. Identify cable characteristics and aging effects being monitored by each selected condition monitoring technique.
h. Perform test and inspection activities for periodic condition monitoring of cables.
i. Periodically review and incorporate plant and industry experience.
j. Periodically review, assess, and trend the condition of monitored cables.
k. Identify degraded conditions and take prompt corrective actions.

2. The NRC staff considers the use of appropriately selected combinations of the typical cable condition monitoring techniques, such as those discussed in section B above, within the framework of a comprehensive cable condition monitoring program to be an acceptable method for satisfying the Commission's regulations with respect to condition or performance monitoring of electrical cables installed in nuclear power plants. The condition monitoring techniques selected should be based on plant-specific design, installation, and operating conditions and operating experience related to the cables used in nuclear plants.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this draft regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance. This guide is intended to provide a compilation of techniques available for monitoring cable performance. The guide is intended to promote discussion between staff and licensees when a facilities operating experience indicates cable failure or degraded cable performance as a causal factor. The NRC staff will use this guidance to evaluate compliance with the Maintenance Rule.

The NRC has issued this draft guide to encourage public participation in its development. The NRC will consider all public comments received in development of the final guidance document. In some cases, applicants or licensees may propose an alternative or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this draft guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

# REFERENCES

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.[1]

2. Regulatory Guide 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC. [2]

3. Information Notice 2002-12, "Submerged Safety-Related Electrical Cables," U.S. Nuclear Regulatory Commission, Washington, DC, April 21, 2002.[3]

4. Information Notice 1989-63, "Possible Submergence of Electrical Circuits Located Above the Flood Level Because of Water Intrusion and Lack of Drainage," U.S. Nuclear Regulatory Commission, Washington, DC, September 5, 1989.

5. Generic Letter 2007-01, "Inaccessible or Underground Power Cable Failures That Disable Accident Mitigation Systems or Cause Plant Transients," U.S. Nuclear Regulatory Commission, Washington DC, February 7, 2007.[4]

6. NUREG/CR-7000, "Essential Elements of an Electric Cable Condition Monitoring Program," Brookhaven National Laboratory, Upton, NY, January 2010.[5]

7. NUREG/CR-6704, "Assessment of Environmental Qualification Practices and Condition Monitoring Techniques for Low-Voltage Electric Cables," Volume 2, "Condition Monitoring Test Results," Brookhaven National Laboratory, Upton, NY, February 2001.

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[1] All NRC regulations listed herein are available electronically through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; e-mail pdr.resource@nrc.gov.

[2] All regulatory guides listed herein were published by the U.S. Nuclear Regulatory Commission. Where an ADAMS accession number is identified, the specified regulatory guide is available electronically through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html. All other regulatory guides are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/.

[3] Information notices (INs) listed herein are available electronically through the Public Electronic Reading Room on the NRC's public Web, site at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; e-mail pdr.resource@nrc.gov.

[4] Generic Letters (GLs) listed herein are available electronically through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; e-mail pdr.resource@nrc.gov.

[5] All NUREG-series reports listed herein were published by the U.S. Nuclear Regulatory Commission. Copies are available for inspection or copying for a fee from the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; e-mail pdr.resource@nrc.gov.

8. SAND96-0344, "Aging Management Guideline for Commercial Nuclear Power Plants—Electrical Cable and Terminations," prepared by Sandia National Laboratories for the U.S. Department of Energy, Washington DC.

9. IEEE Std. 400-2001, "IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems" (Revision of IEEE Std. 400-1991), Institute of Electrical and Electronics Engineers, New York, NY, January 29, 2002.[6]

10. IEEE Std. 400.1-2007, "IEEE Guide for Field Testing of Laminated Dielectric, Shielded Power Cable Systems Rated 5 kV and Above With High Direct Current Voltage" (Revision of IEEE Std. 400-1991), Institute of Electrical and Electronics Engineers, New York, NY, September 21, 2007.

11. IEEE Std. 400.2-2004, "IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)," Institute of Electrical and Electronics Engineers, New York, NY, March 8, 2005.

12. IEEE Std. 400.3-2006, "IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment," Institute of Electrical and Electronics Engineers, New York, NY, February 5, 2007.

13. IEEE Std.1205-2000, "IEEE Guide for Assessing, Monitoring, and Mitigating Aging Effects on Class 1E Equipment Used in Nuclear Power Generating Stations" (Revision of IEEE Std. 1205-1993), Institute of Electrical and Electronics Engineers, New York, NY, March 20, 2000.

[6] Copies of standards are available for purchase from the IEEE Web site at http://www.ieee.org/portal/site. In addition, copies of the IEEE standards may be obtained from the Institute of Electrical and Electronics Engineers, Inc., IEEE Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855.

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NUREG/CR-6794, "Evaluation of Aging and Environmental Qualification Practices for Power Cables Used in Nuclear Power Plants," Brookhaven National Laboratory, Upton, NY, January 2003.

NUREG/CR-6788, "Evaluation of Aging and Qualification Practices for Cable Splices Used in Nuclear Power Plants," Brookhaven National Laboratory, Upton, NY, September 2002.

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