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IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations

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Approved 14 June 2013

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Abstract: An electric penetration assembly is an assembly of insulated electric conductors, conductor seals, module seals (if any), and aperture seals that provides the passage of the electric conductors through a single aperture in the nuclear containment structure, while providing a pressure barrier between the inside and the outside of the containment structure. The electric penetration assembly includes terminal (junction) boxes, terminal blocks, connectors and cable supports, and splices which are designed and furnished as an integral part of the assembly. Requirements for the design, construction, qualification, test, and installation of electric penetration assemblies in nuclear containment structures for stationary nuclear power generating stations are prescribed in this standard.

Criteria intended to facilitate the determination of the features of design, construction, test, qualification, and installation relative to the electric penetration assemblies of primary containments of the nuclear facilities that comply with the United States Nuclear Regulatory Commission's Code of Federal Regulations (10CFR50) are presented in this standard.

Keywords: aperture seals, class MC components, conductor seals, containment electric penetration assembly, containment penetrations, control power penetrations, DBE, design basis events, electric penetration assembly, electrical penetration assembly, fiber seals, IEEE 317™, instrumentation penetrations, low voltage power penetrations, LVP, medium voltage power penetrations, module seals, MVP, penetration feedthroughs, penetration modules, qualified life, SAC, severe accident conditions

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Introduction

This introduction is not part of IEEE Std 317™-2013, IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations.

This standard presents criteria to facilitate the determination of the features of design, construction, test, qualification, and installation relative to the electric penetration assemblies of primary containments of the nuclear facilities that comply with the United States Nuclear Regulatory Commission's Code of Federal Regulations (10CFR50).

Adherence to these criteria alone may not suffice for ensuring the health and safety of the public because it is the integrated performance of the structures, the fluid systems, the instrumentation, and the electric systems of the stations that establishes the consequences of accidents. Each applicant has the responsibility to assure himself and others that this integrated performance is adequate.

The IEEE will maintain this standard current with the state of the technology. Comments on this standard and suggestions for additional material that should be included are invited.

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1. Overview

1.1 Scope

This standard prescribes the requirements for the design, construction, qualification, test, and installation of electric penetration assemblies in nuclear containment structures for stationary nuclear power generating stations. The requirements for external circuits ~~which~~ that connect to penetration assemblies are beyond the scope of this standard. This standard does not include requirements for operation, maintenance, or periodic testing after installation.

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1.2 Purpose

This standard presents criteria to facilitate the determination of the features of design, construction, test, qualification, and installation relative to the electric penetration assemblies of primary containments of nuclear facilities.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI/ASTM D2863-10, Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index).

ANSI EIA 455-171-1987, Attenuation by Substitution Measurement for Short-Length Multimode Graded- Index and Single-Mode Optical Fiber Assemblies.

ANSI/ICEA P-32-382-2007, Short-Circuit Characteristics of Insulated Cables.[1]

ASME Boiler and Pressure Vessel Code.[2]

ASME NQA-1-2008, Quality Assurance Requirements for Nuclear Facility Applications.

[1] ICEA publications are available from the Insulated Cable Engineers Association, ICEA P.O. Box 1568 Carrollton, GA 30112, USA (http://www.icea.net/).

[2] ASME publications are available from the American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10016-5990, USA (http://www.asme.org/).

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ASME NQA-1-2008, PART II, SUBPART 2.2, Quality Assurance Requirements for Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Facilities.

ASTM D635-10, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self- Supporting Plastics in a Horizontal Position.[3]

ICEA S-93-639/NEMA WC 74-2006, Clause 9.8, 5 – 46kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy.[4]

IEEE Std 98™-2002, IEEE Standard for the Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials.[5,6]

IEEE Std 101™-1987 (R 2004), IEEE Guide for the Statistical Analysis of Thermal Life Test Data.

IEEE Std 323™-2003 (R 2008), IEEE Standard for Qualifying Class lE Equipment for Nuclear Power Generating Stations.

IEEE Std 336™-2005, IEEE Guide for Installation, Inspection, and Testing Requirements for Class lE Power, Instrumentation and Control Equipment at Nuclear Facilities.

IEEE Std 344™-2004, IEEE Recommended Practice for Seismic Qualification of Class lE Equipment for Nuclear Power Generating Stations.

[3] ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

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IEEE Std 383™-2003, IEEE Standard for Qualifying Class lE Electric Cables and Field Splices for Nuclear Power Generating Stations.

IEEE Std 627™-2010, IEEE Standard for Qualification of Equipment Used in Nuclear Facilities.

IEEE Std 603™-2009, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

IEEE Std C37.09™-1999 (R 2007), IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.[7]

IEEE Std C37.20.2™-1999 (R2005) IEEE Standard for Metal-Clad Switchgear.

ISA MC 96.1-1982, Temperature Measurement Thermocouples.

~~**3. References**~~

~~SpeciÞc sections and requirements of the codes, standards, and guides listed below are referenced in this standard. No other requirements of the referenced documents are invoked or implied. In case of conßicts between this standard and the referenced standards and guides, this standard shall take precedence over the referenced documents.~~

~~[1] ANSI/IEEE C37.09-1979, American National Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Basis.~~ [1]

~~[2] ANSI MC 96.1-1982, Tables for Thermocouples Temperatures-Electromotive Force (EMF).~~

[1] ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor,New York, NY 10036, USA (http://www.ansi.org/).~~1430 Broadway, New York, NY 10018.~~

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[3] ANSI N45.2-1977, Requirements for Nuclear Facilities, Quality Assurance Program.

[4] ANSI N45.2.2-1978, Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants (during the Construction Phase).

[5] ANSI/ASTM D-568-77, Standard Test Methods for Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position.

[6] ANSI/ASTM D-2863-77, Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index).

[7] ANSI/IEEE C37.20-1969, (Consolidated Edition 1974) (R 1981). IEEE Standard for Switchgear Assemblies Including Metal-Enclosed Bus.

[8] ANSI/IEEE Std 336-1980, IEEE Standard Installation, Inspection, and Testing Requirements for Class lE Instrumentation and Electric Equipment at Nuclear Power Generating Stations.

[9] ANSI/IEEE Std 344-1975 (R 1980), IEEE Recommended Practice for Seismic QualiPcation of Class lE Equipment for Nuclear Power Generating Stations.

[10] ANSI/IEEE Std 383-1974 (R 1980), IEEE Standard for Type Test of Class lE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.

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[13] ASTM D635-81, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position.[4]

[14] ICEA P-32-382-1969, Short-Circuit Characteristics of Insulated Cable.[5]

[15] IEEE Std 98-1983, IEEE Standard for the Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials.

[16] IEEE Std 101-1972 (R 1980), IEEE Guide for the Statistical Analysis of Thermal Life Test Data.

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~~[18] IEEE Std 627-1980, IEEE Standard for Design Qualification of Safety Systems Equipment Used in Nuclear Power Generating Stations.~~

~~[19] NEMA WC 3-1980, Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy (ICEA S-1981 Sixth Edition).~~ [6]

~~2.~~3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.[8]

analysis: A process of mathematical or other logical reasoning that leads from stated premises to the conclusion concerning the qualification of an assembly or components.

containment: Engineered safety primary pressure boundary surrounding the reactor system pressure boundary, to provide a barrier to retain or prevent the release of radiation or hazardous contamination to the outside environment even under conditions of a reactor accident. *Syn:* **confinement structure; vault.**

design basis events (DBE):
Postulated events used in the design to establish the acceptable performance requirements of the structures, systems, and components.

design service conditions:
The service conditions used as the basis for ratings and for the design qualification of electric penetration assemblies.

~~[6] NEMA publications are available from the National Electrical Manufacturers Association (NEMA), 2101 L. Street, NW, Washington, DC 20037.~~

[8] *IEEE Standards Dictionary Online* subscription is available at: *http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.*

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design tests:

Tests performed to verify that an electric penetration assembly meets design requirements.

double aperture seal: Two single aperture seals in series.

double electric conductor seal:

Two single electric conductor seals in series.

double optical fiber seal: Two single optical fiber seals in series.

electric penetration assembly:

An assembly of insulated electric conductors, conductor seals, module seals (if any), and aperture seals that provides the passage of the electric conductors through a single aperture in the nuclear containment structure while providing a pressure barrier between the inside and the outside of the containment structure. The assembly may include optical fibers and fiber seals. The electric penetration assembly includes terminal (junction) boxes, terminal blocks, connectors and cable supports, and splices ~~which~~ that are designed and furnished as an integral part of the assembly.

environmental conditions:

Physical service conditions external to the electric penetration assembly such as ambient temperature, pressure, radiation, humidity, vibration, chemical or demineralized water spray and submergence expected as a result of normal operating requirements, and postulated conditions appropriate for the design basis events applicable to the electric penetration assembly.

generic design: A family of equipment units having similar materials, manufacturing processes, limiting stresses, design, and operating principles~~,~~ that can be represented for qualification purposes by a representative unit(s).

installed life: The interval of time from installation to permanent removal from service, during which the electric penetration assembly is expected to perform its required function(s).

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NOTE—Components of the assembly may require periodic replacement; thus the installed life of such components is less than the installed life of the assembly.

margin: The difference between the most severe design service conditions and the conditions used in the design qualification to account for normal variations in commercial production of equipment and reasonable errors in defining satisfactory performance.

qualified life: The period of time prior to the start of a design basis event for which the equipment was demonstrated to meet the design requirements for the service conditions.

NOTE—At the end of the qualified life, the equipment shall be capable of performing the safety function(s) required for the postulated design basis and post design basis events.

qualified life test: Tests performed on preconditioned test specimens to verify that an electric penetration assembly will meet design requirements at the end of its qualified life.

service conditions: Environmental, power, and signal conditions expected as a result of normal operating requirements, expected extremes in operating requirements, and postulated conditions appropriate for the design basis events applicable to the electric penetration assembly.

severe accident conditions: Postulated events with environmental conditions more severe than those in the design basis events used to establish the acceptable performance requirements of the electric penetration assemblies and that may degrade the containment integrity function of the electric penetration assemblies.

single aperture seal:
A single seal between the containment aperture and the electric penetration assembly.

single optical fiber seal: One single optical fiber seal to create a single pressure barrier seal between the inside and the outside of the containment structure along the axis of the optical fiber.

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single electric conductor seal: A mechanical assembly arranged in such a way that there is a single pressure barrier seal between the inside and the outside of the containment structure along the axis of the electric conductor.

4. Service classification and ratings

4.1 Service classification

The conductors of each circuit of an electric penetration assembly shall be assigned one of the following service classifications based on its use.

4.1.1 Medium-voltage power

Conductors of power circuits having rated values above 1000 V shall be classified as medium-voltage power and shall have the following ratings (see 4.2 and 4.3):

~~1~~a) Rated voltage
~~2~~b) Rated continuous current
~~3~~c) Rated short-time overload current and duration
~~4~~d) Rated short-circuit current
~~5~~e) Rated short-circuit thermal capacity
~~6~~f) Rated capabilities during the most severe design basis event (DBE) environmental conditions

4.1.2 Low-voltage power

Conductors of power circuits rated 1000 V and below shall be classified as low-voltage power and shall have the following ratings (see 4.2 and 4.3):

~~1~~a) Rated voltage
~~2~~b) Rated continuous current
~~3~~c) Rated short-time overload current and duration
~~4~~d) Rated short-circuit current
~~5~~e) Rated short-circuit thermal capacity
~~6~~f) Rated capabilities during the most severe DBE environmental conditions~~.~~

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4.1.3 Low-voltage control

Conductors of control circuits rated 1000 V and below shall be classified as control and shall have the following ratings (see 4.2 and 4.3):

~~1~~a) Rated voltage

~~2~~b) Rated continuous current

~~3~~c) Rated short-time overload current and duration

~~4~~d) Rated short-circuit current

~~5~~e) Rated short-circuit thermal capacity

~~6~~f) Rated capabilities during the most severe DBE environmental conditions

4.1.4 Instrumentation

Conductors of instrumentation circuits shall have a voltage rating defined by the design service conditions.

NOTE—Instrumentation conductors include, for example, coaxial, triaxial, resistance temperature detector RTD, thermocouple, and twisted ~~pair~~ shielded circuits~~.~~ [e.g., twisted shielded pair (TSP) or twisted shielded quad (TSQ)].

4.1.5 Optical fibers

Optical fibers have no electrical voltage or current rating. Fibers may be installed in all four (4) types of the electric penetration's electrical service classifications, with instrumentation type electric penetrations preferred. Fibers shall have the following ratings:

a) Mode type, either single or multi

b) Index, step or graded

c) Numerical aperture (if required for the system)

d) Core size

e) Attenuation dB loss, including connector halves on the electric penetration fibers

NOTE—Fiber optic cables connected to the penetrations may be qualified to IEEE Std 1682™-2011.

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4.2 Ratings

4.2.1 Rated voltage

The rated voltage of power and control conductor(s) of a circuit shall be as follows:

Nominal system voltage (V)	Rated voltage (V)
0 - 300	300
301 - 600	600
601 - 1000	1000
1001 - 5000	5000
5001 - 8000	8000
8001 - 15 000	15 000

4.2.2 Rated continuous current

The rated continuous current shall be the current in amperes that a conductor can carry continuously without the stabilized temperatures of the conductor and the penetration nozzle-concrete interface (if applicable) exceeding their design limits, with all other conductors in the assembly carrying their rated continuous current under the maximum normal environment temperature of the design service conditions.

See ~~Appendix~~ A2, ~~Rated Continuous Current~~, for preferred values.

4.2.3 Rated short-time overload current and duration

The rated short-time overload current and duration shall be the overload current in amperes that each conductor of a circuit can carry for a specified duration, following continuous operation at rated continuous current, without the temperature of the conductors exceeding their short-time overload design temperature limit with all other conductors in the assembly carrying their rated continuous current under the maximum normal environment temperature of the design service

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conditions. The rated short-time overload current shall not be less than seven times the rated continuous current of the conductor, and the duration shall be not less than 10 s.

4.2.4 Rated short-circuit current

The rated short-circuit current shall be the current in amperes that each conductor of a circuit can carry while maintaining electrical integrity (see 5.2.2) and mechanical integrity (see 5.1.6) with all other conductors in the assembly carrying their rated continuous current under the maximum normal environment temperature of the design service conditions.

The rated short-circuit current for alternating-current circuits shall be expressed in rms symmetrical amperes and shall be based on the test procedure in 6.2.8.

See ~~Appendix~~ A3 for preferred values of rated short-circuit current.

The rated short-circuit current for direct-current circuits shall be based on its having a constant dc value unless otherwise specified.

4.2.5 Rated short-circuit thermal capacity (I^2t)

The rated short-circuit thermal capacity shall be the product of short-circuit current in amperes squared and its duration in seconds that each conductor of a circuit can carry following continuous operation at rated continuous current while maintaining electrical integrity (see 5.2.2) and mechanical integrity (see 5.1.6) with all other conductors in the assembly carrying their rated continuous current under the maximum normal environment temperature of the design service conditions.

The rated short-circuit thermal capacity shall be expressed in amperes squared-seconds (I^2t) subject to the following limits:

~~1~~a) The short-circuit current shall not exceed the rated short-circuit current and shall be expressed in rms symmetrical amperes for ac circuits and dc amperes for dc circuits.

~~2~~b) The duration shall not exceed 2 s.

See ~~Appendix~~ A4 for preferred values of rated short-circuit thermal capacity (I^2t).

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4.3 Rated capabilities during the most severe DBE environmental conditions

4.3.1 Rated continuous current during the most severe DBE environmental conditions The conductors in the electric penetration assembly shall have a rated continuous current during the most severe DBE environmental conditions not less than the rated continuous current in 4.2.2 for which the conductors shall maintain electrical integrity (see 5.2.2) and containment integrity (see 5.1.7).

4.3.2 Rated short-time overload current and duration during the most severe DBE environmental conditions

The conductors in the electric penetration assembly shall have a rated short-time overload current and duration during the most severe DBE environmental conditions not less than the rated short-time overload current and duration in 4.2.3 for which the conductors shall maintain electrical integrity (see 5.2.2) and containment integrity (see 5.1.7), with the remaining conductors in the assembly carrying rated continuous current. The conductors shall be capable of meeting the above requirements at the maximum conductor temperature attained during the most severe DBE environmental conditions.

4.3.3 Rated short-circuit current during the most severe DBE environmental conditions

The conductors in the electric penetration assembly shall have a rated short-circuit current during the most severe DBE environmental conditions not less than the rated short-circuit current ~~in~~ for which the conductors shall maintain containment integrity (see 5.1.7) with the remaining conductors in the assembly carrying rated continuous current and without affecting the mechanical and electrical integrity of the remaining conductors. The conductors shall be capable of meeting the above requirements at the maximum conductor temperature attained during the most severe DBE service conditions.

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See ~~Appendix~~ A3 for preferred values of rated short-circuit current during the most severe DBE environmental conditions.

4.3.4 Rated short-circuit thermal capacity (*I2t*) during the most severe DBE environmental conditions

The conductors in the electric penetration assembly shall have a rated short-circuit thermal capacity (*I2t*) during the most severe DBE environmental conditions not less than the rated short-circuit thermal capacity (*I2t*) of 4.2.5, following continuous operation at rated continuous current while maintaining containment integrity of the assembly (see 5.1.7) and without affecting the electrical integrity (see 5.2.2) and the mechanical integrity (see 5.1.6) of the conductors not subjected to the short-circuit current. The conductors shall be capable of meeting the above requirements at the maximum conductor temperature attained during the most severe DBE environmental conditions. The short-circuit thermal capacity (~~-~~*I2t*~~-~~) shall be expressed in ampere squared-seconds subject to the following limits:

~~1~~a) The short-circuit current shall not exceed its rated value.

~~2~~b) The duration shall not exceed 2 s.

See ~~Appendix~~ A4 for preferred values of rated short-circuit thermal capacity (*I2t*) during the most severe DBE environmental conditions.

5. Design requirements

5.1 Mechanical design requirements

5.1.1 Pressure boundary

The mechanical design, materials, fabrication, examinations, and testing of the pressure boundary of the electric penetration assembly shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code[9] ~~[12],~~[7] , Division 1, Section III, Subsection NE for Class MC Components.

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See ~~Appendix~~Annex C for ASME pressure boundary of typical installed electric penetration assemblies.

Stress calculations shall include stresses from all applied loads including electromagnetic forces produced by rated short-circuit currents.

5.1.2 Design pressure and temperature

The design pressure and temperature shall be determined and specified in accordance with the rules of the ASME Boiler and Pressure Vessel Code ~~[12]~~, Division 1, Section III, Subsection NE for MC containment vessels.

NOTE—Under severe accident conditions (SAC), the containment may be subjected to higher pressure and temperature. Consideration may be given to qualify the electric penetration to a pressure rating comparable to the containment rating to prevent leakage paths for the severe accident environment and preserve containment integrity. See 6.4.

5.1.3 Minimum design temperature

The minimum design temperature of the electric penetration assembly shall be -28 ° C ~~(~~ (-20 ° F).

5.1.4 Design gas-leak rate

~~1~~a) The electric penetration assembly, exclusive of the aperture seal(s), shall be designed to have a total gas-leak rate not greater than 1 ~~á~~× 10 -3 std ~~cm 3~~ cm3/s of dry nitrogen at 20 ° C ± 15 ° C (68 ° F ± 27 °-F) at the design pressure.

~~2~~b) The aperture seal(s) of the electric penetration assembly shall be designed to have a total gas-leak rate not greater than 1 ~~á~~× 10 -3 std cm 3/s of dry nitrogen at 20 °C ± 15 °C (68 °F ± 27 °F) at design pressure.

~~3~~c) The electric penetration assembly, including the aperture seal(s), shall be designed to have a total gas-leak rate not greater than 1 ~~á~~× 10-2 std cm3/s of dry nitrogen at the design pressure and temperature.

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5.1.5 Gas-leak rate testing and monitoring provisions

Electric penetration assemblies having double electric conductor seals or optical fiber seals or double aperture seals, or both, shall be designed for and shall include provisions for gas-leak rate testing and monitoring of the double seals after installation.

Valves, fittings, and pressure piping and gauge(s) provided for this purpose shall have a pressure rating not less than 110% design pressure.

Electric penetration assemblies having double electric conductor or optical fiber seals shall include provisions for gas-leak rate monitoring during storage.

5.1.6 Mechanical integrity

The mechanical support systems, conductors, fibers, terminations and conductor support systems, pressure barrier(s), and conductor, fiber, and aperture seals shall be designed to withstand, without failure or loss of function, the following design service conditions:

~~1~~a) Rated continuous current

~~2~~b) Thermal cycling due to normal operation

~~3~~c) Rated short-time overload current and duration

~~4~~ d) Rated short-circuit current

~~5~~e) Rated short-circuit thermal capacity ($I2t$)

~~6~~f) Design basis events including LOCA, high energy line break (excluding direct steam jet impingement), seismic events, and other designated events~~.~~

5.1.7 Containment integrity

The electric penetration assembly including aperture seal(s) shall be designed to have a total gas-leak rate not greater than 1 ~~á~~× 10-2 std cm3/s using dry nitrogen at design pressure and ambient temperature after installation and after any ~~design basis events~~DBEs (excluding direct steam jet impingement).

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5.1.8 Packaging, shipping, receiving, storage, and handling

The electric penetration assembly shall be designed to meet the following requirements:

~~1)~~ a) ~~ANSI N45.2.2-1978 [4].~~ASME NQA-1-2008, PART II, SUBPART 2. Storage shall be in accordance with Level B Packaging shall be in accordance with Level C or better.

~~2~~b) Withstand, without damage, exposure during shipping to temperatures not less than the minimum design temperature ~~of~~noted in 5.1.3 ~~n~~or more than 65.5 °C (150 °F).

~~3~~c) Electric penetration assemblies having double electrical conductor seals or optical fiber seals or double aperture seals, or both, ~~which~~ that are completely assembled and ~~which~~ that require protection from exposure to the atmosphere, shall have the internal parts of the sealed system maintained at a positive pressure and shall include the monitoring provisions in 5.1.5.

5.1.9 Installation by welding

Where the method of attachment to the containment vessel is by welding, the assembly shall be designed for such method of attachment and procedures established so that the welding will not damage the assembly.

5.2 Electrical design requirements

5.2.1 General

The electric penetration assembly shall be designed to meet the following requirements:

~~1~~a) Medium-voltage power conductors shall be free of partial discharge (corona) when energized at rated voltage.

~~2~~b) Instrumentation circuits shall be designed to meet the requirements defined by the design service conditions.

~~3~~c) The insulation system of each conductor shall be capable of withstanding the dielectric tests specified in ~~Section~~Clause 6.

~~4~~d) Thermocouple conductors and connections shall be designed within the error limits for thermocouple circuits in accordance with ~~ANSI~~ISA MC 96.1-1982~~[2].~~.

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~~5~~e) Connections and splices of medium- and low-voltage power and control conductors shall be capable of carrying rated continuous current prior to and following rated short-circuit current without the temperature of the connections or splices exceeding the temperature of the conductor, or the connection failing.

~~6~~f) Electric penetration assemblies having conductors of more than one voltage rating in the assembly shall be designed with a ground barrier separating the conductors of each voltage rating.

~~7~~g) The heat generated by hysteresis and eddy current losses shall be included in the design requirements for power and control conductors.

h) Electro-magnetic compatibility (EMC) for emissions or susceptibility.

5.2.2 Electrical integrity The conductors, connections, and electrical insulation systems shall be designed to withstand, without failure or loss of function, the following design service conditions:

~~1~~a) Rated continuous current and rated voltage

~~2~~b) Thermal cycling due to normal operation

~~3~~c) Rated short-time overload current and duration

~~4~~d) Rated short-circuit current

~~5~~e) Rated short-circuit thermal capacity

~~6) Design basis events~~

f) DBEs including loss of coolant accident (LOCA), high energy line break (HELB) (excluding direct steam jet impingement), seismic events, and other designated events.

5.3 Fire resistance requirements

~~1~~The following fire resistance requirements shall be met:

a) Insulated cables and splices shall be qualified in accordance with ~~ANSI/~~IEEE Std 383~~-1974~~™-2003 (R ~~1980) [10], 2.5~~2008), Clause 8.

~~2~~b) All other organic, nonmetallic material, except those materials ~~which~~ that by their physical configuration will not contribute to a fire, shall meet at least one of the following requirements as applicable:

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~~a)~~ 1) Classified as *non-burning* or *self-extinguishing* in accordance with ASTM D 635-~~81 [13]~~10, or~~ ANSI/ ASTM D 568-77 [5].~~,

~~b)~~ 2) Classified as having an *oxygen index* not less than 26 in accordance with ANSI/ASTM D 2863-~~77 [6]~~10.

5.4 Qualified life

The electric penetration assembly shall be designed to have a qualified life not less than the installed life. If the qualified life of ~~a~~ an electric penetration sub-component(s) is less than the installed life, as determined by the qualification in Clause 6, replacement of the sub-component(s) shall be required prior to the end of its qualified life, or the qualified life extended in accordance with IEEE 323~~-1983 [17].~~™-2003.

6. Qualification

6.1 General

6.1.1 Tests

QualiÞcationQualification shall be established by tests that demonstrate that the electric penetration assembly will perform its intended function when subjected to conditions that simulate installed life under the design service conditions. Qualification shall include design tests ~~which~~that demonstrate the adequacy of the design to meet requirements that are unrelated to aging and shall include qualified life tests ~~which~~that address aging and establish the qualified life of the assembly.

Design tests may be performed in any sequence on different test specimens. Qualified life tests shall be performed on preconditioned test specimens in the sequence given in 6.3 and may be performed on test specimens that have not been subjected to design tests.

Documented analyses, with justification of methods, theories, and assumptions or additional testing of components or assemblies, or both, may be used with existing qualification tests to qualify the design to service conditions ~~which~~that differ from the design service conditions under ~~which~~ that qualification was demonstrated.

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Each conductor or fiber size, rating, and configuration need not be subjected to qualification tests; instead, representative test specimens may be used provided they meet the requirements in 6.1.3.

6.1.2 Margin

The following minimum margins shall be applied only to the service conditions listed below and only where specifically required in the following sections pertaining to qualification:

a) Currents: +5% of value

b) Voltage: +10% of value

c) Temperature: +8 °C (+15 °F). When qualification testing is conducted under saturated steam conditions, the temperature margin shall be such that test pressure will not exceed saturated steam pressure corresponding to peak service temperature by more than 7 × 104 Pa (10 lbf/in2)

d) Pressure: +10% of gage, but not more than 7 × 104 Pa (10 lbf/in2)

e) Vibration: +10% added to the acceleration of the input motion spectra of the equipment

f) Radiation:+10% (on accident dose)

6.1.3 Test specimen requirements

Test specimens used in qualification tests shall meet the following requirements:

a) Be of the same generic design as the production units

b) Be manufactured using production facilities and processes ~~which~~that are representative of those used for the production units

c) Be of such configuration as to produce thermal, electrical, and mechanical stresses representative of the design being qualified

Tests on components or partially assembled electric penetration assemblies are acceptable where the stresses and functional requirements are equivalent to those in the fully-assembled state.

Tests on conductors or fibers shall include terminations when they are an integral part of the electric penetration assembly.

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6.2 Design tests

The following design tests shall be performed for each generic design. The tests may be performed in any sequence on different test specimens.

6.2.1 Gas leak rate test

~~1~~a) The gas leak rate of the test specimen, exclusive of aperture seals, shall not exceed a total leak rate equivalent to 1 ~~á~~× 10-3 std cm3/s of ~~city~~ dry nitrogen when tested at not less than design pressure and at a temperature of 20 °C ±~~-~~15 °C (68 °F ± 27 °F).

~~2~~b) The gas leak rate of the test specimen, including non~~-~~welded aperture seals, shall not exceed a total leak rate equivalent to 1 ~~á~~× 10-2 std cm3/s of dry nitrogen when tested at design pressure and temperature.

NOTE—An acceptable means of conducting this test is to adjust the pressure upward to compensate for the difference between the room ambient temperature and the design temperature by use of the pure gas laws.

6.2.2 Pneumatic pressure test

Where the electric penetration assembly is designed as a pressure vessel in accordance with the ASME Boiler and Pressure Vessel Code ~~[12]~~, it shall be pneumatically pressure tested in accordance with Division 1, Section III, Subsection NE, Article NE-6000 of the code.

6.2.3 Dielectric strength tests

The following dielectric strength tests shall be conducted at test facility room ambient conditions of temperature, pressure, and relative humidity:

~~1~~a) Power frequency voltage test. Each medium-voltage power, low-voltage power, and control conductor shall be given a 60 Hz sinusoidal voltage test for not less than ~~I~~1 min applied between each conductor and ground and between each conductor and adjacent conductors not separated by a ground barrier. The test voltage shall be based on the voltage rating of the conductor in accordance with the following table:

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Conductor rated voltage (V)	RMS test voltage (V)
300	1600
600	2200
1000	3000
5000	19 000
8000	36 000
15 000	36 000

~~2~~ b) Impulse voltage tests. Each medium-voltage power conductor shall be given a full-wave 1.2 × 50 ~~ms~~µs impulse voltage test series, with a crest voltage not less than the following:

Conductor rated voltage (V)	Impulse crest voltage (kV)
5000	60
8000	95
15 000	95

The impulse voltage tests and acceptance criteria shall be in accordance with ~~ANSI/~~6.2.1.2 in IEEE Std C37.20~~-1969 (R 1981) [7], 5.2.1.2. 3~~.2™-1999 (R2005).

c) Instrumentation conductors shall be tested to demonstrate that they meet the requirements of the design service conditions.

6.2.4 Insulation resistance test

An insulation resistance test shall be performed at test facility room ambient conditions of temperature, pressure, and relative humidity in accordance with the following:

~~1~~a) Medium-voltage power conductors shall be tested at 500 V dc (minimum) and shall have a minimum resistance of 1000 MW between the conductor and ground and between the conductor and adjacent conductors not separated by a ground barrier.

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~~2~~b) Low-voltage power and control conductors shall be tested in accordance with 6.2.4~~(1~~ (a) of this standard and shall have a minimum resistance of 100 MW.

~~3~~c) Instrumentation conductors shall be tested to demonstrate that they meet the requirements of the design service conditions.

6.2.5 Partial-discharge (corona) test

Medium-voltage power conductors shall be tested for partial discharge (corona) between phase conductors and shall have a partial-discharge extinction voltage not less than rated voltage. The test apparatus, calibration, and test procedure shall be in accordance with 9.8.2 of ICEA S-93-639/ NEMA ~~WC3-1980 [19], Part 6.~~WC 74-2006. The test shall be performed at room ambient conditions of pressure, temperature, and humidity.

6.2.6 Rated continuous current test

A test shall be performed with each conductor and its termination of the test specimen carrying its rated continuous current under the maximum normal environment temperature of the design service conditions. The maximum stabilized temperatures shall be recorded and shall not exceed the design limits.

6.2.7 Rated short-time overload current test

The short-time overload current rating of each size conductor of the test specimen shall be verified by testing under the maximum normal environment temperature of the design service conditions. The test currents and duration shall be in accordance with 4.2.3. The maximum temperatures of the overloaded conductors attained during the test shall be recorded and shall not exceed the design limits.

6.2.8 Rated short-circuit current test

The short-circuit current rating of each size conductor of the test specimen shall be verified by testing in accordance with the following procedures:

~~1~~a) The test specimen shall simulate the electric penetration assembly installed condition and include all components ~~which~~ that are stressed during short-circuit conditions.

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2b) The test may be conducted at test facility room ambient temperatures; however, the conductor temperatures at the start of the test shall not be less than the maximum stabilized temperature attained during the rated continuous current test in 6.2.6.

3) a1) Set up the test circuit with a bolted fault connection in place of the penetration. The test circuit parameters should be set up for an *X*/*R* ratio of 8 or more for low-voltage power and control service and an *X*/*R* ratio of 16 or more for medium-voltage service. ANSI IEEE Std C37.09-1979 [1]™-1999 may be used for interpretation of the test data.

b2) The test circuit shall produce a short-circuit current not less than rated short-circuit current plus 5% margin. Where the short-circuit current for ac circuits does not have a constant symmetrical value, the rms value of the symmetrical current at the end of the test period shall not be less than the rated short-circuit current plus 5% margin.

4c) Remove the bolted fault and insert the penetration into the test circuit. Apply the short-circuit current. The length of the penetration, including pigtails for accomplishing the fault and the connection to the test circuit should not exceed 20 ft. The short-circuit current with the electric penetration assembly in the test circuit shall not be less than the rated short-circuit current.

5d) The duration of short-circuit current flow in the test specimen shall not be less than 0.033 s.

6e) After the short-circuit test, the test specimen shall pass the leak-rate test in 7.1 and the electrical tests in 7.5 (continuity verification only) and 78.3.

6.2.9 Rated short-circuit thermal capacity (*I2t*) test

The short-circuit thermal capacity (*I2t*) of each size conductor of the test specimen shall be verified by testing in accordance with the following procedure:

1a) The test specimen shall simulate the electric penetration assembly installed condition and include all components whichthat are stressed during short-circuit conditions.

2b) The test may be conducted at test facility room ambient temperatures; however, the conductor temperatures at the start of the test shall not be less than the maximum stabilized temperature attained during the rated continuous current test in 6.2.6.

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~~3~~c) The current in the conductor and its duration shall produce an integrated current squared-seconds not less than the rated short-circuit thermal capacity.

~~4~~d) The maximum temperature attained during the test shall be recorded and not exceed the short-circuit design limits and shall be based on all heat produced by the short-circuit current being stored in the conductors.

~~5~~e) After the short-circuit thermal capacity (*I2t*) test, the test specimen shall pass the leak-rate test as specified in 7.1 and the electrical tests in 7.5 (continuity verification only) and 7.3. Where the test specimen includes the aperture seal, the test specimen shall pass the leak-rate test as specified in ~~8~~ 7.3.

NOTE—This test may be combined with the rated short-circuit current test as specified in 6.2.8. The tests of 6.2.8 and 6.2.9 may be omitted as design tests if performed as part of the qualified-life tests.

6.2.10 Seismic test

The test specimen shall be seismically qualified in accordance with ~~ANSI/~~IEEE Std 344~~-1975 (R 1980) [9]~~TM-2004 for the input motion spectra in the design service conditions plus margin. Testing shall be performed under conditions ~~which~~that simulate the installed assembly including consideration of terminal boxes, external cables, and raceways. During the test, all conductors in the test specimen shall maintain uninterrupted continuity and shall withstand rated voltage plus 10% margin (see 6.1.2).

After the test, the test specimen shall pass the leak-rate test as specified in 7.1 and the dielectric test as specified in 7.3.

Where the test specimen includes the aperture seal, the test specimen shall pass the leak-rate test as specified in 8.3.

NOTE—The seismic test may be omitted as a design test if performed as part of the qualified-life tests.

6.2.11 Installation welding test

Where the method of penetration attachment is by welding, a test shall be conducted to demonstrate that a representative electric penetration assembly can be welded into the containment vessel

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