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IEEE Std 690™-2004
(Revision of
IEEE Std 690-1984)

690™

IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations

IEEE Power Engineering Society

Sponsored by the
Power Generation Committee

IEEE

3 Park Avenue, New York, NY 10016-5997, USA

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IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations

Sponsor

Power Generation Committee
of the
IEEE Power Engineering Society

Approved 23 September 2004

IEEE-SA Standards Board

Abstract: Direction for the design and installation of safety related electrical cable systems, including associated circuits, in nuclear power generating stations is provided. Guidance for the design and installation of those nonsafety related cable systems that may affect the function of safety related systems is also provided.
Keywords: circuit, electrical cable system, nuclear power generating station

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Introduction

(This introduction is not part of IEEE Std 690-2004, IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations.)

This standard is the result of efforts by the working group to provide a document for use as a standard in the design and installation of cable systems for Class 1E circuits in Nuclear Power Generating Stations. This document is written as a standard and as such utilizes the word shall.

This standard was revised to update material and references and to remove definitions that are now found in IEEE 100, *The Authoritative Dictionary of IEEE Standard Terms*. The Appendix was deleted since much of the information is in other standards that contain more current information.

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IEEE Standard for the Design and Installation of Cable Systems for Class 1E Circuits in Nuclear Power Generating Stations

1. Overview

1.1 Scope

This standard provides direction for the design and installation of safety related electrical cable systems, including associated circuits, in nuclear power generating stations. Also provided is guidance for the design and installation of those nonsafety related cable systems that may affect the function of safety related systems.

NOTE—The term *associated circuits* is not repeated throughout the text; however, all requirements for the design and installation of cable systems for Class 1E circuits shall apply equally to associated circuits unless it can be shown by test or analysis that the associated circuits cannot affect the performance of the Class 1E circuits.

1.2 Purpose

The purpose of this standard is to identify existing standards and to establish requirements pertaining to safety related cable systems in nuclear power generating stations. Solutions are recommended for areas of concern such as fire protection, raceways, separation, cable performance requirements, and installation acceptance testing and documentation.[1]

2. Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANS 59.4, Generic Requirements for Light Water Nuclear Power Plant Fire Protection.[2]

[1] Other solutions may also be acceptable based on an engineering review of the specifics involving the installation. Each situation should be reviewed and examined on its own merits.

[2] ANS publications are available from the American Nuclear Society, 555 North Kensington Avenue, LaGrange Park, Illinois 60526, USA (http://www.ans.org).

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ASME NQA 1, Quality Assurance Program Requirements for Nuclear Power Plants.[3]

ASTM E119 Rev A, Standard Methods of Fire Tests of Building Construction and Materials.[4]

ASTM E1725, Standard Test Methods of Fire-Resistive Barrier Systems for Electrical System Components.

IEEE Std 323™, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations.[5]

IEEE Std 336™, IEEE Standard Installation, Inspection, and Testing Requirements for Power, Instrumentation and Control Equipment at Nuclear Facilities. [6]

IEEE Std 383™, IEEE Standard for Qualifying Class 1E Electrical Cables and Field Splices for Nuclear Power Generating Stations.

IEEE Std 384™, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits.

IEEE Std 400™, IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems.

IEEE Std 525™, IEEE Guide for the Design and Installation of Cable Systems in Substations.

IEEE 572™, IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations.

IEEE Std 634™, Cable Penetration Fire Stop Qualification Test. [7]

IEEE Std 835™, IEEE Standard Power Cable Ampacity Tables.

IEEE Std 848™, IEEE Standard Procedure for the Determination of Ampacity Derating of Fire-Protected Cables.

IEEE Std 946™, IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations.

IEEE Std 1143™, IEEE Guide on Shielding Practice for Low Voltage Cables.

IEEE Std 1050™, IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations.

IEEE Std 1185™, IEEE Guide for Installation Methods for Generating Station Cables.

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

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[3] ASME publications are available from the American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10016-5990, USA (http://www.asme.org).
[4] ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org).
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[7] As this standard goes to press, IEEE Std 634-2004 is approved but not yet published. Anticipated publication date is May 2005. Contact the IEEE Standards Department at 1 (732) 562-3800 for status information.

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IEEE Std 1210™, IEEE Standard Test for Determining Compatibility of Cable-Pulling Lubricants with Wire and Cable.

NEMA WC 51-2003/ICEA P-54-440, Ampacity of Cables Installed in Cable Trays.[8]

NFPA 10: Standard for Portable Fire Extinguishers.[9]

NFPA 12: Standards for Carbon Dioxide Extinguishing Systems.

NFPA 13: Standard for Installation of Sprinkler Systems.

NFPA 14: Standard for the Installation of Standpipes, Private Hydrants and Hose Systems.

NFPA 15: Standard for Water Spray Fixed Systems for Fire Protection.

NFPA 70-2002, National Electrical Code ® (NEC ®).

NFPA 72-2002, National Fire Alarm Code ®.

NFPA 90A: Standard for the Installation of Air Conditioning and Ventilating Systems.

NFPA 2001: Standard on Clean Agent Fire Extinguishing Systems.

UL 1581, Reference Standard for Electrical Wires, Cables, and Flexible Cords, 4th Edition, May 6, 2003.[10]

3. Definitions

Definitions in previous issues of this standard have been incorporated into IEEE 100, *The* Au*thoritative Dictionary of IEEE Standard Terms,* Seventh Edition and should be referenced for definitions of terms used in this standard.

4. Cable, Field Splice, and Connection Qualification

This clause establishes qualification requirements that shall be utilized in specifying cables, field splices, and connections of cable systems for Class 1E circuits.

4.1 Requirements

a) Cables, field splices, and connections shall have a qualified life for all service conditions that are postulated for the areas where they are to be used and shall be qualified in accordance with IEEE Std 323, IEEE Std 383 and IEEE Std 572.

b) All cables shall pass the vertical tray flame test described in IEEE Std 1202, except that switchboard wires, coaxial, twin axial and triaxial cables shall, as a minimum, pass the UL VW-1 flame test.

[8] NEMA publications are available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, Virginia 22209, USA.
[9] NFPA publications are available from the National Fire Protection Association, Battermarch Park, Quincy, MA 02269, USA
[10] UL standards are available for purchase from COMM-2000 1414 Brook Drive, Downers Grove, IL 60515, fax: 1-888-853-3512, phone: 1-888-853-3503, on-line: http://www.comm-2000.com.

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5. Conductor Sizing

This clause establishes cable conductor sizing requirements for various types of cable installations for Class 1E circuits. Power cables shall be sized in accordance with IEEE Std 835 and NEMA WC 51-2003/ICEA P-54-440.
Cables shall be sized to carry load current with the following special considerations:

a) Unless specific site ambient conditions or the safety analysis of the plant supports other ambient temperatures, the minimum ambient temperatures used in calculating cable ampacities shall be 30°C for buried installations and 40°C for exposed installations. Conductor size shall be selected to carry required normal, emergency overload, and short-circuit current without exceeding rated temperature of the insulation at the maximum postulated ambient temperature. Temperature extremes under design basis events shall be addressed by the qualification of the cable in accordance with IEEE Std 383.

b) Where installed cable along its route is exposed to different conditions (direct buried, sun exposure, exposed conduit, cable penetration fire stops, covered cable trays, wireways, near hot steam lines, etc.) conductor size shall be selected for the limiting condition.

c) Selection of conductor size shall also consider voltage regulation requirements, shield circulating current, and mechanical strength in addition to cable current requirements.

d) Cable ampacity (selection of correct conductor size for the load) shall also consider the appropriate de-rating (conduit/tray fill, tray covers and bottoms, ambient temperature, conductor temperature, application of fire wrap/barriers/coatings, etc) due to installation conditions.

6. Electrical Segregation

This clause establishes requirements for the electrical segregation of cable systems for Class 1E circuits according to voltage levels, signal levels, and vulnerability to electrical noise pickup. Cables installed in stacked cable trays should be arranged by descending voltage levels with the higher voltage at the top.

6.1 Cable Classifications

6.1.1 Medium-Voltage Power Cables

Designed to supply power to devices of plant auxiliary systems rated 2001 V to 15 000 V.

6.1.2 Low-Voltage Power Cables

Designed to supply power to devices of the plant auxiliary systems rated 2000 V or less.

6.1.3 Control Cables

Applied at relatively low-current levels or used for intermittent operation to change the operating status of a control device of the plant auxiliary system.

6.1.4 Instrumentation and Specialty Cables

Used for transmitting variable current or voltage signals (analog) or those used for transmitting coded information (digital). For the purposes of this standard specialty cables are types such as, thermocouple, coaxial, triaxial, twin axial, fiber-optic, etc.

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6.2 Requirements

a) Medium-voltage power cables shall be installed so that the medium-voltage cannot be impressed on any lower voltage system through a failure of cable insulation or shielding.

b) Medium-voltage power cable systems shall be designed and installed so that electric and magnetic fields will not be impressed on any lower voltage system and mutual inductive coupling will be minimized.

c) Instrumentation cables shall be installed to minimize noise pickup from adjacent circuits and equipment.

7. Separation and Identification

This clause establishes requirements for the separation and identification of cable systems for Class 1E circuits.

7.1 Requirements

Cable systems for Class 1E circuits shall meet the separation and identification requirements of IEEE Std 384.

8. Shielding and Shield Grounding

This clause establishes requirements for shielding and shield grounding of medium-voltage power and instrumentation cable systems for Class 1E circuits.

8.1 Medium-Voltage Power Cable

8.1.1 Shielding Requirements

Cables rated 5 kV and above shall be shielded, except for special application cable designs. Shielding can also be used to monitor or test cable installation for additional assurance of insulation integrity. See IEEE Std 525 for additional guidance on shielding requirements.

8.1.2 Shield Termination Requirements

Shielded cables shall be terminated with appropriate materials, including voltage stress relief devices that do not compromise the integrity of the cable's shield or insulation systems.

8.1.3 Shield Grounding Requirements

a) Cable shields and metallic sheaths/armor shall be solidly grounded at one or more points, as appropriate, so that they operate at or near ground potential.

b) Shields or sheaths that are grounded at more than one point carry induced and circulating currents. Compensation for the heating effect of the induced and circulating currents shall be considered when calculating the cable ampacity.

c) See IEEE Std 525 for additional discussion of shield grounding issues including induced shield voltages in single conductor cable (which should be kept below 25 V), shield losses that affect ampacity, and maximum lengths for single conductor cable with single-point grounding.

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8.2 Instrumentation Cable

8.2.1 Requirements

a) Cable shields shall be electrically continuous except where specific reasons dictate otherwise. When two lengths of shielded cable are connected at a terminal block, an insulated point of the terminal block shall be used for connecting the shields.

b) The shield of each cable shall be isolated to prevent stray and multiple grounds from occurring.

c) The shield shall not be used as an electrical conductor for phase or grounding purposes when it is only designed to reduce electrostatic or electromagnetic coupling.

d) The shielding criteria (for example, shield effectiveness, grounding techniques, etc.) of coaxial, triaxial, and instrumentation cables shall be in accordance with system design requirements and equipment manufacturer's instructions.

e) The method of grounding instrumentation cable shields is critical to achieving suitable electrical noise immunity for instrumentation system signal ground references. Guidance is provided in IEEE Std. 1050 and IEEE Std 1143.

9. Cable-Penetration Fire Stops, Fire Breaks, and System Enclosures

This clause establishes requirements for the selection and application of cable-penetration fire stops, cable-fire breaks, and cable-system enclosures (cocoons) for cable systems for Class 1E circuits.

9.1 General Requirements

The selection of material for use in cable-penetration fire stops, cable-fire breaks, and cable-system enclosures (cocoons) is governed by appropriate national and local fire codes and commitments in the plant’s licensing documents. In addition, the following possibilities shall be considered:

a) Compatibility between the fire-resistive materials and the cable and raceway materials.

b) Toxic or corrosive gases or fumes developed during installation or a fire.

c) Expansion that might crush insulation or jacketing during installation and operation.

d) Cable ampacity.

e) Ability to withstand pressure differentials (cable-penetration fire stops only).

f) Ability to withstand a hose-stream test that is acceptable for use on an electrical fire (cable-penetration fire stops only).

9.2 Cable-Penetration Fire Stop Requirements

a) Cable-penetration fire stops shall be provided wherever the cable system penetrates a rated fire resistive barrier.

b) The cable-penetration fire stop shall have a fire rating equal to, or greater than, the required fire rating of the barrier.

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c) The fire rating and installation of the fire stop shall be qualified in accordance with IEEE Std 634. Modifications or additions of cables through the fire stop shall not compromise the integrity of the qualified fire stop.

9.3 Cable Tray Fire Break Requirements

Cable tray fire breaks shall be installed in cable tray systems as deemed necessary by the fire hazards analyses (see ANS 59.4).

9.4 Cable-System Enclosure (Cocoon) Requirements

Cable-System Enclosures (cocoons) used to permit separation distances less than those stated in IEEE Std 384, 6.1.1.2 shall be in compliance with the requirements of IEEE Std 384, 6.1.1.3. These enclosed cable systems are also referred to as fire-protected cable systems. Refer to IEEE Std 848 for guidance concerning ampacity derating for fire-protected cables.

10. Fire-Detection Systems

This clause establishes requirements for the selection and application of fire-detection systems for cable systems for Class 1E circuits. The application requirements are as follows:

a) Automatic fire-detection devices shall be installed in accordance with NFPA 72, in areas of high cable concentration.

b) Fire-detection systems shall be electrically supervised to comply with requirements of NFPA 70, Article 760 and NFPA 72.

11. Fire-Extinguishing Systems

This clause establishes requirements for the selection and application of fire-extinguishing systems protecting cable systems for Class 1E circuits.

11.1 Fixed Fire-Extinguishing System Application Requirements

a) A fire hazard analysis (see ANS 59.4) shall be conducted to determine if fixed automatic fire-extinguishing systems are necessary for areas of high cable concentration and spaces below raised floors or above false ceilings containing exposed cables.

b) When the analysis in (a) determines that fixed extinguishing systems are required, automatic water-spray systems designed in accordance with NFPA 13, or NFPA 15 shall be used. If the activation of fixed automatic water-spray discharge could cause undesirable consequences to sensitive equipment that would negate single failure criteria, such equipment shall be protected from the spray and sealed against potential water damage due to water traveling along the cable system. If the equipment cannot be protected, an extinguishing system utilizing another extinguishing agent, such as carbon dioxide (NFPA 12) or a clean agent (NFPA 2001), shall be provided in accordance with the appropriate NFPA standard. These alternative gaseous suppression systems can also be used for spaces below raised floors.

c) System operational testing shall be in accordance with NFPA standards.

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d) Fixed fire-extinguishing systems, whether manual or automatic, shall alert control-room operators of system operation or of any abnormal condition. Fire-extinguishing systems shall be electrically supervised to comply with the requirements of NFPA 72, and Class 1 circuits as defined in NFPA 70, Article 725.

e) In areas where forced ventilation would circulate smoke or a gaseous extinguishing agent, or both, to other areas, mechanical ventilation systems shall be shut down prior to system actuation, and fire dampers shall be closed by mechanical or electrical release devices prior to fire-protection system discharge.

11.2 Portable Fire-Extinguishing Requirements

a) Portable fire extinguishers shall be located throughout the plant in accordance with NFPA 10 to provide adequate coverage of all cable systems for Class 1E circuits.

b) For personnel safety, water-base or water solution portable fire extinguishers, unless specifically listed and tested for that application, shall not be used on fires involving energized cables.

11.3 Standpipe and Hose-Station Requirements

a) Standpipe and hose stations shall be located throughout the plant in accordance with NFPA 14 to provide adequate coverage of all cable systems for Class 1E circuits.

b) Hose stations shall be provided with nozzles that are approved by a national test laboratory for use near energized electrical equipment.

12. Handling and Installation

This clause establishes requirements for the construction methods and materials for the handling and installation of cable systems for Class 1E circuits.

12.1 General Requirements

a) The installation and inspection of cable systems for Class 1E circuits shall meet the requirements of IEEE Std 336 and IEEE Std 1185.

b) Cables shall be installed in raceway systems that are qualified for the seismic design basis events.

c) Cables shall be installed so that the independence of Class 1E equipment and circuits is maintained in accordance with IEEE Std 384.

d) The cable raceway system shall be permanently identified prior to installation of cable. Identification of cables and raceways shall meet the requirements of IEEE Std 384.

e) Cable field splice types and locations shall be recorded and filed for plant maintenance reference. See Clause 14 for documentation procedure requirements. To facilitate locating and maintaining splices, it is good practice to place splices in an enclosure.

12.2 Storage Requirements

a) During storage, and especially after cutting, the ends of cables shall be sealed against moisture and contamination with approved sealing methods.

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b) Reels shall be stored and handled in accordance with the manufacturers' recommendations to avoid damage and deterioration of the cable.

12.3 Cable-Installation Requirements

a) Cables shall be installed in raceway systems that have suitable pull points (boxes, manholes, etc.) so that maximum allowable pulling tensions and sidewall pressures are not exceeded.

b) Cables shall be installed in raceway systems that have adequately sized bends, boxes, and fittings so that cable manufacturer's allowable bending radii for cable installations are not violated.

c) Where steel conduits or sleeves are used, all phases of three phase ac circuits and both legs of single-phase ac circuits shall be installed in the same conduit or sleeve to minimize induction heating.

d) For an unprotected portion of dc systems from the battery to the switchboard it is suggested that the positive and negative legs of the circuits be routed in separate, preferably rigid non-metallic conduits to reduce the possibility of polarity to polarity faults. Refer to Clause 7 of IEEE Std 946 for additional guidance.[11]

e) Cables shall be installed so that the movement of mechanical systems will not affect the integrity of the cable system.

f) Support equipment, piping, instrument tubing or other non-electrical facilities shall not be installed in raceways designed to carry cables unless the raceway system is specifically designed to accommodate the additional loads and special precautions are taken to protect the cables against the effects of failure of the supported devices and from their contents.

g) Pulling instructions for all cables shall follow the cable manufacturers' recommendations.

h) Cables shall not be pulled around sharp corners or obstructions.

i) Cables shall not be pulled at temperatures below the cable manufacturers' recommended minimum pulling temperature. See IEEE Std 1210.

j) Cable pulling lubricants shall be compatible with the cable jackets.

k) Bare wire rope shall not be used to pull cables in conduits.

l) Medium-voltage power cables shall be properly sealed before and after installation. All other cables shall be properly sealed before and after installation in wet locations.

m) The cable end within a pulling device shall be removed from the cable prior to termination.

n) When the cable pull is complete, cable manufacturers' recommendations for bending radius shall be followed for permanent training.

o) Protection (i.e., top covers) of the cables shall be provided on trays at floor levels and at locations where there is likelihood of physical damage.

p) For additional guidance on cable installation methods and cable-pulling lubricants refer to IEEE Std 1185 and IEEE Std 1210, respectively.

[10]There are no standards mandating how the unprotected leads of batteries must be installed. Different practices, such as installing the battery leads in the same conduit, are based on evaluation of risk and concerns for increase of circuit reactance due to the separation of battery leads and should be evaluated.

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12.4 Raceway—Cable-Fill Requirements

a) The number of cables in any tray shall be limited by cable ampacity requirements, and the structural capability of the tray and its supports.

b) A cable tray may be filled to its specified design calculated depth. More cable shall not be added to the same tray unless an inspection and an analysis has been made to determine that additional cables can be safely installed in the same tray without exceeding the thermal ratings of the all cables.

c) An analysis shall be made to determine the range of weight of cable loading and this figure shall be used in the seismic analysis of the cable-tray support system. These loadings shall not be exceeded by placing more cables in the tray than allowed by the seismic design.

d) Conduit fill shall be in accordance with NFPA-70, Ch 9, Table 1, unless an analysis has been made that indicates that additional cables can be installed.

12.5 Requirements for Supporting Cables in Vertical Runs

a) Cable terminals shall not be subjected to excessive tensions resulting from vertical cable runs.

b) Vertically run cables shall be secured, as required, by support devices installed at intervals in the raceway systems. In vertical trays, cables shall also be secured at intermediate locations as necessary to keep all cables completely within and secured to the tray.

13. Acceptance Testing of Installed Cables

This clause establishes requirements for testing of cables including field splices and connectors after installation of cable systems for Class 1E circuits. The purpose of the tests is to verify that major cable insulation damage did not occur during storage and installation. It should be noted that these tests may not detect damage that may eventually lead to cable failure in service. Damage to cable jackets or insulation shields on medium-voltage cable or to cable jackets or the insulation on low-voltage cable are examples of cable damage that may not be detected by these tests. These tests will also not detect environmental problems, such as proximity to hot pipes, which can lead to cable failure. Guidance on field testing and evaluation of shielded power cables can be found in IEEE Std 400 and in standards under development, such as P400.1, which will deal with field testing of laminated type cables.

13.1 Requirements

a) Testing of installed cable systems shall meet the requirements of IEEE Std 336.

b) Medium voltage power cables should be hi-pot tested prior to equipment connection. The method of hi-pot testing should be appropriately determined. Other testing methods such as VLF can be performed in lieu of hi-pot testing if trending of service aged cables is desired.

c) Low-voltage cables shall be either insulation-resistance tested prior to connecting cables to equipment or functionally tested (at equipment operation voltage) as part of the checkout of the equipment system.

d) Cable test results shall be recorded and filed for future plant reference.

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14. Documentation

This clause establishes documentation requirements for the design and installation of cable systems for Class 1E circuits.

14.1 Requirements

a) Documents, as required, shall be prepared as work is performed to furnish evidence of the quality of items and of activities affecting quality.

b) Documents shall include the results of reviews, inspections, tests, and materials analysis. The documents shall also include, as appropriate, data such as qualifications of procedures, equipment, computer programs, and personnel. Documents shall, as a minimum, identify the date of review, inspection or test, identity of the reviewer, inspector, data recorder, the type of review or observation, the results, the acceptability, and the actions taken in connection with any deficiencies noted.

c) The collection, storage, and maintenance of documents shall meet the requirements of ASME NQA 1.

d) Certificates of conformance shall meet the requirements of ASME NQA 1.

e) Design, installation and protection requirements not included in this standard shall be documented in accordance with the specific documentation requirements of the IEEE standards referenced in Clause 2 of this standard.

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Annex A

(informative)

Bibliography

[B1] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.[12]

[B2] IEEE Std 576™-2000, IEEE Recommended Practice for Installation, Termination, and Testing of Insulated Power Cable as Used in Industrial and Commercial Applications.

[B3] IEEE Std 628™-2001, IEEE Standard Criteria for the Design, Installation, and Qualification of Raceway Systems for Class 1E Circuits for Nuclear Power Generating Stations.

[B4] NRC Supplement 1 to Generic Letter 86-10, Implementation of Fire Protection Requirements, March 25,1994.

[12] IEEE publications are available from the Institute of Electrical and Electronic Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org).

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