



IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV

IEEE Power and Energy Society

Developed by the
Insulated Conductors Committee

IEEE Std 404™-2022
(Revision of IEEE Std 404-2012)



STANDARDS

IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV

Developed by the

Insulated Conductors Committee
of the
IEEE Power and Energy Society

Approved 8 November 2022

IEEE SA Standards Board

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Abstract: Electrical ratings and test requirements of cable joints used with extruded and laminated dielectric shielded cable rated in preferred voltage steps from 2.5 kV to 500 kV are established in this standard. In addition, test requirements for joint metallic-shield and jacketing components are defined. A variety of common joint constructions are also defined. This standard has been designed to provide uniform testing procedures that can be used by manufacturers and users to evaluate the ability of underground power cable joints, and associated metallic-shields and jacketing components, to perform reliably in service.

Keywords: basic insulation level (BIL), cable joints, dielectric integrity tests, extruded dielectric cable, IEEE 404™, laminated dielectric cable, sheath/shield sectionalizers, transition joints, withstand voltage

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Introduction

This introduction is not part of IEEE Std 404-2022, IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV.

This standard supersedes IEEE Std 404-2012, IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV.

This standard provides manufacturers and users with a consistent set of qualification test requirements for all cable joints. It also provides production test requirements for many cable joints used on extruded dielectric cables. Material properties and sampling rates are included for joint designs not easily production tested in their final form.

This revision of the standard provides closer harmonization to international standards for those cable joints used on extruded dielectric cables rated 69 kV and above.

It provides more applicable testing protocols to verify appropriate joint operation in the field for extruded dielectric cable joints in a joint-series. A joint series is a family of joints designed and manufactured to cover a wide range of cable including various conductor sizes and materials as well as various extruded insulation thicknesses and materials.

It changes the format of the design test sequence tables to provide a clearer and more concise format to eliminate interpretation errors.

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Joints Rated 2.5 kV to 500 kV

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1. Overview

1.1 Scope

This standard establishes electrical ratings and test requirements of cable joints used with extruded and laminated dielectric shielded cables rated in preferred voltage steps from 2.5 kV to 500 kV. In addition, it defines test requirements for joint jacket seal devices and joint metallic-shield devices.-

This standard also defines a variety of common joint constructions.

Joints that connect more than two cables or connect cables with two different conductor sizes are not covered by this standard. However, manufacturers and users are encouraged to use appropriate parts of this standard to evaluate these joints.

1.2 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*).

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.

AEIC CS1, Specification for Impregnated Paper-Insulated Metallic-Sheathed Cable, Solid Type.^{8†}

AEIC CS2, Specification for Impregnated Paper and Laminated Paper Polypropylene Insulated Cable, High Pressure Pipe Type [Cable](#).

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.

^{8†}AEIC publications are available from the Association of Edison Illuminating Companies, 600 N. 18th Street, P.O. Box 2641, Birmingham, AL 35291-0992, USA ([http:// www .aeic .org/](http://www.aeic.org/)). AEIC publications are also available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112-5704, USA ([https:// global .ihs .com/](https://global.ihs.com/)).

AEIC CS3, Specification for Impregnated-Paper-Insulated Metallic Sheathed Cable, Low Pressure Gas-Filled Type.

AEIC CS4, Specification for Impregnated-Paper-Insulated Low and Medium Pressure Self-Contained Liquid Filled Cable.

AEIC CS8, Specification for Extruded Dielectric Shielded Power Cables Rated 5 Through 46 kV.

AEIC CS9, Specification for Extruded Insulation Power Cables and Their Accessories Rated Above 46 kV Through 345 kV ac.

ANSI C119.4, Electric Connectors—Connectors to Use Between Aluminum-to-Aluminum or Aluminum-to-Copper Conductors Designed for Normal Operation at or below 93 °C and Copper-to-Copper Conductors Designed for Normal Operation at or Below 100 °C.^{9 2}

ASTM D149-~~97a~~, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies.^{10 3}

ASTM D412-~~98~~, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers Tension.

ASTM D991-~~89~~, Standard Test Method for Rubber Property-Volume Resistivity of Electrically Conductive and Antistatic Products.

ASTM D4325-~~98~~, Standard Test Methods for Nonmetallic Semi-Conducting and Electrically Insulating Rubber Tapes.

ASTM D4496-~~94~~, Standard Test Method for DC Resistance or Conductance of Moderately Conductive Materials.

^{9 2}—ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA ([https:// www .ansi .org/](https://www.ansi.org/)).

^{10 3}—ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA ([https:// www .astm .org/](https://www.astm.org/)).

ICEA P-32-382, Short-Circuit Characteristics of Insulated Cable. ¹¹ 4

ICEA P-45-482, Short-Circuit Performance of Metallic-shields and Sheaths on Insulated Cable.

IEEE Std 4TM, IEEE Standard ~~Techniques~~ for High-Voltage Testing. [Techniques](#). ^{12,13} 5-6

~~IEEE Std 82TM, IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors.~~

[IEEE Std 82TM-2002, IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors.](#)¹⁴

IEEE Std 575TM-1988, IEEE Guide for ~~the Application of Sheath~~ Bonding [Shields and Sheaths of Methods for Single-Conductor Power Cables Rated 5 kV through 500 kV.](#)¹⁵ ~~and the Calculation of Induced Voltages and Currents in Cable Sheaths.~~⁷⁻

IEEE Std 592TM, IEEE Standard for Exposed Semiconducting Shields on High-Voltage Cable Joints and Separable Insulated Connectors.

IEEE Std C37.09TM, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated [Maximum Voltage Above 1000 V.](#) ~~on a Symmetrical Current Basis.~~

¹¹ ICEA publications may be purchased via the link under Techstreet Store (<https://www.techstreet.com/searches/22339588>) or IHS Markit (<https://ihsmarkit.com/search/results.html?search=icea>).

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¹⁴ IEEE Std 82-2002 has been withdrawn; however, copies can be obtained from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹⁵ 7 IEEE Std 575-1988 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<https://global.ihs.com/>).

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. ^{16 8-}

3.1 Cable joint categories

Cable joints are generally described by one of the categories that follow. These descriptive categories are provided only for convenience. They are not intended to cover all possible joint constructions. Some joint constructions may incorporate characteristics of two or more of the design categories listed.

extruded: A joint in which both cables are insulated with extruded dielectric materials rated 2.5 kV to 500 kV.

laminated: A joint in which both cables have a dielectric that consists of fluid-impregnated paper or paper/ synthetic laminated tape, or varnished cloth.

transition: A joint that connects an extruded dielectric cable to a laminated dielectric cable.

3.2 Joint constructions

field vulcanized: A joint constructed in the field using externally applied heat and pressure to cross-link the joint polymeric materials.

filled: A joint consisting of an outer shell that is filled with an insulating material to occupy the space around the individual insulated conductor(s).

¹⁶ *IEEE Standards Dictionary Online* is available at: [http:// dictionary .ieee .org](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.

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

heat-shrink: A joint provided to the end user as one or more expanded polymeric components that undergo thermally activated recovery when heated to an appropriate temperature. Production electrical testing cannot be performed on this type of joint because the stress control, insulation, and shield layers are not integrated during the molding or extrusion process.

multi-component cold-shrink: A joint provided to the end user as two or more expanded components that are applied over a prepared cable and reduced in diameter without the use of heat by removal of the supporting cores. Production electrical testing cannot be performed on this type of joint because the stress control, insulation, and shield layers are not integrated during the molding or extrusion process. *See also:* **single-component cold-shrink.**

premolded: A joint that is factory molded in the shape that it will take when installed. Installation is performed by sliding the joint over a prepared cable. The use of heat is not a part of the installation procedure. Production electrical testing can be performed on this type of joint because the stress control, insulation, and shield layers are integrated during the molding process.

single-component cold-shrink: A joint provided to the end user as an expanded single component device that is applied over a prepared cable and reduced in diameter without the use of heat by removal of a supporting core. Production electrical testing can be performed on this type of joint because the stress control, insulation, and shielding layers are integrated during the molding or extrusion process. *See also:* **multi-component cold-shrink.-**

taped: A joint constructed in the field with the use of one or more tapes that are applied over the cable layers. Heat may or may not be applied as part of the installation procedure. Production electrical testing cannot be performed on this type of joint.

3.3 Other terms

family of joints: A group of two or more joints designed for use on extruded and/or laminated dielectric cables rated 2.5 kV to 46 kV. All joints within the family shall have the same insulation and conductive materials, conductive shield thickness, and maximum electrical stresses within the insulation and along the joint/cable interfaces.

fingerprint tests fingerprinting: Tests made to establish and subsequently confirm the properties of materials or components used in cable accessories. The samples used for the initial tests shall be from the same batch as those used in the accessory design tests. For the purposes of this standard, this only applies to field-fabricated joint constructions such as heat shrinkable, multi-component cold-shrink joints, field vulcanized, and taped joints.-

sectionalizer: A sectionalizer is used to minimize induced current in the cable sheath/shield by electrically interrupting the semiconducting shield and conducting metallic sheath or shield of the two cable lengths that are joined together. Sectionalizers are described in IEEE Std 575-1988.

splice body: The component in a power cable joint kit that provides the dielectric insulation and may or may not contain the stress control and shielding as integral components.

4. Service conditions

Today's cable joint designs are considered suitable for use under the following service conditions. However, it should be understood that this list was compiled based more on user and manufacturer experience than on specific requirements of this standard. It is not meant, in any way, to imply that any or all of these conditions are fully verified in this standard. For specific questions regarding these or other service conditions, the manufacturer should be consulted.

- a) Alternating currents
- b) In-air, including exposure to direct sunlight
- c) Buried in earth
- d) Intermittently or continuously submerged in water at a depth not exceeding 7 m (23 ft)
- e) Environmental temperatures within the range of $-30\text{ }^{\circ}\text{C}$ to $+50\text{ }^{\circ}\text{C}$ for joints used on fluid-filled and laminated dielectric cables. All other cable joints are suitable for use at temperatures within the range of $-40\text{ }^{\circ}\text{C}$ to $+65\text{ }^{\circ}\text{C}$
- f) In underground chambers, tunnels, conduits, manholes, and vaults

- g) Approximately horizontal installation of laminated dielectric joints rated 69 kV to 500 kV

5. Ratings

5.1 Voltage

The voltage ratings and test levels of cable joints shall be in accordance with Table 1 through Table 4.

5.2 Current and temperature

The current and temperature ratings of the cable joint shall be equal to or greater than those of the cable for which it is designed as verified in 7.5, 7.6, 7.11, and the basic insulation level (BIL) test conducted at emergency operating temperature in 7.4.3. For transition joints, the maximum temperature rating is based on the cable with the lower temperature rating.

Table 1— Voltage ratings and design test levels for extruded dielectric cable joints rated 2.5 kV to 46 kV

Voltage rating phase-to-phase, U (kV rms) ^a	Voltage rating phase-to-ground, U_0 (kV rms) ^b	Basic insulation level (BIL) (kV crest)	AC voltage design tests			Column D 1-min AC withstand voltage (kV rms)	Minimum partial discharge voltage level, $1.5 U_0$ (kV rms)
			Column A cyclic aging voltage (kV rms)	Column B 5-min at $4.5 U_0$ (kV rms)	Column C 5 h at $3.5 U_0$ (kV rms)		
2.5	1.4	60	4	6	5	9	2
5	2.9	75	9	13	10	18	4
8	4.6	95	14	21	16	23	7
15	8.7	110	26	39	31	35	13
25	14.4	150	43	65	50	52	22
35	20.2	200	61	91	71	69	30
46	26.6	250	67 ^c	100 ^c	80 ^c	80	40

^a To obtain test values for voltage classes that are not listed, use linear interpolation between the next higher and lower listed values and round off to the nearest whole kilovolt.

^b For grounded systems.

^cTheses values are interpolated between 35 kV and 69 kV class and not as multipliers of U_0 .

Table 2— Voltage ratings and design test levels for extruded dielectric cable joints rated 69 kV to 500 kV

Voltage rating phase-to-phase, U (kV rms) ^a	Voltage rating phase-to-ground, U_0 (kV rms) ^b	Basic insulation level (BIL) (kV crest)	AC voltage tests		Minimum partial discharge voltage level, $1.5 U_0$ (kV rms)
			Column A 15 min withstand test at $3 U_0$ (kV rms)	Column B 6 h HV time test at $2.5 U_0$ (kV rms)	
69	39.8	350	120	100	60
115	66.4	550	200	166	100
138	79.7	650	240	200	120
161	93.0	750	280	232	140
230	132.8	1050	400	332	200
345	199.2	1300	600	500	300
500	288.7	1550	870	725	435

^aTo obtain test values for voltage classes that are not listed, use linear interpolation between the next higher and lower listed values and round off to the nearest whole kilovolt.

^bFor grounded systems.