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QUALIFICATION TESTS OF ELECTRIC CABLES, FIELD SPLICES, AND CONNECTIONS FOR LIGHT-WATER-COOLED NUCLEAR POWER PLANTS

A. INTRODUCTION

Criterion III, "Design Control," of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that, where a test program is used to verify the adequacy of a specific design feature, it include suitable qualification testing of a prototype unit under the most adverse design conditions. This regulatory guide describes a method acceptable to the NRC staff for complying with the Commission's regulations with regard to qualification testing of electric cables, field splices, and connections for service in light-water-cooled nuclear power plants to ensure that the cables, field splices, and connections can perform their safety-related functions.[1] The fire test provisions of this guide do not apply to qualification for an installed configuration.

B. DISCUSSION

IEEE Std 383-1974, "IEEE Standard for Type Test[2] of Class IE Electric Cables, Field Splices and Connections for Nuclear Power Generating Stations,"[3] was prepared by Working Group 12.2 of the Insulated Conductors Committee of the Power Engineering Society of the Institute of Electrical and Electronics Engineers, Inc. (IEEE), approved by the IEEE Nuclear Power Engineering Committee, and subsequently approved by the IEEE Standards Board on February 28, 1974. It was approved as an ANSI standard, ANSI N41.10-1975, April 30, 1975. The standard delineates procedures for developing a program for qualification testing of cables, field splices, and connections. It supplements IEEE Std 323-1974, "IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations," which describes basic requirements for equipment qualification. IEEE Std 323-1974 is endorsed, with certain exceptions, by Regulatory Guide 1.89, "Qualification of Class 1E Equipment for Nuclear Power Plants."

Shortly after IEEE Std 383-1974 was issued, several laboratories and cable testing facilities experienced difficulty in producing a consistent flame source by using the burner and flame source procedures specified in the standard. An IEEE task force investigation into the problem was eventually expanded to include an evaluation of various flame sources to determine if the 70,000 Btu/hr flame source specified in the standard was correct for use in fire qualification testing. The investigation found that inconsistencies in the flame source were traceable to the inadvertent use of incorrectly sized burners during certain tests.

A series of tests to determine if the correct flame source had been selected was conducted, and the results, as evaluated by the IEEE task force and the NRC staff, indicated no basis for changing the 70,000 Btu/hr. Investigation into fire testing is continuing by

[1] Regulatory Guide 1.29, "Seismic Design Classification," provides guidance with regard to identifying electric cables, field splices, and connections to which the design verification requirements of Appendix B to 10 CFR Part 50 apply.

[2] As used in this regulatory guide, the terms "qualification test" and "type test" are synonymous.

[3] Copies may be obtained from the Institute of Electrical and Electronics Engineers, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

IEEE and NRC, and significant results will be incorporated in future revisions of this guide.

The flame tests covered by Section 2.5 of the standard provide a test primarily of the self-extinguishing tendency of the cable insulation material. These tests are conducted with cables in a specific configuration and subjected to a defined fire source. However, the fire resistance of cables may vary significantly under different environmental conditions, cable configurations, and fire sources. It should be recognized that the objective of the flame test is to provide guidance for the selection of fire-resistant cables rather than to establish the adequacy of the installation of cables in a nuclear power plant. Adequacy of cables as installed depends on many factors. Morever, the adequacy of the cable system as installed depends on other factors in addition to the properties of the cables. For example, cable separation criteria are delineated in Regulatory Guide 1.75, "Physical Independence of Electric Systems," and fire protection guidelines are delineated in Regulatory Guide 1.120, "Fire Protection Guidelines for Nuclear Power Plants."

IEEE Std 383-1974 is concerned with cables both inside and outside the containment and establishes procedures for simulating operating conditions so that type testing will be adequate for the intended service conditions. It covers normal operating and design basis event conditions, except that the fire test is a reference configuration and flame rather than the design basis configuration and flame.

C. REGULATORY POSITION

Conformance with the requirements of IEEE Std 383-1974, "IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations," is acceptable for qualifying electric cables, field splices, and connections as components (fire test provisions do not apply to qualification for an installed configuration) for service in light-water-cooled nuclear power plants to ensure that the cables, field splices, and connections can perform their safety-related function subject to the following:

1. In lieu of Section 1.3.4.2.3, "Other Design Basis Events," the following should be used:

> "The remainder of the complete spectrum of design basis events (e.g., events such as a steam line break) shall be considered in case they represent different types or more severe hazards to cable operation."

2. In lieu of Section 1.3.5.3, "Test Design Basis Event," the following should be used:

> "Type tests for design basis event conditions shall consist of subjecting non-aged and aged cables, field splices, and connections to a sequence of environmental extremes that simulate the most severe postulated conditions of a design basis event and specified conditions of installation. Type tests shall demonstrate margin by application of multiple transients, increased level, or other justifiable means. Satisfactory performance of the cable will be evaluated by electrical and physical measurements appropriate to the type of cable during or following the environmental cycle, or both. The factors for margin given in Section 6.3.1.5 of IEEE Std 323-1974 shall be used where applicable.
>
> "The values of pressure, temperature, radiation, chemical concentrations, humidity, and time in IEEE Std 323-1974 do not represent acceptable limits for all nuclear power stations. The user of this standard shall ensure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable or connections will be installed."

3. In lieu of Section 2.1, "Introduction," the following should be used:

> "Type tests described in this document are methods that shall be used to qualify electrical cables, field splices, and connections for use in nuclear power generating stations. Tests of the cable or connection assembly, as applicable, shall then supplement the cable tests in order to qualify the connections and other aspects unique to planned usage.
>
> "The values of pressure, temperature, radiation, chemical concentrations, humidity, and time indicated in IEEE Std 323-1974 do not represent acceptable limits for all nuclear power generating stations.
>
> "The user of this guide shall ensure that the values used in the required type tests represent acceptable limits for the service conditions in which the cable, or connections, or both, will be installed.
>
> "Results of prior tests that are being used as the bases for the present tests shall be referenced in the documentation."

4. In lieu of Section 2.3.2, "Long-Term Physical Aging Properties," the following should be used:

> "Aging data shall be submitted to establish long-term performance of the insulation. Data may be evaluated using the Arrhenius technique. A minimum of 3 data points, including 136°C and two or more others at least 10°C apart in temperature, shall be used.
>
> "If there is not sufficient evidence that accelerated aging techniques can reliably produce

end-of-life conditions, the following ongoing qualification procedure should be used:

"*Ongoing Qualification Procedure*—Some types of cables, field splices, and connections (hereafter referred to only as cables) may not respond in a representative manner to accelerated aging techniques to establish end-of-design-life conditions. Consequently, the qualified life would be less than the required design life. There are two suggested methods of achieving long-term (design life) qualification: (a) After a planned period less than the qualified life of the cable has been reached, representative cables should be replaced with new cables and the removed cables subjected to a qualification test similar to that performed prior to installation. This test should include additional accelerated aging. Successful completion of this test extends the qualified life of the installed cables. This procedure should be repeated until the qualified life equals or exceeds the required design life. (b) Additional identical cables should be installed in a nuclear power generating station location where power loading and service conditions equal or exceed those of the cable to be qualified. A cable should be removed after a planned period less than the previously qualified life and subjected to a qualification test similar to that performed prior to installation. This test should include accelerated aging. Successful completion of this test extends the qualified life of the installed cable. Sufficient additional identical cables should be initially installed in order that the above procedure can be repeated until the qualified life equals or exceeds the required design life.

"If the above methods demonstrate that the qualified life is less than the design life, a periodic replacement plan should be instituted."

5. The radiological source term and exposure rate simulating LOCA conditions referred to in Section 2.4.2, "Radiation Exposure—Total," should be obtained from Regulatory Guide 1.89 rather than from IEEE Std 323-1974.

6. In lieu of Section 2.5.1, "General," the following should be used:

"This section describes the method for type testing of grouped cables via the vertical tray flame test to determine their relative self-extinguishing tendencies. Testing shall include both aged and unaged cable specimens."

7. In lieu of Section 2.5.2.2, the following should be used:

"The fire test provisions of the standard are useful in screening out cable insulation materials that are inadequately self-extinguishing, but they shall not be construed as qualification of any installed cable system configuration. If field splices are to be used in cable trays, special provisions shall be made to demonstrate that the fire retardant properties of the cable are not altered unacceptably in an adverse way by the field splice."

8. Section 2.5.4.2—Vertical tray configuration should be used and understood to mean perpendicular to the plane of the horizon.

9. In lieu of Section 2.5.4.4, the following should be used:

"The gas burner flame source shall consume propane gas so as to release approximately 70,000 Btu per hour at an air-gas ratio of 5 to 1. Natural grade propane shall be used. The procedure detailed below shall be followed:"

10. In lieu of the first sentence of Section 2.5.4.4.1, the following should be used:

"The ribbon gas burner[4] shall be mounted horizontally such that the flame impinges on the specimen midway between the tray rungs and so that the burner face is in front of and 4 inches from the cable and approximately 2 feet above the bottom of the tray."

11. In lieu of Section 2.5.4.4.3, the following should be used:

"Flame size will normally be achieved when the propane flow is 27.8 standard ft^3 per hour and the air flow is 139 standard ft^3 per hour."

12. Section 2.5.4.5 is not endorsed by this regulatory guide.

13. The recommendations indicated by "should" and the options indicated by "may" in the sections of IEEE Std 383-1974 indicated below have sufficient importance to be treated the same as requirements of the standard:

a. Section 1.3.1, "Cable Description"
b. Section 1.3.2, "Field Splices or Connection Description"
c. Section 1.3.4.1, "Meeting Service Conditions"; the first sentence.

[4]An American Gas Furnace Co. 10-in, 11-55 drilling, ribbon-type, catalog no. 10X 11-55 with an air-gas Venturi mixer, catalog no. 14-18 (2 lbf/in^2 max. gauge pressure) is the only presently available model that has been found satisfactory for purposes of these tests.

d. Section 1.3.4.2.1, "Design Basis Event—LOCA"
e. Section 1.4.1, "General"
f. Section 1.4.3, "Test Results"
g. Section 1.4.4, "Test Evaluation"
h. Section 2.2, "Type Test Samples"
i. Section 2.3.3, "Thermal and Radiation Exposure"
j. Section 2.3.3.3
k. Section 2.3.3.4
l. Section 2.4.3, "LOCA Simulation"
m. Section 2.4.3.1
n. Section 2.4.3.2
o. Section 2.4.4, "Post LOCA Simulation Test"
p. Section 2.5.2.1
q. Section 2.5.4.3
r. Section 2.5.4.4.2
s. Section 2.5.5, "Evaluation"
t. Section 2.5.6, "Instrument Cable and Single Conductors from Multiconductor Assembly"; the recommendation that the tested cable pass a flame resistance test in accordance with ASTM D2220-68.

14. Section 3, "References," of IEEE Std 383-1974 lists additional applicable IEEE standards. The specific applicability or acceptability of these referenced standards has been or will be covered separately in other regulatory guides, where appropriate.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for utilizing this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method, the method described herein for complying with specified portions of the Commission's regulations will be used by the staff in evaluating all construction permit applications docketed after May 1, 1978.

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