IEEE Std 383™-2003
(Revision of
IEEE Std 383-1974)

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IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations

IEEE Power Engineering Society

Sponsored by the
Nuclear Power Engineering Committee

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Nuclear Power Engineering Committee
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Approved 12 December 2003

IEEE-SA Standards Board

Abstract: This standard provides general requirements, direction, and methods for qualifying Class 1E electric cables, field splices, factory splices, and factory rework for service in nuclear power generating stations. Categories of cables covered are those used for power, control, and instrumentation services, including signal and communication cables. Field cables, wires, and splices are within the scope of this standard. Cables, wires, and splices within or integral to other devices (e.g., instruments, panels, motors, etc.) should be qualified using the requirements in the applicable device standard or IEEE Std 323™-1983, as appropriate. However, this standard's requirements may be applied to the wire and cable within these devices.
Keywords: class 1E electric cables, factory rework, factory splices, field splices, qualified life, representative cable, representative splices

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Introduction

(This introduction is not part of IEEE Std 383-2003, IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations.)

This standard was undertaken as part of the normal IEEE five-year review policy. The purpose of this revision is to provide greater guidance for cable and field splice qualification and to clarify the existing principles of qualification provided by IEEE Std 383-1974. It is not the intent of this revision that cables and field splices qualified to previous editions of this or other standards be requalified to this revision.

This document addresses the qualification of both field splices and factory made splices. Factory splices include splices and insulation repairs constructed in accordance with industry standards.

IEEE Std 383-1974 dealt with type testing as the preferred qualification method. Alternative methods of qualification by past operating experience, ongoing qualification, and qualification by analysis have always been available through IEEE Std 323-1983. They have been specifically included in this revision to emphasize their applicability.

A loss-of-coolant-accident (LOCA) as the design basis event (DBE) is described in subclause 6.4.3 of this standard. Other DBEs, including high-energy line breaks (HELB), may be addressed by type testing and may be combined with the LOCA where practical. A reference to HELB testing is now included.

The vertical flame test procedure of IEEE Std 383-1974 has been removed, and a reference to IEEE Std 1202™-1991 has been substituted.

IEEE Std 383-1974 contained as part of its title and scope the term *connections*. Connections have been removed from the title and scope of this revision because IEEE Std 572™-1985 is specific to the qualification of connections.

The table for recommended test sample selection sizes has been deleted.

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Interpretations

Current interpretations can be accessed at the following URL: http://standards.ieee.org/reading/ieee/interp/index.html.

Participants

This standard was prepared by the Working Group on Qualification of Class 1E Electrical Cables and Field Splices for Nuclear Power Generating Stations and the Subcommittee on Tests and Measurements of the Insulated Conductors Committee. At the time this standard was completed, the Working Group on Qualification of Class 1E Electrical Cables and Field Splices for Nuclear Power Generating Stations had the following membership:

J. L. White, Jr., *Chair*
G. R. Pitman, *Past Chair*

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J. B. Gardner
R. Konnik
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The Subcommittee 2 (Subcommittee on Qualification) of Nuclear Power Engineering Committee that recommended approval of this standard had the following membership:

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The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

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When the IEEE-SA Standards Board approved this standard on 12 December 2003, it had the following membership:

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IEEE Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations

1. Overview

1.1 Scope

This standard provides general requirements, direction, and methods for qualifying Class 1E electric cables, field splices, factory splices, and factory rework for service in nuclear power generating stations. Categories of cables covered are those used for power, control, and instrumentation services, including signal and communication cables. Field cables, wires, and splices are within the scope of this standard. Cables, wires, and splices within or integral to other devices (e.g., instruments, panels, motors, etc.) should be qualified using the requirements in the applicable device standard or IEEE Std 323™-1983,[1] as appropriate. However, this standard's requirements may be applied to the wire and cable within these devices.

1.2 Purpose

The purpose of this standard is to provide specific direction for the implementation of IEEE Std 323-1983 as it pertains to the qualification of electrical cables and field splices.

2. References

This standard shall be used in conjunction with the following standards. When the following specifications are superseded by an approved revision, the revision shall apply.

ICEA T-27-581/NEMA WC53, Standard Test Methods.[2]

IEEE Std 1™-1986, IEEE Standard General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation.[3, 4]

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[1]Information on references can be found in Clause 2.

[2]ICEA publications are available from ICEA, P.O. Box 20048, Minneapolis, MN 55420, USA (http://www.icea.org/).

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IEEE Std 98™-2002, IEEE Standard for the Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials.

IEEE Std 99™-1980, IEEE Recommended Practice for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electrical Equipment.

IEEE Std 101™-1987, IEEE Guide for the Statistical Analysis of Thermal Life Test Data.

IEEE Std 308™-2001, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.

IEEE Std 317™-1983, IEEE Standard for Electrical Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.

IEEE Std 323-1983, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.

IEEE Std 334™-1994, IEEE Standard for Qualifying Continuous Duty Class 1E Motors for Nuclear Power Generating Stations.

IEEE Std 336™-1985, IEEE Standard Installation, Inspection and Testing Requirements for Power, Instrumentation and Control Equipment.

IEEE Std 572™-1985, IEEE Standard for Qualifications of Class 1E Connection Assemblies for Nuclear Power Generating Stations.

IEEE Std 775™-1993, IEEE Guide for Designing Multi-Stress Aging Tests of Electrical Insulation in a Radiation Environment.

IEEE Std 1064™-1991, IEEE Guide for Multi-Factor Stress Functional Testing of Electrical Insulation Systems.

IEEE Std 1202™-1991, IEEE Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies.

NFPA 262-2002, Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air Handling Spaces.[5]

3. Definitions

For the purposes of this standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B1][6] should be referenced for terms not defined in this clause.

3.1 factory rework: The addition or reapplication, during factory production, of insulation, extruded semi-conducting layers, or jacket material on a portion of a manufactured length of conductor or cable.

3.2 factory splices: The inclusion by the manufacturer of a joint and requisite reinsulation of immediate splice zone to enable a cable of the required length to be manufactured and delivered.

[5]NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (http://www.nfpa.org/).
[6]The numbers in brackets correspond to those of the bibliography in Annex A.

3.3 representative cable: A cable or group of cables used during qualification testing to represent a number of cable styles. The representative cables shall contain the following characteristics of the cable styles: a) manufactured by a specific manufacturer using the same processes and controls; b) contains the same materials, including insulation, jackets, fillers, binder tape, shields, and factory splices (if appropriate); c) the same or higher service rating; d) the same or higher volts per mil operating level; and e) construction or configuration features (e.g., number or type of conductors) that conservatively represent the features of the cable styles being qualified.

3.4 representative splice: A splice or group of splices used during qualification testing to represent a number or range of splice styles. The representative splices shall contain the following characteristics of the splice styles: a) materials manufactured by a specific manufacturer using the same processes and controls, b) the same materials, c) the same or higher service rating, d) the same or higher volts per mil operating level, and e) construction or configuration features (e.g., number of conductor break-outs, V-type or inline type) that conservatively represent the features of the splice styles being qualified.

4. Principle qualification criteria

It is required that Class 1E cable and field splices meet or exceed specified performance requirements throughout their installed life. This is accomplished, in part, by ensuring that cables are manufactured in accordance with applicable industry standards (as defined in Clause 7) and that cables and field splices are subjected to quality assurance programs that include, but are not limited to, design, qualification, and production quality control.

It is the role of qualification to ensure that Class 1E cable and field splices can be demonstrated to perform as specified and that no failure mechanism exists that could lead to common cause failures under postulated service conditions.

It is the degradation with time (aging), followed by exposure to the environmental extremes of temperature, pressure, humidity, radiation, mechanical stress, or chemical spray or a combination of these resulting from design basis events (DBEs), which present a potential for common cause failures of Class 1E cable and field splices. For these reasons, it is necessary to establish a qualified life for cables and field splices required to function during and following DBEs, which subject the cables and field splices to DBE environments that exceed their normal and abnormal levels. This shall be accomplished using the qualification methods described in the following sections of this standard, including type testing, operating experience, analysis as a supplement to type testing and operating experience, ongoing qualification, or any combination thereof.

For whichever qualification method is chosen, upon conclusion of the qualification program, documentation is required that demonstrates cable and field splice adequacy to perform Class 1E function(s). The documentation shall be in an auditable form that allows verification by competent personnel, other than the qualifier, and shall contain:

— The cable or field splice’s specification or qualification plan

— The documents that demonstrate compliance with the qualification plan

— Inspection and maintenance requirements

— Summaries and conclusions

For all qualification programs, the end result shall be the collection of documentation that demonstrates the equipment’s adequacy to perform its safety function(s) with no failure mechanisms that could lead to common-cause failures. The documentation shall allow verification by competent personnel that the equipment has been properly qualified.

5. Principles of qualification

An objective of qualification is to establish a qualified life for cables and field splices that are installed in environmentally "harsh" areas and must perform a safety function during and following the DBE. The qualified life of the cables and field splices can be expressed in years at a specified operating temperature. Qualification of Class 1E cables shall be accomplished using either a specific or generic qualification process.

A qualified life is not required for cables and splices located in a mild environment, if the cables and splices are operated within the limits established by applicable specifications and standards. Failures associated with unanticipated conditions should be evaluated to determine if the root cause requires corrective actions to prevent the occurrence of common cause failures.

a) *Specific Qualification*. In specific qualification, the qualification criteria are established for a set of requirements designed to envelope a single application. The qualification program shall demonstrate operability of a cable, and field splice under all applicable service conditions, including time. For specific qualification, the specified electrical parameters may be used in lieu of the cable or field splice's rated parameters.

b) *Generic Qualification*. In generic qualification, the qualification specification criteria are established for a generic set of requirements designed to envelop a number of applications. To establish qualification for a specific application, the specific application requirements shall be equal to or less severe than the generic qualification requirements.

The specific or generic qualification of Class 1E cable and field splices and its application interfaces shall be accomplished by using one or more of the methods described below.

5.1 Qualification by type testing

Type testing of sample cable or field splice is the preferred method of qualification. The type tests shall be designed to demonstrate that the cable or field splice is capable of performing its Class 1E functions after being subjected to stresses caused by specified service conditions, including DBE, for its qualified life. The tests shall simulate conditions that meet or exceed the specified service conditions at the location of the cable or field splice. Test samples shall be assembled by documented production or fabrication assembly methods and then subjected to the test program. The components of the sample shall be selected at random if in production, or a prototype shall be manufactured and assembled using simulated production procedures. They shall be tested in a position that represents their most severe generic- or plant-specific application.

Qualification by type testing shall include the collection and analysis of data necessary to demonstrate that

a) The test sample is representative of assemblies in actual plant applications.

b) The test conditions are at least as severe as the conditions defined in the qualification plan.

c) The test data gathered relating to test sample performance factors are sufficient to enable the user to determine if the required safety functions can be achieved for the specific application(s).

5.2 Qualification with operating experience

Auditable operating experience data are best used to establish qualification for normal service conditions of cable or field splices, to determine extrapolation limits, failure modes, and failure rates, or to confirm prior conclusions regarding service condition effects. Operating experience data are generally of limited use when establishing qualification to harsh DBE conditions and may be used if the in-service samples have performed successfully during applicable DBE conditions after exposure to aging conditions. Documentation of the operating environment shall include details of physical location and installation-related information of the cable or field splices in the operating facilities. The cable or field splices shall be considered to be qualified by demonstrating that

a) The documented service conditions are at least as severe as the service conditions of the intended application.
b) The cable or field splice being qualified is representative of those in service.
c) The documented performance of the in-service cable and field splices is equal to or exceeds the specified performance requirements.

The qualification report shall identify and justify any differences that exist in satisfying the above requirements. The period of time for which this demonstration can be documented shall designate the qualified life of the product.

5.3 Qualification with analysis

Qualification by analysis alone is not acceptable. Analysis shall be performed only as a supplement to type testing and operating experience for such purposes as the following:

a) Support test assumptions and results
b) Evaluate test data or operating experience data
c) Determine the cause of a test failure and, where justified, establish qualification to less-severe service conditions or acceptance criteria
d) Apply type-test results for in-plant application
e) Augment a generic test to demonstrate that performance-related physical properties are similar, that the materials are compatible, and that the materials interact in a manner similar to those used on a qualified cable or field splice

When analysis is used to support qualification of cable or field splices to less-severe service conditions or acceptance criteria, the less-severe conditions or criteria shall be clearly delineated in the qualification report.

5.4 Extending qualified life

Qualified life may be extended in cases where the qualified life is shorter than the anticipated installed life by the use of ongoing qualification, including the methods discussed below:

a) A cable or field splice shall be qualified for an initial qualified life based on available data. Although operating within the initial qualified life period, other cables or field splices of the same type may be placed in a natural or accelerated aging environment that ages them under controlled conditions. These other test samples shall then be removed from the age-conditioning environment and type tested. The type testing may include additional accelerated age conditioning and shall include DBE and post-DBE simulations. Successful completion of the type test extends the qualified life by the additional aging period. This procedure may be repeated until the qualified life equals the required installed life or until the maximum life is reached if it is less than the required installed life.
b) When a cable or field splice is more robust than originally predicated, a monitoring program may be used to extend the qualified life of installed cable and field splices. This requires that the characteristics subject to aging deterioration be monitored at specific intervals and compared with specified acceptance criteria. The acceptance criteria shall be based on post-age-conditioning characteristics for the qualified cable or field splice. Absence of a change beyond the acceptance criteria indicates that the cable or field splice is not adversely affected by aging and is qualified for another interval. The monitoring intervals shall be established to prevent deterioration beyond the acceptance criteria prior to corrective action. Corrective actions include specified maintenance, modification, or replacement.

c) Qualified life may be extended if it can be shown that the service or environmental conditions originally assumed were overly conservative with respect to those that apply at the equipment's locations in its installed configuration.

Any of these methods is considered ongoing qualification. Other methods with proper justification may be acceptable. The applicability of any of the above methods or other ongoing qualification methods shall be justified. The specific program to be followed shall be documented, and auditable evidence of qualification status shall be maintained.

5.5 Combined qualification

Cable and field splices may be qualified by combinations of type test, documented previous operating experience, and analysis. Type tests or operating experience combined with analysis are examples of combined qualification. The qualification shall provide auditable data by which the combined methods can be shown to constitute satisfaction of the specified qualification program.

6. Qualification by type testing methods

Type testing is the preferred method of demonstrating or assisting in demonstrating that cables and field splices are capable of meeting performance requirements under applicable service conditions. Margins shall be applied to type test parameters for DBE testing. These margins increase the severity of the test to assure conservatism. Guidance on the use and application of margin is contained in IEEE Std 323-1983. Type testing shall be in accordance with a test plan (see IEEE Std 323-1983). Satisfactory assessment of cable and field splice performance shall be accomplished by electrical and physical measurements appropriate for the required service condition, and for the type of cable and field splice being evaluated.

6.1 Type test sample selection

The samples selected for type testing shall be representative of the cable and field splices being qualified.

6.1.1 Single, multiconductor, and multiplexed cables

Insulated wire used as a jacketed or unjacketed single conductor cable or a component of a multiconductor or multiplexed cable shall be qualified with the insulation exposed to the test environment. This exposure is intended to establish the ability of the wire insulation to perform its intended function independent of the jacket material. However, medium voltage cable shall only be tested as a completed cable, including jackets, shields, and stress control layers where applicable.

Jacketed single conductor specimens shall also be tested to demonstrate that a) there is no adverse interaction between the jacketing system and the underlying insulation for single conductor and multiplexed cables and b) jacket integrity is maintained for connector and splice applications requiring such integrity. Bonded jacket specimens are considered to adequately simulate interactions in constructions with and without such bonding. A bonded jacket refers to construction that causes that cable jacket to adhere to the cable insulation. This bonding can be achieved with fabrication techniques or by using adhesives or bonding agents between the jacket and insulation during manufacture.

Multiconductor cable shall also be qualified as a complete cable to demonstrate that there is no adverse interaction between the outer jacket and the underlying insulation, fillers, and binders of the construction type.

Qualification of a type test sample cable shall qualify cable with the same insulation thickness and with heavier thickness without regard to voltage rating, within the same voltage class (e.g., 5 kV qualifies 15 kV, and 600 V wall thickness qualifies 1000 V walls) if and only if the applied peak voltage stress in V/mil during the test is equal to or greater than the peak voltage stress that a test sample of the higher voltage rating would require.

6.1.2 Coaxial, triaxial, and twinaxial cables

Type tests of coaxial, twinaxial, and triaxial specimens qualify only those cables of identical materials. Consideration should be given to unique construction features when choosing representative samples. These considerations include, but are not limited to, shield braid angle and the use of shield filler materials to provide water blocking or suppression of triboelectric effects.

Coaxial, triaxial, and twinaxial cable shall be tested with their jackets to establish that the jacket maintains the following:

— Integrity as a moisture barrier and has no adverse interaction with the underlying insulation

— Integrity for connector and splice applications requiring such integrity

— Required dielectric characteristics between the outer shield and ground

Thermal and steam effects during DBE simulations may cause differential shrinkage or expansion of concentric cable layers in coaxial and triaxial cable with the potential for conductor shorting or loss of critical dielectric characteristics. Suitable test specimen lengths and configurations shall be included in the DBE test to evaluate this potential failure mode.

6.1.3 Field splices

Sample splices shall qualify only splices of the same representative construction and fabrication procedures. A single conductor splice (i.e., electrically interconnecting two conductors) shall qualify splices with similar design characteristics. A multiconductor splice (i.e., electrically interconnecting three or more conductors) shall qualify splices with similar design characteristics. Design characteristics include configuration (In-line or "V" type), connection (bolted or crimped), construction layers (jacket, insulation, shield, semiconductive), layer thickness, and cable interface (cable jacket/insulation materials, seal overlap length, sealing adhesive, and interface preparation).

6.2 Description of cables and field splices

The description or specification as a minimum shall include the following information as applicable.

6.2.1 Cables

6.2.1.1 Conductor

Material type identification, size, stranding, and coating.

6.2.1.2 Insulation

Materials identification, manufacturer compound identification number, thickness, cure method (where applicable), color, and form. In the case of medium voltage cables, this same information is required for the extruded semiconducting shields.

6.2.1.3 Assembly

Number and arrangement of conductors, fillers, and binders, including filler and binder material identification.

6.2.1.4 Shielding

Material identification, thickness, and form, including the braid angle for braided shields.

6.2.1.5 Fillers and binders

Material type identification, including manufacturer compound identification number and type.

6.2.1.6 Covering

Material type identification (jacket or armor), jacket configuration (inner, outer, or both), manufacturer compound identification number, type of armor, thickness, and form.

6.2.1.7 Characteristics

As defined by the pertinent service requirements. Examples of pertinent service requirements include, but are not limited to, voltage, current, frequency, conductor temperature, and ambient conditions.

6.2.1.8 Identification

Manufacturer’s trade name or catalog number.

6.2.2 Field splices

6.2.2.1 Cables

The information defined in 6.2.1.1–6.2.1.7, or manufacturer designation and description traceable to such information, for each substrate wire.

6.2.2.2 Conductor connection

Type (e.g., bolted, crimped, etc.), material identification, and method of assembly.

6.2.2.3 Assembly

Whether factory fabricated or field assembled. If field assembled, the specific procedures, inspection/tests, and equipment used during assembly.

6.2.2.4 Materials

Identification of all insulation, mastic, and jacketing materials, including manufacturer compound identification numbers, thickness, color, and form.

6.2.2.5 Characteristics

As defined by the pertinent service requirements, including configuration, connection, construction layers, and cable interface.

6.2.2.6 Identification

Manufacturer's trade name or catalog number.

6.3 Age conditioning

Normal operating conditions over time may enhance or degrade the ability of cables and field splices to withstand the extreme environments and loads imposed during the DBE. Therefore, unless otherwise justified, the type testing for the DBE conditions shall involve both aged and unaged samples.

Age conditioning pertains to temperature and radiation, applied either simultaneously or sequentially, in an accelerated manner.

Where substantial service-related synergistic, dose rate, and diffusion-limited oxidation or acceleration-related dose rate effects of pertinent insulating and jacketing material types have been identified, and where methods to reproduce them in accelerated testing are known, such methods shall be used with due consideration to cost, time, and complexity. Thermal and radiation aging synergistic effects may be addressed by simultaneous exposure to radiation and thermal environments or an appropriate choice of sequential exposure order, level, or duration. Dose rate and diffusion-limited oxidation effects are often minimized by reducing the acceleration level and extending the exposure duration.[7] As a minimum, if no evidence of a synergistic effect exists, a clear statement, noting that this is the case, shall be included with the qualification report.

The basis for establishing thermal age conditioning of samples to simulate their qualified life may be the Arrhenius method, or another method of proven validity and applicability for the materials in question. The Arrhenius method and associated activation energy values shall conform to the guidance in IEEE Std 1-1986, IEEE Std 98-2002, and IEEE Std 101-1987.

6.4 Test procedures

6.4.1 Aging properties

Aging data shall be used to establish the activation energy of the critical materials, including insulation, jacket (when the cable jacketing may impact cable qualification), mastics (when used and credited as part of field splice qualification), and semiconducting material if used. If the Arrhenius method is used to establish an activation energy, a minimum of three data points, at least 10°C apart, shall be used. The precision of the data from which the qualified life has been projected shall be given. Most likely, for cable constructions of most types, the materials comprising the composite cable assembly will be affected differently by the effects of accelerated aging. An assessment of the accelerated aging-related sensitivity of all critical cable components shall be completed to establish an overall aging program that does not either significantly overage or underage some of these critical components. Separate specimens may be required to be aged, for example, for the insulation in one case, and for the jacket in the other. A documented rationale of the approach used for accelerated aging of the composite assembly is required as part of the overall qualification documentation package.

A cable component is considered critical for the purposes of aging if it is susceptible to deterioration as a result of normal service conditions, and such deterioration can significantly affect required cable or field splice functions under DBE exposure. For example, in a composite insulation, the outer layer may age in a manner that when overaged causes failure of the entire insulation system when exposed to a DBE. All critical components of the cable insulation system must be included in at least one test specimen. However,

[7] IEEE Std 1064-1991 and IEEE Std 775-1993 provide guidance on multifactor test methods.

components of the insulation may be included as specimens in the test program either as insulated conductor or material sample (e.g., slab or dumbbell) to allow further qualification insights to be gained.

6.4.2 Thermal and radiation exposure for normal service

In accordance with 6.3, specimens shall be aged to their expected end of qualified life condition. In instances wherein a combination of materials, each with different aging characteristics, is used in the product construction, separate aging of the different components may be necessary. Supplemental aging and analysis using specimen samples of a slab, dumbbell, or tube construction may be used to demonstrate the acceptability of these materials during the service life of the cables. The use of these supplemental samples shall be justified in the qualification report. These samples and tests cannot be used in lieu of the test specimens required by 6.1. There may be cases of the specific application testing involving the qualification of cable or splices for application in an inert atmosphere such as used in some Boiling Water Reactor applications. The impact of the inert environment can be credited as a basis for use of aging techniques other than Arrhenius; however, justification shall be provided for the alternative technique.

The following test sequence may be used for thermal and radiation aging and to demonstrate that the cable and field splice sample are operational after aging. The sequence of thermal prior to radiation exposure, as is suggested below, is not essential and may therefore be reversed, as may be desired by the qualifying agency for purposes of addressing potential synergistic effects or, absent these, ease of completing the aging process:

a) Form suitable lengths of samples selected in accordance with 6.1 into test specimens so that the effective length of each specimen under test will not be less than 3.05 m. Samples shall include a field splice if splices are to be qualified. In the case of the splice materials testing, the 3.05 m minimum length does not apply to the splice; however, the splice should be a part of an assembly including pigtails, that is, a minimum of 3.05 m long to facilitate the test.

b) Subject specimens to circulating air oven aging at a temperature and time developed using Arrhenius techniques or another method of proven validity to simulate the thermal degradation that takes place during the qualified life.

c) The samples with thermal conditioning as in [6.4.2 item b)] shall be subjected to radiation conditioning in air to the total integrated dose expected from all sources in normal service during the qualified life.

d) After the radiation exposure of [6.4.2 item c)], The cable samples shall be straightened (if coiled) and then coiled with an inside diameter not exceeding 20 times the overall cable diameter to demonstrate a lack of embrittlement and adequate flexibility. The coiled sample shall then be immersed in tap water at room temperature for a minimum one-hour “soak” period. At the end of the “soak” period and while still immersed, the coiled sample shall pass a voltage withstand test, conductor to conductor and conductor to water and shield if present, for five minutes at a potential of 80 Vac/mil of insulation or 240 Vdc/mil of insulation. In addition to this test, a dc insulation resistance or high potential test shall be performed in accordance with ICEA T-27-581/NEMA WC53 to demonstrate jacket integrity for coaxial, triaxial, and twinaxial cables or other shielded cables requiring jacket integrity and dielectric capability. These samples need not go through further qualification testing or another submerged voltage withstand test.

   For field splices, the ac test voltage may be based on either splice or cable insulation thickness but shall not be less than two times rated-voltage plus 1000 V.

   For some splice designs, the mandrel bend test may be inappropriate. For these designs, the dielectric test may be accomplished without the mandrel bend if other test data are available, demonstrating that the materials of construction remain flexible after the test exposures.

e) Consideration should be given to acquiring performance of material condition data during or after the aging simulations. Such data may be used for potential future qualified life extension purposes in accordance with 5.4.

6.4.3 Radiation exposure during design basis event

This sublcause is predicated upon, but not necessarily limited to, a loss of coolant accident (LOCA) or high-energy line break (HELB). Prepare at least two samples of each type of cable or splice so the effective length of each sample (if splice, including cable pigtails) under test will not be less than 3.05 m, in accordance with the following procedure:

a) At least one specimen is to be unaged.

b) At least one specimen is to be thermal and radiation aged in accordance with [6.4.2 item b)] and [6.4.2 item c)].

All samples shall then be subjected to conditioning by radiation in air to the total integrated dose expected for the postulated DBE environment.

6.4.4 Design basis event simulation

The user shall specify the parameters of the DBE(s), the electrical and environmental parameters to be monitored, and the acceptance criteria for the anticipated applications. The DBE simulation and test procedures shall envelop the environmental and electrical parameters and shall encompass the acceptance criteria as a minimum. Specialty cables such as coaxial, twinaxial, or triaxial are often selected for purpose of their extra shielding feature or for added insulation value. In these instances, performance shall be assessed for the specific application instead of the cable's ultimate capability. Any specialized applications using these cables for their high-frequency capability, for example, must be specifically evaluated to define performance criteria.

The samples from 6.4.3 shall be tested in a pressure vessel so constructed that the samples can be energized with rated voltage and current while exposed to the environmental extremes of a DBE. The chamber shall have provisions for monitoring and varying temperature and steam pressure, for recycling chemical spray, and for electrically loading and performance testing of the specimens as specified herein. The specific chamber design is not considered critical to the test performance; however, to the extent practical, all cable surfaces shall be similarly exposed. The cable shall be in contact with a suitable ground plane.

a) After the samples are installed inside the pressure vessel, the test vessel shall be stabilized at the pre-DBE temperature for a duration of at least one hour prior to the start of the accident transient. Test specimens shall be energized at qualification voltage and current throughout the stabilization period. The energized samples shall be exposed to one full cycle of a DBE environment, which as a minimum, is as severe as the specified DBE profile with margin and inclusive of chemical sprays.

b) The samples shall function electrically, within the specified electrical parameters, throughout the DBE simulation for the required operating time. Performance data shall be collected and recorded either continuously or at specified intervals throughout the test duration. If data are not continuously monitored, the sampling intervals must be sufficient to demonstrate compliance with the performance criteria. Performance criteria, such as current, insulation resistance, and impedance, shall be pertinent to the sample construction and application and will differ from power, control, and instrumentation applications, such as the functional role of the jacket in protecting shields in concentric constructions.

Test duration is established based on the specified DBE environmental profile with due consideration for the post-DBE decrease of some environmental parameters and required functionality in the post-DBE period. A basis for the post-DBE duration shall be established, recognizing that compression of that period may need to be accomplished for practical purposes. An approach such as the evaluation of equipment, which must remain operable in the long term, including the use of alternative means to maintain the reactor in safe condition, may provide a suitable basis for compression of the post-DBE duration.

6.4.4.1 Post-design basis event simulation test

Upon completion of the DBE simulation, to demonstrate retention of a degree of flexibility, margin in electrical performance and ability to withstand some movement and vibration, the samples shall be straighten (if bent) and coiled around a mandrel with a diameter of approximately 40 times the overall cable diameter and immersed in tap water at room temperature for a period of one hour. While still immersed, the specimens shall pass voltage withstand test specified under [6.4.2 item d)]. Some specialty cables, such as certain coaxial or triaxial are selected for their added insulation. In these instances, margin may be demonstrated at lower withstand test voltages. If the test voltage selected is other than the test voltage specified in [6.4.2 item d)], the voltage shall not be less than twice rated plus 1000 V.

6.4.5 Retained flexibility

To demonstrate the retention of a degree of flexibility, a sample of the cable shall meet the requirements of [6.4.2 item d)] for radiation-only qualification and 6.4.4.1 for LOCA or HELB qualification.

7. Qualification for normal and mild events

Cables and field splices located in normal and mild environments shall be specified, designed, and selected to perform in their intended service conditions. This includes evaluating thermal and radiation data to establish the service life. A qualified life is not required for cables and splices located in a mild environment. Qualification for cables and splices located in mild environments shall be demonstrated by providing certified evidence that the cables meet or exceed the specified requirements, including those of recognized industry associations. For the purposes of this standard, recognized industry associations are the Association of Edison Illuminating Companies (AEIC) and the National Electrical Manufacturers Association (NEMA)/Insulated Cable Engineers Association (ICEA). It is incumbent on the user to ensure that the criterion that constitutes a mild environment as defined in IEEE Std 323-1983 is met.

8. Flame test qualification

Cables shall be flame retardant in accordance with the requirements of IEEE Std 1202-1991 or NFPA 262-2002. Switchboard cables, coaxial, twinaxial, and triaxial cables shall as a minimum pass the UL VW-1 flame test.

9. Documentation

9.1 General

Data used as evidence of the qualification of cables and field splices shall be organized in an auditable file or report and shall provide evidence that the range of cables and field splices are qualified for the intended applications and meet specified performance requirements. The documentation shall include the following information.

a) Detailed description of the style and range of cable, field splice, and factory rework and factory splice(s) (as applicable) being qualified. The description shall identify the materials of construction, including any filler and/or binder material. Specific detail delineating the nature of factory rework and /or factory splice(s) shall be provided.

b) Qualification plan or procedure, which contains the specified performance requirements, environmental service conditions and DBE parameters, and range of cables and field splices being qualified, and an explanation of the methodology and bases for establishing qualification, including a description of and justification for the analyses and operating experience used as part of the qualification.
c) Specified environmental service conditions and DBE parameters.
d) Specified performance requirements and test results.
e) Analysis of test anomalies and test data.
f) Establishment of basis for successful qualification results.
g) Description of and justification for operating experience or analysis used as part of the basis for qualification.
h) Review/approval signatures and date.

9.2 Type test documentation

The type test documentation shall a) demonstrate compliance with the relevant aspects of the qualification plan or specification (9.1); b) fully describe the test program, including test specimens, arrangements, simulated conditions, performance data, and results; and c) evaluate the adequacy of the test results to establish qualification to the specified requirements. The type test documentation shall include, but not be limited to, the following information.

a) The physical arrangement of the specimens and test equipment description.
b) Time program and sequence of all environmental factors.
c) The type and location of all environmental and specimen monitoring sensors for each variable.
d) The programmed voltage and currents.
e) The electrical measurements and tests performed during the environmental exposures.
f) Testing and examinations subsequent to DBE simulation.
g) Identification of measuring test equipment, including accuracy and date of calibration.
h) Test results shall include an analysis of anomalies encountered during the test and their impact on the results. Test results shall also demonstrate whether the intended environmental sequences were achieved and whether the cable or field splice demonstrated the ability to perform its intended function.
i) Evaluation of test data shall be made to determine the adequacy of cable and field splice performance.

9.3 Documentation of qualification by methods other than type testing

a) Data to support qualification or to extend existing qualification to a modified product using operating experience, analysis, or ongoing qualification data shall include the following as applicable:
    1) Available measured data
    2) Past failure analysis and trends
    3) Description of periodic maintenance and inspections
    4) Description of expected service conditions
    5) Applicability of the data and analysis to intended function
    6) Program(s) to be followed to maintain qualification
    7) Basis for continued applicability of previous testing to modified product

b) Documentation shall include the following:
   1) Discussion of similarity between cables and field splices that are being qualified and those cables and field splices for which operating experience, analysis, or ongoing information is available
   2) Conclusion regarding qualified life

9.4 Traceability of materials

Specifications of detailed descriptions of the materials used in construction of the cables and field splices shall be available and controlled to provide evidence that the qualification results are directly applicable to all manufactured lots of the product.

10. Modifications

When there are changes in materials or design of cables and field splices, or in postulated environments such that there are differences between these properties and those assumed in the qualification program, prior qualification shall be reviewed to determine the effect on the qualification status. This review shall indicate whether additional type tests or supplemental analyses are required to establish the qualification for the modified product or conditions. This review also shall include the basis for the decision that additional type tests or supplemental analyses are or are not required by providing a detailed justification or analysis of the data that support the conclusion. The information shall be retained with the qualification documentation and shall form a part of the auditable documentation as specified in 9.3.

Annex A

(informative)

Bibliography

[B1] IEEE 100, The Authoritative Dictionary of IEEE Standards Terms.