



# REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

## REGULATORY GUIDE 1.211

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# QUALIFICATION OF SAFETY-RELATED CABLES AND FIELD SPLICES FOR NUCLEAR POWER PLANTS

## A. INTRODUCTION

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for complying with the Commission's regulations for the qualification of safety-related cables and field splices for nuclear power plants.

The regulations established by the NRC in Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50) (Ref. 1) require that structures, systems, and components that are important to safety in a nuclear power plant must be designed to accommodate the effects of environmental conditions (i.e., remain functional under postulated design-basis events (DBEs)). Toward that end, General Design Criterion (GDC) 1, "Quality Standards and Records," GDC 2, "Design Bases for Protection Against Natural Phenomena," GDC 4, "Environmental and Dynamic Effects Design Bases," and GDC 23, "Protection System Failure Modes," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 contain the general requirements. Augmenting those general requirements, the specific requirements pertaining to the qualification of certain electrical equipment important to safety are contained in 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants." In addition, Criterion III, "Design Control," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants," to 10 CFR Part 50 requires that, when a test program is used to verify the adequacy of a specific design feature, the test program must include suitable qualification testing of a prototype unit under the most severe DBE.

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.

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This guide was issued after consideration of comments received from the public.

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## **B. DISCUSSION**

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) Standard 383-2003, "IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations," was published June 10, 2004 (Ref. 2). The standard was developed by the Working group on Cables (Subcommittee (SC 2.4)) of the Nuclear Power Engineering Committee of the IEEE and was approved by the IEEE Standards Association on December 12, 2003 (Reaffirmed in 2008). It provides general requirements, direction, and methods for qualifying safety-related cables, field splices, factory splices, and factory rework for service in nuclear power plants. Categories of cables covered include those used for power, control, and instrumentation services, including signal and communication cables. Most importantly, IEEE Standard 383-2003 requires that the safety-related cables and field splices must meet or exceed specified performance requirements throughout their installed life and be subjected to a quality assurance program that includes design, qualification, and production quality control.

The objectives of equipment qualification are to ensure that safety-related cables (single, multiconductor, and multiplex, as well as coaxial, triaxial, and twinaxial) and field splices can be demonstrated to perform their safety functions under postulated DBEs, and that no failure mechanism exists that could lead to common-cause failures under postulated service conditions. It is the degradation over time, followed by exposure to the environmental extremes of temperature, pressure, humidity, radiation, mechanical stress, or chemical spray (or a combination thereof) resulting from DBEs, that presents a potential for common-cause failures of safety-related cables and field splices. As a result, it is necessary to establish a qualified life for cables and splices that are installed in harsh environments and must perform a safety function during and following a DBE.

These objectives should be accomplished using qualification methods (type testing, operating experience, analysis as a supplement to type testing and operating experience, ongoing qualification, or any combination thereof). However, qualification by analysis alone is not acceptable. Type testing of sample cables or field splices is the preferred qualification method. In addition, IEEE Standard 383-2003 requires documentation, in an auditable form, to demonstrate that cables and field splices are capable of adequately performing their safety functions during and following a DBE.

In Clause 3.3 of IEEE Std 383-2003, an exact description of the "representative" cable is required to ensure that sufficient information is available for the "representative" cable to allow future engineering extrapolation of the conclusions from the results of the type tested cable to other cables reported to be "represented" by the type test.

Different specialty cables (coaxial, triaxial, and twinaxial) have different critical characteristics based on the application such as noise rejection or signal propagation. It is imperative, if an engineering analysis is used to justify an application of one specialty cable based on qualification of a different type of specialty cable, that the critical characteristics be identified in both applications and compared to the qualification type test results. Further, Clause 6.1.2 of IEEE Std 383-2003, requires that suitable test specimen lengths and configuration be included in the DBE test to evaluate the potential for conductor shorting or loss of critical dielectric characteristics due to differential shrinkage or expansion in coaxial and triaxial cables. The NRC staff has witnessed cables which have passed a qualification type test without connectors only to fail the test when the connectors were attached. The failure was traced to

unequal thermal expansion of the different cable components fixed at both ends of the cable with connectors.

NRC research suggests the potential for cracking of age-embrittled cable materials during subsequent installation of field splices. Field splices of age-embrittled cables should be avoided.

Power cables that are routed underground should be capable of performing their function when subjected to anticipated environmental conditions such as moisture or flooding. Also, based on recent underground power cable failures, the staff has concluded that field splices of medium-voltage cables in inaccessible locations should be avoided

### **C. REGULATORY POSITION**

The NRC staff considers conformance with the requirements of IEEE Standard 383-2003 an acceptable method for use in satisfying the Commission's regulations with respect to the qualification of safety-related cables and field splices, subject to the following exceptions:

- (1) Clause 6.2.1.4, "Shielding," of IEEE Std. 383-2003 should be supplemented to include:
  - (a) information on other shields such as insulation or overall static shield, and
  - (b) percent overlap and lay for tape shields.
- (2) Clause 6.2.1.1, "Conductor," should include the stranding configuration (i.e., round, compressed or compact).
- (3) Clauses 6.2.1.8 and 6.2.2.6, "Identification," should include the date of applicable manufacturing standards and the date of manufacture.
- (4) Clause 6.4.4 (b) should be supplemented with the following:

"The qualification type tests for coaxial, triaxial and twinaxial cables should include sufficient testing of cable's critical electrical performance characteristics to permit an adequate analysis of the compatibility of the coaxial, triaxial and twinaxial cables for the specific application, as appropriate."
- (5) Clause 9.1, "General," should be supplemented to include the following:

"Documentation should also include manufacturer's inspection and maintenance requirements."
- (6) Programs for monitoring of environmental conditions (such as temperature, radiation levels), and condition monitoring should be implemented for safety-related power, instrumentation, and control cables. Condition monitoring programs may include any appropriate technique(s), supplemented with walkdowns to look for visible signs of anomalies attributable to aging with particular emphasis on the identification of localized adverse environments or "hot spots." For safety-related power cables that are inaccessible or installed underground, appropriate inspection, testing and monitoring programs should be implemented to detect degradation. The condition monitoring and its frequency may be adjusted based on the cable performance.

IEEE Standard 383-2003 references several industry codes and standards. If a referenced code or standard has been separately incorporated into the regulations, licensees and applicants must comply with

the standard as set forth in the regulations. By contrast, if the NRC staff has endorsed a referenced standard in a regulatory guide, that standard constitutes an acceptable method of meeting a regulatory requirement as described in the regulatory guide.

## **D. IMPLEMENTATION**

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance

In some cases, applicants or licensees may propose or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this 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.<sup>1</sup>
2. IEEE Standard 383-2003, "IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations," Institute for Electrical and Electronics Engineers, Piscataway, NJ, Published June 10, 2004.<sup>2</sup>

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<sup>1</sup> All publicly available NRC published documents such as Regulations, Regulatory Guides, NUREGs, and Generic Letters listed herein are available electronically through the Electronic Reading room on the NRC's public Web site at: <http://www.nrc.gov/reading-rm/doc-collections/>. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail [PDR.Resource@nrc.gov](mailto:PDR.Resource@nrc.gov).

<sup>2</sup> Copyrighted or proprietary documents such as IEEE standards may be available for purchase through the issuing organization.