

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

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of the
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Foreword

(This Foreword is not a part of IEEE Std 317-1983, 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 the additional material that should be included are invited.

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

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 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.

2. Definitions

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.

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.

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.

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 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.

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).

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 specified 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.

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

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.

3. References

Specific 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 conflicts 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).

[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.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

- [8] ANSI/IEEE Std 336-1980, IEEE Standard Installation, Inspection, and Testing Requirements for Class IE Instrumentation and Electric Equipment at Nuclear Power Generating Stations.
- [9] ANSI/IEEE Std 344-1975 (R 1980), IEEE Recommended Practice for Seismic Qualification of Class IE Equipment for Nuclear Power Generating Stations.
- [10] ANSI/IEEE Std 383-1974 (R 1980), IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations.
- [11] ANSI/NFPA-70-1981, National Electrical Code.²
- [12] ASME Boiler and Pressure Vessel Code.³
- [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.
- [17] IEEE Std 323-1983, IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations.
- [18] IEEE Std 627-1980, IEEE Standard for Design Qualifications 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

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.

²The National Electrical Code is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269. Copies are also available from the Sales Department of American National Standards Institute, 1430 Broadway, New York, NY 10018.

³ASME publications are available from the American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017.

⁴ASTM publications are available in the US from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 10103.

⁵ICEA publications are available in the US from Insulated Cable Engineers Association, Inc, PO Box P, South Yarmouth, MA 02664.

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

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) Rated voltage
- 2) Rated continuous current
- 3) Rated short-time overload current and duration
- 4) Rated short-circuit current
- 5) Rated short-circuit thermal capacity
- 6) Rated capabilities during the most severe 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) Rated voltage
- 2) Rated continuous current
- 3) Rated short-time overload current and duration
- 4) Rated short-circuit current
- 5) Rated short-circuit thermal capacity
- 6) Rated capabilities during the most severe DBE environmental conditions.

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) Rated voltage
- 2) Rated continuous current
- 3) Rated short-time overload current and duration
- 4) Rated short-circuit current
- 5) Rated short-circuit thermal capacity
- 6) 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, thermocouple, and twisted pair circuits.

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 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) 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) The duration shall not exceed 2 s.

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

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.

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 (I^2t) During the Most Severe DBE Environmental Conditions

The conductors in the electric penetration assembly shall have a rated short-circuit thermal capacity (I^2t) during the most severe DBE environmental conditions not less than the rated short-circuit thermal capacity (I^2t) 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 (I^2t) shall be expressed in ampere squared-seconds subject to the following limits:

- 1) The short-circuit current shall not exceed its rated value.
- 2) The duration shall not exceed 2 s.

See Appendix A4 for preferred values of rated short-circuit thermal capacity (I^2t) 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 [12],⁷ Division 1, Section III, Subsection NE for Class MC Components. See Appendix 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.

5.1.3 Minimum Design Temperature

The minimum design temperature of the electric penetration assembly shall be $-28\text{ }^{\circ}\text{C}$ ($-20\text{ }^{\circ}\text{F}$).

5.1.4 Design Gas-Leak Rate

- 1) The electric penetration assembly, exclusive of the aperture seal(s), shall be designed to have a total gas-leak rate not greater than $1 \cdot 10^{-3}$ std cm^3/s † of dry nitrogen at $20\text{ }^{\circ}\text{C} \pm 15\text{ }^{\circ}\text{C}$ ($68\text{ }^{\circ}\text{F} \pm 27\text{ }^{\circ}\text{F}$) at the design pressure.
- 2) The aperture seal(s) of the electric penetration assembly shall be designed to have a total gas-leak rate not greater than $1 \cdot 10^{-3}$ std cm^3/s of dry nitrogen at $20\text{ }^{\circ}\text{C} \pm 15\text{ }^{\circ}\text{C}$ ($68\text{ }^{\circ}\text{F} \pm 27\text{ }^{\circ}\text{F}$) at design pressure.
- 3) The electric penetration assembly, including the aperture seal(s), shall be designed to have a total gas-leak rate not greater than $1 \cdot 10^{-2}$ std cm^3/s of dry nitrogen at the design pressure and temperature.

5.1.5 Gas-Leak Rate Testing and Monitoring Provisions

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

⁷Numbers in brackets correspond to those of the references listed in Section 3.