



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

IEEE Power and Energy Society

Developed by the
Nuclear Power Engineering Committee

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STANDARDS

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

Developed by the

Nuclear Power Engineering Committee
of the
IEEE Power and Energy Society

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IEEE SA Standards Board

Abstract: An electric penetration assembly is an assembly of insulated electric conductors, conductor seals, module seals (if any), and aperture seals that provide 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 317-2025, 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 containments of the nuclear facilities that comply with the United States Code of Federal Regulations (10 CFR 50) [B1].

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

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 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.

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 containments of nuclear facilities.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

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/ICEA S-93-639/NEMA WC 74-2022, Clause 9.8, 5–46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy.^{8,9}

ASME Boiler and Pressure Vessel Code.¹⁰

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

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

ASTM D635, Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position.¹¹

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

IEEE Std 98™, IEEE Standard for the Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials.^{12,13}

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

IEEE Std 336™, IEEE Recommended Practice for Installation, Inspection, and Testing for Class IE Power, Instrumentation, and Control Equipment at Nuclear Facilities.

IEEE Std 383™-2023, IEEE Standard for Qualifying Electric Cables and Splices for Nuclear Facilities.

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

IEEE Std 627™-2019, IEEE Standard for Qualification of Equipment Used in Nuclear Facilities.

IEEE Std C37.09™, IEEE Standard Test Procedures for AC High-Voltage Circuit Breakers Rated Maximum Voltage Above 1000 V.

IEEE Std C37.20.2™-2022, IEEE Standard for Metal-Clad Switchgear.

IEEE/IEC 60780-323-2016, International Standard—Nuclear facilities—Electrical equipment important to safety—Qualification.

IEEE/IEC 60980-344, International Standard—Nuclear facilities—Equipment important to safety—Seismic qualification.

ISA MC 96.1-1982, Temperature Measurement Thermocouples.

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

⁸ ICEA publications are available from the Insulated Cable Engineers Association (<https://www.icea.org/>).

⁹ NEMA publications are available from the National Electrical Manufacturers Association (<https://www.nema.org/>).

¹⁰ ASME publications are available from the American Society of Mechanical Engineers (<http://www.asme.org/>).

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3. Definitions, acronyms, and abbreviations

3.1 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.¹⁴

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.

conductor: A bus bar, a wire, or a combination of wires stranded together and not insulated from one another, suitable for carrying an electric current from one piece of electrical equipment to another or to ground. It may be bare (without insulation) or insulated (with insulation to prevent unintended current flow).

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

design basis event (DBE): A postulated event 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.

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 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).

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.

¹⁴*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

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.

severe accident: accident conditions more severe than a design basis event and involving significant core degradation.

severe accident condition (SAC): A postulated event 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 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.

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.

splice: A fitting for joining two conductors capable of carrying the full current capacity and the breaking load of the conductor.

terminations: A mechanical connection of two or more components, used to transmit electrical currents or voltages.

3.2 Acronyms

DBE	design basis event
EMC	electromagnetic compatibility
EMI	electromagnetic interference
HELB	high-energy line break
LOCA	loss of coolant accident
RFI	radio frequency interference
SAC	severe accident condition

3.3 Abbreviations

ID	inside diameter
OD	outside diameter

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 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 ratings defined in 4.2 and 4.3.

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 ratings defined in 4.2 and 4.3.

4.1.3 Low-voltage control

Conductors of control circuits rated 1000 V and below shall be classified as low-voltage control and shall have the ratings defined in 4.2 and 4.3.

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, thermocouple, and twisted-shielded circuits (e.g., twisted shielded pair or twisted shielded quad).¹⁵

4.1.5 Optical fibers

Optical fibers have no electrical voltage or current rating. Fibers may be installed in all four types of the electric penetration assembly service classifications, with instrumentation type electric penetration assemblies preferred. Fibers shall have the following characteristics:

- 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 decibel loss, including connector halves on the electric penetration fibers

NOTE—Fiber optic cables connected to the penetrations may be qualified to IEEE Std 1682 [B10].¹⁶

¹⁵ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

¹⁶ The numbers in brackets correspond to those of the bibliography in Annex E.