IEEE Std 48-1996(R2003)
(Revision of IEEE Std 48-1990)

IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV

Sponsor

Insulated Conductors Committee
of the
IEEE Power Engineering Society

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Abstract: All indoor and outdoor cable terminations used on alternating-current cables having laminated or extruded insulation rated 2.5 kV through 765 kV are covered, except for separable insulated connectors, which are covered by IEEE Std 386-1995.
Keywords: accelerated contamination testing, correction factors, dielectric field tests, environmental exposure, nonstandard service conditions, rating, solar radiation, standard service conditions, test requirements, ultraviolet light

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Introduction

(This introduction is not part of IEEE Std 48-1996, IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV.)

This standard supersedes IEEE Std 48-1990, IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations.

Several definitions have been added to reflect use of polymeric designs and to differentiate between various environments encountered. To clarify test procedures, Class 1 terminations have been divided into three classes: Class 1A for extruded dielectric cable, Class 1B for laminated dielectric cable, and Class 1C for pressure-type systems.

Partial discharge requirements for laminated cable terminations have been replaced by ionization test requirements, which are more applicable for laminated cable constructions. Retesting is not intended now as the partial discharge is more difficult. Reflecting cable voltage trends, table 1 contains test requirements up to 765 kV for laminated dielectric terminations and 230 kV for solid dielectric cable terminations.

Clause 9 has been expanded to include a pollution severity guide to assist the user to define a particular environment and help determine type and creepage length needed. Effects of solar radiation are addressed and test methods are recommended. The user is also advised to refer to the manufacturer for contamination testing, particularly if difficult environments are encountered.

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Contents

IEEE Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV Through 765 kV

1. Scope

This standard covers all indoor and outdoor cable terminations used on alternating-current cables having laminated or extruded insulation rated 2.5 kV through 765 kV, except separable insulated connectors, which are covered by IEEE Std 386-1995, IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V [B16].[1]

Cable terminations and component parts shall be capable of withstanding the tests specified in this standard.

2. References

This standard shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

IEC 270-1981, Partial Discharge Measurements.[2]

IEEE Std 4-1995, IEEE Standard Techniques for High-Voltage Testing (ANSI).[3]

IEEE Std 82-1994, IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors (ANSI).

IEEE Std 835-1994, IEEE Standard Power Cable Ampacity Tables (ANSI).

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[1]The numbers in brackets correspond to those of the bibliography in clause 10.

[2]IEC publications are available from IEC Sales Department, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

3. Definitions

The definitions and terminology used herein apply specifically to cable terminations treated in this standard. For additional definitions, see [Bl5].

3.1 apparatus termination: A termination designed for use in sealed enclosures where the external dielectric strength is dependent upon liquid or special gaseous dielectric and where the ambient temperature of the medium immediately surrounding the termination may reach 55 °C.

3.2 breakdown: A disruptive discharge occurring through a dielectric.

3.3 chalking: The powdered surface on the polymeric insulator consisting of particles of filler resulting from ultraviolet exposure or leakage current activity.

3.4 cracking: Rupture of the polymeric insulator material to depths equal to or greater than 0.1 mm.

3.5 crazing: Surface microfractures of the insulator material to depths less than 0.1 mm resulting from ultraviolet exposure.

3.6 design tests: Tests made by the manufacturer to obtain data for design or application, or to obtain information on the performance of each type of high-voltage cable termination.

3.7 external connector (aerial lug): A connector that joins the external conductor to the current-carrying parts of a cable termination.

3.8 field tests: Tests that may be made on a cable system (including the high-voltage cable terminations) by the user after installation, as an acceptance or proof test.

3.9 flashover: A disruptive discharge around or over the surface of an insulating member, between parts of different potential or polarity, produced by the application of voltage wherein the breakdown path becomes sufficiently ionized to maintain an electric arc.

3.10 high-voltage cable termination: A device used for terminating alternating-current power cables having laminated or extruded insulation rated 2.5 kV and above, which are classified according to the following:

a) Class 1 termination: Provides electric stress control for the cable insulation shield terminus; provides complete external leakage insulation between the cable conductor(s) and ground; and provides a seal to the end of the cable against the entrance of the external environment and maintains the operating design pressure, if any, of the cable system. This class is divided into three types:
    - Class 1A: For use on extruded dielectric cable
    - Class 1B: For use on laminated dielectric cable
    - Class 1C: Expressly for pressure-type cable systems

b) Class 2 termination: Provides electric stress control for the cable insulation shield terminus, and provides complete external leakage insulation between the cable conductor(s) and ground.

c) Class 3 termination: Provides electric stress control for the cable insulation shield terminus.

NOTE—Some cables below 15 kV do not have an insulation shield. Terminations for such cables would not be required to provide electric stress control. In such cases, this provision would not be part of the definition.

3.11 indoor termination–dry: A termination intended for use where it is protected from solar radiation and precipitation and not subject to periodic condensation, or other excessive humidity (90% RH or more). May be installed in air conditioned or heated areas.

3.12 indoor termination–wet: A termination intended for use where it is protected from direct exposure to both solar radiation and precipitation, but is subjected to climatic conditions that can cause condensation onto the termination surfaces.

3.13 outdoor termination: A termination intended for use where it is not protected from direct exposure to either solar radiation or precipitation. These are Class 1A, 1B, or 1C terminations. Class 2 terminations may also qualify.

3.14 outdoor termination–polluted: A termination intended for use where it is not protected from direct exposure to either solar radiation or precipitation, and is exposed to nonstandard (unusual) service conditions such as extreme seacoast salt deposits, solid precipitates, etc. Often requires extra maintenance such as washing or extra creepage length.

3.15 partial discharge (corona) extinction voltage: The voltage at which partial discharge (corona) is no longer detectable on instrumentation adjusted to a specified sensitivity, following the application of a specified higher voltage.

3.16 pressure-type termination: A Class 1C termination intended for use on positive pressure cable systems.

- Single pressure zone termination: A pressure-type termination intended to operate with one pressure zone.
- Multipressure zone termination: A pressure-type termination intended to operate with two or more pressure zones.

3.17 radio influence voltage (RIV): The radio noise appearing on conductors of electric equipment or circuits, as measured using a radio-noise meter as a two-terminal voltmeter in accordance with specified methods.

3.18 routine tests: Tests made on each high-voltage cable termination or upon a representative number of devices, or parts thereof, during production for purposes of quality control.

3.19 termination insulator: An insulator used to protect each cable conductor passing through the device and provide complete external leakage insulation between the cable conductor(s) and ground.

3.20 weathersheds: The external part of the termination insulator that protects the core and provides the wet electrical strength and leakage distance.

3.21 withstand test voltage: The voltage that the device must withstand without flashover, disruptive discharge, puncture, or other electrical failure when voltage is applied under specified conditions.

NOTE—For power frequency voltages, the values specified are RMS values and for a specified time. For lightning or switching impulse voltages, the values specified are crest values of a specified wave. For direct voltages, the values specified are average values and for a specified time.

4. Service conditions

4.1 Standard service conditions

Devices conforming to this standard shall be capable of successful operation under the following service conditions. Refer to [Bl4] for more information.

4.1.1 Physical conditions

a) Temperature

  1) The temperature of the medium in direct contact with the termination shall not be less than –30 °C, nor more than +40 °C.

  2) For apparatus terminations, the temperature of the medium in direct contact with the termination (ambient inside enclosure) shall not exceed 55 °C. The devices designed for this service will be connected to the equipment bus which may, at full load, reach a maximum temperature of 85 °C.

b) The altitude shall not exceed 1000 m (3300 ft) where atmospheric air is part of the thermal or dielectric system or both.

4.1.2 System conditions

The nominal power system frequency is not less than 48 Hz nor more than 62 Hz.

4.2 Nonstandard service conditions

The following service conditions may require special consideration in design or application of the cable terminations, and should be called to the attention of the manufacturer.

4.2.1 Physical conditions

a) Temperature of the surrounding medium (ambient temperature) less than –30 °C and more than +40 °C

b) Altitude exceeding 1000 m (3300 ft) where atmospheric air is part of the thermal or dielectric system or both (see clause 9)

c) Damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture or dripping water, salt on roadways, etc.

d) Unusual mechanical conditions such as vibration, shock, cantilever loading, wind loading, icing, etc.

e) Unusual transportation or storage conditions

f) Unusual space limitations

g) Unusual internal pressures

h) Unusual maintenance difficulties

4.2.2 Electrical conditions

— Power frequencies less than 48 Hz or greater than 62 Hz

5. Rating

The rating of a high-voltage cable termination shall include the following items, where applicable:

a) *BIL (basic lightning impulse insulation level).* The crest value of a lightning impulse voltage of a specified wave shape, which the high-voltage cable termination is required to withstand under specified conditions.

b) *BSL (basic switching impulse insulation level).* The crest value of a switching impulse voltage of a specified wave shape, which the high-voltage cable termination is required to withstand under specified conditions.

c) *Insulation class.* The nominal phase-to-phase operating voltage of a three-phase cable system where the device may be applied, which reflects the associated design tests and impulse insulation levels.

NOTE—High-voltage cable terminations may be applied on other than three-phase circuits if the rated maximum design voltage to ground is not exceeded.

d) *Maximum and minimum cable conductor diameter.* The largest and smallest cable conductor diameters that the high-voltage cable termination is designed to accommodate without special modifications.

e) *Maximum and minimum cable insulation diameter.* The largest and smallest diameters over the insulation of round conductor cables, as measured by a circumferential tape, that the high-voltage cable termination is designed to accommodate without special modifications.

f) *Maximum design voltage to ground.* The maximum voltage at which the high-voltage cable termination is designed to operate continuously under normal conditions.

NOTE—It is not intended that this maximum voltage limit be applied to transient overvoltages or unusual service operating conditions where the system voltage may exceed those values for only short periods of time.

g) *Rated internal pressure.* The nominal internal pressure for which the termination is designed to operate when this pressure is greater than one atmosphere absolute under standard conditions.

NOTE—Regarding continuous current rating (ampacity), the application of various types of cable terminations requires engineering consideration as to the ampacity of the completed installation. A cable termination by itself cannot be assigned a design or nominal current or ampacity rating since this parameter is completely dependent upon the type and material of the cable conductor, the thickness and type of cable insulation, the maximum allowable cable conductor temperature for the type of cable insulation involved, and the anticipated maximum ambient temperature of the medium surrounding the cable termination.

IEEE Std 835-1994[4] will indicate the wide range of ampacities permitted under the various conditions anticipated in service with different voltage ratings and maximum cable conductor temperature limitations.

The termination of high-voltage cables generally requires the addition of insulating materials for dielectric purposes, which usually increase the thermal resistance to heat flow from the cable conductor to the surrounding air or other medium. The types and amounts of dielectric or other materials are generally a function of the type of cable being terminated, the insulation class, the range of cable sizes that can be accommodated, and operating service conditions.

The supplier of cable terminating devices or material should be consulted for the ampacity of the design for the intended application with a specific type and size of cable.

It is recommended that the ampacity of the cable termination be limited (barring any other terminating material limitation) by a hot spot cable conductor temperature within the termination zone equal to the cable conductor temperatures established for the particular cable insulation involved.

[4]Information on references can be found in clause 2.

6. Product markings

The following information is suggested for Class 1, 2, and 3 termination labels, where required or specified by the user:

a) Manufacturer's name, type, designation number, manufacturing date, or date code
b) IEEE termination class number
c) Insulation class
d) Maximum design voltage to ground
e) Maximum and minimum cable conductor size
f) Maximum and minimum cable insulation diameter
g) BIL
h) Rated internal pressure (gauge), when applicable.

NOTE—Any information not included on the product shall be included in product installation instructions.

7. Test requirements

7.1 Design tests

To comply with this standard, high-voltage cable terminations shall successfully pass the following tests as noted.

7.1.1 Dielectric tests

See note 10 of table 1, or 4.1.

a) Power frequency voltage 1 min dry withstand test in accordance with column 3 of table 1 or 2 and 8.4.1.1 (all classes).

b) Power frequency voltage 10 s wet withstand test in accordance with column 4 of table 1 or 2 and 8.4.1.2. This test is made on outdoor terminations only (Classes 1 and 2 when applicable).

c) Power frequency voltage 6 h dry withstand test in accordance with column 5 of table 1 or 2 and 8.4.1.3 (all classes).

d) Power frequency partial discharge (corona) extinction voltage test in accordance with column 8 of table 2 and 8.4.1.5 for extruded dielectric cable terminations.

   Ionization factor measurements are to be used for laminated dielectric cable terminations in accordance with column 8 of table 1, 8.4.1.6, and table 6.

   Power frequency RIV testing in accordance with column 7 of table 1 or 2 and 8.4.1.4 if the termination is for use on other cable (all classes) or if there is a question on external metallic hardware affecting the radio influence voltage if the termination is for use on any other cable (all classes).

e) Lightning impulse voltage withstand test in accordance with column 9 of table 1 or 2 and 8.4.1.7 (all classes).

f) Switching impulse voltage wet withstand test (if applicable) in accordance with column 10 of table 1 and 8.4.1.8 (all classes).

g) Direct voltage 15 min dry withstand test in accordance with column 11 of table 1 or 2 and 8.4.1.9 (all classes).

h) Cyclic aging test in accordance with 8.4.2 (all classes).

NOTE—Some Class 3 terminations, especially above 15 kV, may not meet impulse requirements in column 9 of table 1 or 2, usually because of inadequate creepage length. If so, actual values shall be agreed upon by manufacturer and user, but must meet the BIL of the equipment connected to the termination.

Table 1—Standard dielectric tests for high-voltage laminated dielectric cable terminations assembled and ready for service

Insulation class (kV) (12) Column 1	Max design voltage to ground (kV) (13) Column 2	1 min Dry withstand (kV RMS) Column 3	10 s Wet withstand (3) (kV RMS) Column 4	6 h Dry withstand (kV RMS) Column 5	Cyclic aging dry (kV RMS) Column 6	Radio influence voltage dry (μV) Column 7	Max ionization factor % all voltage classes Column 8	Lightning impulse (BIL) dry withstand (kV crest) Column 9	Switching impulse (BSL) (3) wet (dry) withstand (kV crest) Column 10	Direct voltage test (9) 15 min dry withstand (kV avg) Column 11
2.5	1.6	20	20	10	3	50	See table 5 and 8.4.1.6	60	—	40
5	3.2	25	25	15	6	50		75	—	50
8.7	5.5	35	30	25	10	50		95	—	65
15	9.5	50	45	35	17	50		110	—	75
25	16	65	60	55	29	100		150	—	105
34.5	22	90	80	75	40	150		200	—	140
46	29.5	120	100	100	53	200		250	—	170
69	44	175	145	120	80	300		350	—	245
115	73	205	190	160	133	400		450	—	275
120	73	260	230	190	140	450		550	—	320
138	88	310	275	210	160	500		650	—	355
161	102	365	315	250	186	500		750	—	395
230	146	390	380	320	265	500		900	—	450
230	146	460	445	320	265	500		1050	—	510
345	220	520	—	440	300	500		1175	(900)	555
345	220	575	—	440	300	500		1300	825	600
345	220	575	—	440	300	500		1300	900	600
500	318	575	—	440	435	500		1300	(1100)	600
500	318	690	—	440	435	500		1550	1050	700
500	318	750	—	575	435	500		1675	1110	745
500	318	750	—	575	435	500		1675	1175	745
765	486	1300	—	755	663	500		2075	1435	965
765	486	1300	—	755	663	—		2175	1505	965

NOTES TO TABLE 1
1—Power frequency includes any frequency from 48 Hz to 62 Hz.
2—All withstand values are test voltages without negative tolerance but may include an atmospheric correction factor.
3—Indoor cable terminations are not subjected to the wet test. Indoor terminations rated 345 kV and higher shall withstand dry switching impulse voltage tests as noted in brackets in column 10.
4—The required lightning and switching impulse values shall be met with both positive and negative polarity tests.
5—On assembled multiple conductor cable terminations, the tests shall be made between each conductor and ground with the terminals on adjacent conductors grounded.
6—The values in this table are for general use. It is recognized that cable terminations of higher or lower insulation class or BIL may be used where conditions warrant and when specified and agreed upon.
7—When the dielectric strength of the cable termination is dependent upon taping or the use of auxiliary insulation, such insulation shall be used when any design tests are made.
8—When a cable termination is assembled with cable for its dielectric test in the equipment or in the apparatus in which it will operate, the applied test voltage shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in the table.
9—The direct voltage test shall be made with negative polarity on the conductor. Refer to 7.3 of this standard for comments regarding the direct voltage test values.
10—Certain types of resistance or capacitance graded cable terminations are sensitive to prolonged overvoltage testing and may not be able to withstand some of the power frequency and direct voltage tests, although they are perfectly satisfactory for service. In such cases, the manufacturer shall so specify and shall perform such other special tests as agreed upon by the user.
11—For grounded systems.

7.1.2 Pressure leak tests

All Class 1 terminations shall be pressure leak tested in accordance with 8.4.3 as follows:

- Class 1A test procedures a) and b)
- Class 1B test procedures a) [30 lbf/in^2 only] and b)
- Class 1C test procedures b) and c)

7.2 Routine tests

NOTE—Because of the variety of termination designs and materials, especially with polymeric terminations, each manufacturer generally specifies and performs its own particular routine and quality assurance tests. It is impractical to establish standard routine tests that will be applicable to every situation. Therefore, other routine tests may be performed as agreed upon by the manufacturer and user in addition to those listed herewith.

a) *Dielectric tests.* See note 10 of table 1 or 2. A dielectric test on the termination insulator in accordance with 8.5.1 (all classes).

b) *Partial discharge tests*. As an option, partial discharge tests in accordance with 7.1.1 item d) can be used.

   NOTE—This applies only to factory-manufactured termination insulators. Termination insulators fabricated on the cable in the field cannot be given this test.

c) *Pressure leak tests.* A pressure leak test on all pressure-tight parts and factory-assembled seals in accordance with 8.5.2 (Class 1C).

Table 2—Standard dielectric tests for high-voltage extruded dielectric cable terminations assembled and ready for service

Insulation class (kV) (12) Column 1	Max design voltage to ground (kV) (13) Column 2	1 min Dry withstand (kV RMS) Column 3	10 s Wet withstand (3) (kV RMS) Column 4	6 h Dry withstand (kV RMS) Column 5	Cyclic aging dry (kV RMS) Column 6	Radio influence voltage dry (μV) Column 7	Partial discharge (corona) extinction voltage (11) (kV RMS) Column 8	Lightning impulse (BIL) dry withstand (kV crest) Column 9	Switching impulse (BSL) (3) wet (dry) withstand (kV crest) Column 10	Direct voltage test (9) 15 min dry withstand (kV avg) Column 11
2.5	1.6	20	20	10	4.5	50	2	60	—	40
5	3.2	25	25	15	9	50	4.5	75	—	50
8.7	5.5	35	30	25	15	50	7.5	95	—	65
15	9.5	50	45	35	26	50	13	110	—	75
25	16	65	60	55	43	100	21.5	150	—	105
34.5	22	90	80	75	60	150	30	200	—	140
46	29.5	120	100	100	60	200	40	250	—	170
69	44	175	145	120	80	300	60	350	—	245
115	73	205	190	160	133	400	80	450	—	275
120	73	260	230	190	140	450	100	550	—	320
138	88	310	275	210	160	500	120	650	—	355
161	102	365	315	250	186	500	140	750	—	395
230	146	460	445	330	265	—	200	1050	—	510

NOTES
1—Power frequency includes any frequency from 48 Hz to 62 Hz.
2—All withstand values are test voltages without negative tolerance but may include an atmospheric correction factor.
3—Indoor cable terminations are not subjected to the wet test. Indoor wet terminations to be tested at three times phase-to-ground voltage.
4—The required lightning and switching impulse values shall be met with both positive and negative polarity tests.
5—On assembled multiple conductor cable terminations, the tests shall be made between each conductor and ground with the terminals on adjacent conductors grounded.
6—The values in this table are for general use. It is recognized that cable terminations of higher or lower insulation class or BIL may be used where conditions warrant and when specified and agreed upon.
7—When the dielectric strength of the cable termination is dependent upon taping or the use of auxiliary insulation, such insulation shall be used when any design tests are made.
8—When a cable termination is assembled with cable for its dielectric test in the equipment or in the apparatus in which it will operate, the applied test voltage shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in the table.
9—The direct voltage test shall be made with negative polarity on the conductor. Refer to 7.3 of this standard for comments regarding the direct voltage test values.
10—Certain types of resistance or capacitance graded cable terminations are sensitive to prolonged overvoltage testing and may not be able to withstand some of the power frequency and direct voltage tests, although they are perfectly satisfactory for service. In such cases, the manufacturer shall so specify and shall perform such other special tests as agreed upon by the user.
11—The minimum detector sensitivity shall be 5.0 pC.
12—For use with 100% insulation cable as defined in AEIC CS5-87 or CS6-87. To obtain test values for voltage classes that are not listed, use linear interpolation between the two closest listed values and round off to the nearest whole kilovolt.
13—For grounded systems.

7.3 Dielectric field tests

See note 10 of table 1 or 2. Field tests are tests that may be made in accordance with 8.6 on the completely installed cable system (including the cable terminations) by the user as an installation acceptance or proof test (all classes).

The values listed in column 11 of table 1 or 2 are not intended to be the test voltages for a given rated voltage cable system, but are only to serve as a guide for the maximum voltage that the cable termination may be expected to withstand under normal conditions without flashover or without affecting its dielectric characteristics.

The magnitude of the actual test voltage to be used for the installed cable system shall be determined by reference to applicable AEIC or ICEA cable specifications. The cable termination manufacturer shall be consulted before conducting any field tests that exceed the values listed in table 1 or 2.

NOTE—Some cable insulation may be damaged by direct voltage field tests. The cable manufacturer should be consulted before testing.

Transformers, regulators, and other equipment that cannot be disconnected from the cable system while conducting the field test should be investigated to be sure that the withstand voltage strength of this equipment is not exceeded.

8. Test procedures

8.1 Preparation of test specimen

The test specimen shall comply with the following requirements as specified in 8.4 through 8.6:

a) It shall be clean.

b) It shall be dry and clean.

c) It shall be assembled with cable of the type and maximum conductor size for which the high-voltage cable termination is designed, and filled (as applicable) with the grade and quantity of materials specified by the manufacturer and assembled with any electric stress-controlling features such as stress-relief cones, etc., in the manner specified by the manufacturer. For dielectric tests, a mandrel with insulation having the same physical and electrical characteristics as that used on the cable may be substituted for cable, and the test assembly shall include the standard types of external connectors (aerial lugs).

   NOTE—It is recommended that pre-molded terminations that depend on maximum and minimum cable insulation diameters for sizing should be tested using the minimum cable insulation diameter and maximum conductor size.

d) It shall be completely assembled and the entrances sealed. High-voltage cable terminations incorporating gland-type entrances shall be assembled with a mandrel so that the cable seal is made by compressing the gland-searing material against the mandrel.

e) It shall be mounted in a manner determined by the manufacturer, who shall consider typical service conditions. All details of the test mounting shall be recorded and shall be available upon request.

f) It shall have the high-voltage test connection leave the terminal of the high-voltage cable termination in a direction approximately parallel to the axis of the device for a distance of not less than the dry arcing distance over the insulator. No other object except the supporting structure shall be close enough to the device to appreciably affect the test results.

g) It shall be completely assembled with its own metal parts and have provision for admitting air or other medium to the interior (if liquid medium is used, fill completely) and provisions for measuring internal pressure during the test. Units that are intended to operate with internal pressure, whether such pressure is from the cable system or a separate source, shall be tested at the minimum pressure under which the cable system or terminal would be expected to operate in actual service.

8.2 Standard test conditions

8.2.1 Atmospheric and precipitation conditions

The standard atmospheric and precipitation conditions are given in table 3.

Table 3—Standard atmospheric and precipitation conditions

Air temperature	20 °C	20 °C	68 °F
Barometric pressure	101.3 kPa	760 mmHg	29.92 inHg
Humidity	11 g/m^3	11 g/m^3	6.867×10^{-4} lb/ft^3
Average precipitation rate for all measurements (vertical and horizontal components)	1.0–1.5 mm/min		
Limits for any individual measurement (vertical or horizontal component)	0.5–2.0 mm/min		
Temperature of collected water	ambient temperature ± 15 °C		
Resistivity of collected water corrected to 20 °C[a]	100 ± 15 Ω·m		

[a]For switching impulses, if the prescribed water resistivity cannot be obtained, a lower value may be used but the actual value must be stated in the test report. For correction of water resistivity to 20 °C, refer to IEEE Std 4-1995.

Where test conditions differ from those above, suitable corrections shall be made as outlined in 8.3.

8.2.2 Rate of voltage application for power frequency and direct voltage tests

The initial voltage shall not be greater than 20% of the test voltage. The applied voltage may be quickly raised to 75% of the test value. The continued rate of voltage increase shall be such that the time to reach the expected test voltage shall be between 15 s and 30 s after the 75% value has been reached.

8.2.3 Duration of voltage application for power frequency and direct voltage withstand tests

The required voltage shall be held for the specified time (table 1 or 2) after the full value has been reached.

8.2.4 Testing equipment and voltage measurements

The character of the test equipment and the method of measuring voltage shall conform to IEEE Std 4-1995.

8.3 Correction factors

a) Correction *D* for variation in relative air density and *H* for variation in humidity shall be made when the conditions under which the tests are conducted vary from the standard test conditions given in 8.2.1. Correction factors shall be used for only the following tests:

   1) *Power frequency voltage 10 s wet withstand test.* The applied test voltage shall be the specified test voltage multiplied by *D* as determined by item c) below.

   2) *Lightning impulse voltage wet withstand test.* The applied test voltage shall be the specified test voltage multiplied by *D/H* as determined by items c) and d) below, respectively.

   3) *Switching impulse voltage wet withstand test.* The applied test voltage shall be the specified test voltage multiplied by *D* as determined by item c) below.

b) The air temperature at the time of the test shall be between 10 °C and 40 °C (50 °F and 104 °F).

c) The relative air density, *D*, at the time of the test should preferably be between 0.95 and 1.05 and shall be determined as follows:

$$D = (A)\left[\frac{P}{t_0 \pm t}\right]$$

where

D = relative air density
A = 2.89 for P in kilopascals
A = 0.386 for P in millimeters of mercury
or 17.61 for P in inches of mercury
t_0 = 273 for t in degrees Celsius
or 459 for t in degrees Fahrenheit

d) The humidity correction factor, *H*, for variation in humidity is given in figure 1. The vapor pressure at the time of the test should preferably be between 7.6 mmHg and 15.2 mmHg (1000 Pa and 2000 Pa) (0.3 inHg and 0.6 inHg).

e) All data used in determining any correction factors shall be recorded.

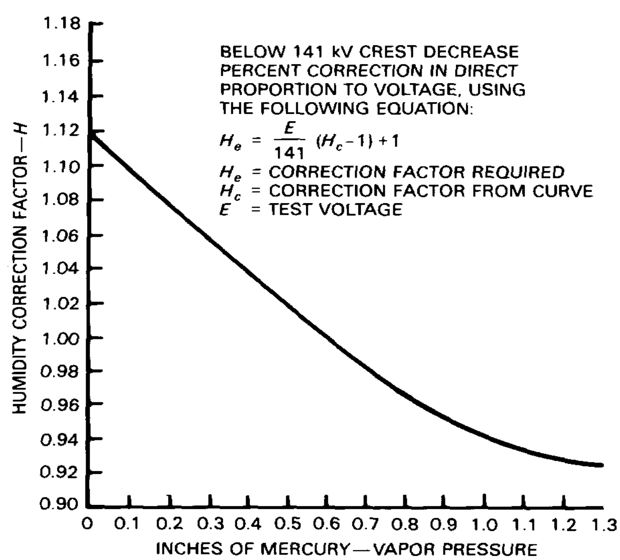


Figure 1—Humidity correction factor, 1.2 × 50 μs impulse

8.4 Design tests

Tests for extruded dielectric cable terminations are summarized in table 4. Termination tests are summarized in table 5.

Table 4—Design tests and sequence for extruded cable terminations

Design test	Subclause	Minimum number of samples		
		4	4 (2[a])	2
Partial discharge (corona) extinction voltage	8.4.1.5	❑ ⇓ ⇓		
Power frequency voltage 1 min dry withstand	8.4.1.1	❑ ⇓ ⇓		
Power frequency voltage 6 h dry withstand	8.4.1.3	❑ ⇓ ⇓		
Power frequency voltage 10 s wet withstand (outdoor terminations)	8.4.1.2	❑ ⇓ ⇓ ⇓ ⇓		
Direct voltage 15 min dry withstand	8.4.1.9	❑ ⇓ ⇓		
Lightning impulse voltage withstand	8.4.1.7	❑ ⇓		
Partial discharge (corona) extinction voltage	8.4.1.5		❑ ⇓	❑ ⇓
Cyclic aging	8.4.2 item c)		❑ ⇓	❑ ⇓
Lightning impulse voltage withstand	8.4.1.7		❑ ⇓	❑ ⇓
Partial discharge (corona) extinction voltage	8.4.1.5		❑ ⇓	❑ ⇓
Pressure leak test (Class 1 terminations only)	8.4.3			❑

[a]Four samples for single-phase terminations in insulation classes up to and including 46 kV, and two samples for single-phase terminations in insulation classes above 46 kV according to 8.4.2 item b). Two samples for one-piece, three-phase terminations according to 8.4.2 item b).

NOTES—
❑ = test
⇓ = specimen, proceed to following test

Table 5—Design tests and sequence for laminated dielectric cable terminations—Class 1B and 1C

Design test	Subclause	Minimum number of samples		
		4	4 (2[a])	2
Ionization factor	8.4.1.6	❑ ⇓		
Power frequency voltage 1 min dry withstand	8.4.1.1	❑ ⇓ ⇓		
Power frequency voltage 6 h dry withstand	8.4.1.3	❑ ⇓ ⇓		
Power frequency voltage 10 s wet withstand (outdoor terminations)	8.4.1.2	❑ ⇓ ⇓		
Direct voltage 15 min dry withstand	8.4.1.9	❑ ⇓ ⇓		
Impulse withstand voltage	8.4.1.7	❑ ⇓		
Ionization factor	8.4.1.6	❑	❑ ⇓	
Cyclic aging	8.4.2 item c)		❑ ⇓	
Ionization factor	8.4.1.6		❑	
Impulse withstand voltage	8.4.1.7			
Pressure leak test	8.4.3			❑

[a]Four samples for single-phase terminations in insulation classes up to and including 46 kV, and two samples for single-phase terminations in insulation classes above 46 kV according to 8.4.2 item b). Two samples for one-piece, three-phase terminations according to 8.4.2 item b).

Switching impulse voltage wet withstand test, 8.4.1.8, shall be used at 345 kV and above in lieu of the power frequency voltage 10 s wet test.

8.4.1 Dielectric tests

8.4.1.1 Power frequency voltage 1 min dry withstand test

The test specimen shall be prepared for test in accordance with 8.1 items b), c), e), and f) and tested in accordance with 8.2 and column 3 of table 1 or 2. If the test specimen withstands the specified test voltage for the specified time, it shall be considered as having passed the test. If flashover occurs, the test shall be repeated. If the repeat test also results in flashover or other dielectric breakdown, the test specimen shall be considered as having failed. If the specimen passes the repeat test, the test specimen shall be considered as having passed the test.

8.4.1.2 Power frequency voltage 10 s wet withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and column 4 of table 1 or 2. This test is required on outdoor terminations only. Wet tests shall be made in accordance with IEEE Std 4-1995.

If the test specimen withstands the specified test voltage for the specified time, it shall be considered as having passed the test. If flashover occurs, the test shall be repeated. If the repeat test also results in flashover or other dielectric breakdown, the test specimen shall be considered as having failed. If the specimen passes the repeat test, the test specimen shall be considered as having passed the test.

8.4.1.3 Power frequency voltage 6 h dry withstand test

The test specimen shall be prepared for test in accordance with 8.1 items b), c), e), and f) and tested in accordance with 8.2 and column 5 of table 1 or 2. If the test specimen withstands the specified test voltage for 6 h, it shall be considered as having passed the test. If the test is interrupted, the total duration of voltage application shall be increased by twice the duration of each interruption.

8.4.1.4 Radio influence voltage (RIV) test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and IEC 270-1981.

The applied test voltage shall be the maximum design voltage to ground indicated in column 2 of table 1 or 2. The test specimen shall have successfully passed the test if the RIV does not exceed the value indicated in column 7 of table 1 or 2 measured at 1 MHz.

NOTE—Some cables may develop higher influence voltage levels than specified in column 7. In such cases, another type of cable or equivalent insulated test mandrel may be substituted for the noisy cable to determine the true characteristics of the termination under test.

8.4.1.5 Partial discharge (corona) extinction voltage test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and IEC 270-1981.

The partial discharge detecting apparatus shall be adjusted to have a sensitivity that will permit detection of discharge pulses of at least 5.0 pC. The test voltage shall be raised to at least 120% of the value listed in column 8 of table 2. If partial discharge exceeds 5.0 pC, the test voltage shall be lowered to the value listed in column 8 and shall be maintained at this level for at least 3 s but not more than 60 s. The test specimen shall have successfully passed the test if the partial discharge level does not exceed 5.0 pC during this period.

NOTE—Some cables may indicate a partial discharge extinction voltage lower than that specified in column 8. In such cases, another type of cable or equivalent insulated test mandrel may be substituted for noisy cable to determine the true characteristics of the termination under test.

8.4.1.6 Ionization factor test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and table 6.

The ionization factor is the difference, at 60 Hz**,** between the percent dielectric power factor measured at an average stress of 100 V/mil and the percent dielectric power factor measured at an average stress of 20 V/mil. The measurement voltage is based on the insulation thickness of the laminated cable. The measurement shall be made at 25 °C ± 5 °C.

8.4.1.7 Lightning impulse voltage withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f) and tested in accordance with 8.2 and column 9 of table 1 or 2.

Table 6—Maximum allowable ionization factor values for laminated dielectric cable terminations

Class 1B terminations Impregnated-paper-insulated cables—Solid-type %	
Rated voltage (kV)	**Maximum ionization factor (%)**
10–200	0.6
21–350	0.4
35–460	0.2
46–690	0.2

Class 1C terminations		
Cable type	**Rated voltage (kV)**	**Maximum ionization factor (%)**
High-pressure	69–161 162–765	0.1 0.05
Low pressure, Gas-filled (at 10 lb/in^2 gage)	10–29 30–46	0.4 0.2
Low and medium pressure, Liquid-filled	15–161 230 345–500	0.1 0.1 0.1

a) A nominal 1.2 × 50 µs wave, both positive and negative, shall be used. The characteristics of the impulse wave shall conform to the requirements contained in IEEE Std 4-1995, except that the virtual front time shall not exceed 5 µs in the cases where the capacitance of the test piece is such as to prevent attainment of requirement.

b) Ten consecutive impulses at each polarity shall be applied to the test specimen. If a flashover or other dielectric breakdown does not occur, the test specimen shall be considered as having passed the test. If two or more of the applied impulse waves cause flashover, the specimen shall be considered as having failed. If one of the applied impulses causes flashover, ten additional impulses shall be applied. If flashover or other dielectric breakdown does not occur, the specimen shall be considered as having passed the test.

NOTE—When a specimen is tested with a unidirectional impulse, the insulation under test sometimes becomes polarized. It is suggested, therefore, that each set of impulses with a given polarity be preceded by impulses of that polarity at approximately 50%, 65%, and 80% of the required value in table 1 or 2. This procedure will neutralize the polarization effects of any previous tests. Refer to IEEE Std 82-1994.

8.4.1.8 Switching impulse voltage wet withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), c), e), and f) and tested in accordance with 8.2 and column 10 of table 1. This test is required on certain classes of terminations only (see note below), under standard wet test conditions as defined in IEEE Std 4-1995.

a) A nominal 250 × 2500 µs wave, both positive and negative, shall be used.

b) Ten consecutive impulses at each polarity shall be applied to the test specimen. If a flashover or other dielectric breakdown does not occur, the test specimen shall be considered as having passed the test. If two or more of the applied impulse waves cause flashover, the specimen shall be considered as having failed. If one of the applied impulses causes flashover, ten additional impulses shall be applied. If flashover or other dielectric breakdown does not occur, the specimen shall be considered as having passed the test.

NOTE—This test applies to cable terminations rated 345 kV and higher only, and is used in lieu of the power frequency voltage 10 s wet withstand test (see table 1). In the case where the cable termination is classified as an indoor type (see clause 3), a switching impulse test must be made, dry. The test values are referred to in column 10 of table 1 in brackets.

8.4.1.9 Direct voltage 15 min dry withstand test

The test specimen shall be prepared for test in accordance with 8.1 items a), c), e), and f) and tested in accordance with 8.2 and column 11 of table 1 or 2.

a) A direct voltage of negative polarity, having a ripple of less than 3% at the required test value, shall be used.

b) The test voltage shall be applied for the specified duration starting after the required test voltage has been reached. If the test specimen withstands the required test voltage for 15 min, it shall be considered as having passed the test. If a flashover occurs, the test shall be repeated. If the repeat test also results in flashover or other dielectric breakdown, the test specimen shall be considered as having failed.

8.4.2 Cyclic aging test

a) The test specimen shall be prepared for test in accordance with 8.1 items a), b), c), e), and f).

b) Each test specimen shall be assembled as follows:

    1) For single-phase terminations in insulation and classes up to and including 46 kV, a total of four terminations shall be tested with two on one length of power cable and two on another. For single-phase terminations in insulation classes above 46 kV, a minimum of two terminations shall be tested with one on each end of a power cable. A minimum of 2 m (6 ft) of cable shall be used between terminations.

    NOTE—A typical load cycle test circuit for single-phase terminations is shown in figure 2. In this test setup, the loading current and the high voltage are applied with separate, independent power supplies. The metallic shield of each power cable is connected to a single grounding point to prevent current from circulating in the metallic shield of either cable.

    2) For one piece, three-phase terminations, a total of two samples shall be tested on one length of power cable. A minimum of 2 m (6 ft) of cable shall be used between terminations.

    NOTE—A typical load cycle test circuit for three-phase terminations is shown in figure 3. In this test setup, the phases are connected in a series loop to easily facilitate the circulation of current through the conductors. The loading current and the high voltage are applied with separate, independent power supplies. A test setup using three-phase power is also acceptable. The cable connecting the terminations may be three single-conductor cables or one three-conductor cable. In either case, the metallic shield(s) must be interrupted and single-point grounding must be utilized to prevent circulating shield currents.

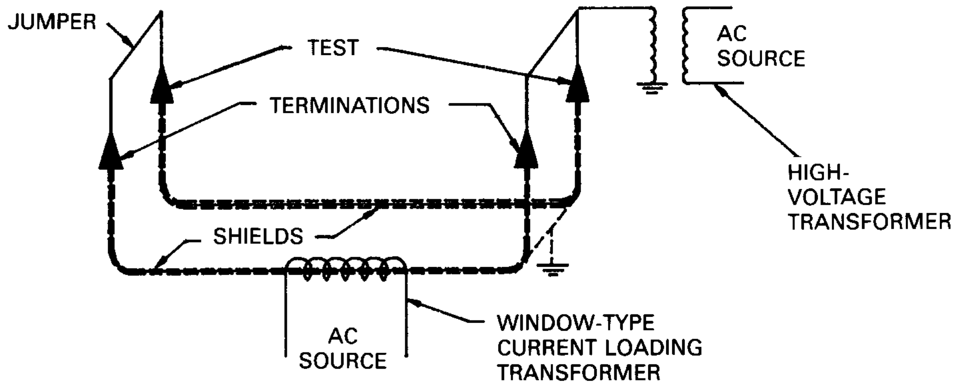
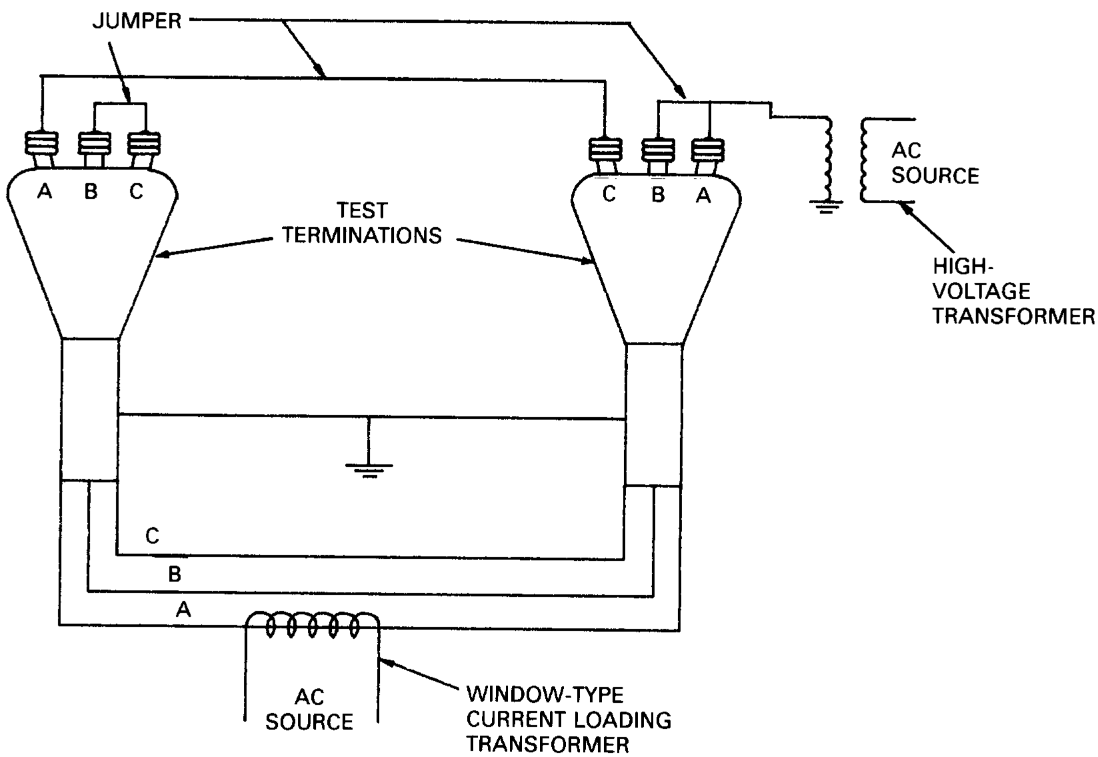


Figure 2—Single-phase terminations



NOTE: This method of cyclic aging requires only single-phase voltage and current power supplies. Test setups using three-phase power supplies are also acceptable.

Figure 3—One-piece three-phase terminations

In both the single- and three-phase test setups, the window-type current transformer may be installed on one of the jumper leads to help minimize circulating currents in the cable metallic shield(s). The jumper leads may be an uninsulated wire or bus, an unshielded power cable, or a shielded power cable.

The test configurations shown in figures 2 and 3 are only examples of how the test may be performed. Other test setups may be used to obtain the same goal.

For large, higher voltage cables, more than 2 m of cable may be required to prevent the conductor temperature midway between the terminations from being influenced by the terminations. Up to 5 m (approximately 15 ft) may be required.

c) Testing shall be in accordance with 8.2 and the following:

   1) Applied test voltage for Class 1A extruded dielectric cable terminations shall be in accordance with column 6 of table 2.

   2) Applied test voltage for Class 1B and 1C laminated dielectric cable terminations shall be in accordance with column 6 of table 1.

   3) Voltage shall be applied continuously to the test specimens for a 30-day period. See 7.4.2, item c) 1) or item c) 2).

   4) Load current, in addition to voltage [item c) 3) above], shall be applied to the test specimens. During the current-on period, the cable conductor temperature midway between the terminations shall be within 5 °C of the cable’s maximum rated emergency operating temperature for a period of 6 h. During the current-off period, the conductor temperature midway between the terminations shall drop to within 5 °C of the ambient air temperature.

If this condition cannot be met, then every five cycles the current (and voltage) shall remain off for 48 h. The load cycle shall be resumed at the end of the 48 h period. (This procedure may be followed even if the 5 °C condition can be met if a test facility prefers not to run the tests during the weekend.)

The test specimens shall complete 30 load cycles. If the 48 h off period is used, it is not considered in the test cycles.

NOTE— One load cycle is 24 h long with a current-on period and a current-off period. The duration of the current-on and current-off periods is governed by the amount of time it takes a given test specimen to achieve the desired temperature.

The cable’s emergency rating temperature should be determined by reference to applicable AEIC or ICEA cable specifications or to the cable manufacturer in the case of special use cables.

Temperature can be determined by reading the jacket temperature midway between terminations and comparing it to a “dummy” cable equivalent, where both jacket and conductor temperature have been determined. Equivalent current loadings can also be useful.

   5) Partial discharge (corona) extinction voltage test level shall be determined for each specimen before the 30 load cycle test period is started and after completion of the 30 load cycle test period. Partial discharge levels shall be determined in accordance with 8.4.1.5.

   6) After completion of the cyclic aging test and partial discharge (corona) extinction voltage test level, each specimen shall be tested with lightning impulse voltage (10 shots at each polarity) in accordance with 8.2, 8.4.1.7, and column 9 of table 1 or 2.

NOTE—For laminated dielectric cable terminations (Class 1B and 1C), the ionization factor test shall be used in place of partial discharge in accordance with table 6 and 8.4.1.6.

d) Class 1 B and 1 C terminations shall show no visual indications of fluid leakage at the completion of the cyclic aging test.

If the two specimens (one specimen for 46 kV and above or for a three-phase specimen) withstand all of the above specified test conditions for the specified time, they shall be considered as having passed the test.

If the test is interrupted or otherwise affected, the cycle(s) affected shall be repeated. If dielectric breakdown occurs in any test specimen, all test specimens shall be considered as having failed.

NOTE—The cyclic aging test is not intended to establish current rating for a termination (see clause 5).

8.4.3 Pressure leak tests

The test specimen shall be prepared at room temperature in accordance with 8.1 items a), b), d), and g) and tested in accordance with items a) and b), or b) and c) below. See 7.1.2 for determining which tests to use. The test specimen shall have successfully passed if no leak or rupture occurs.

NOTE—The following pressures are gauge except in item b) below.

a) Apply 200 kPa (30 lbf/in^2) for 1 h at room temperature. If gas pressure is used, the test specimen shall be immersed at a depth of not less than 5 cm in a liquid bath or the exterior surface shall be coated with soap solution. If liquid pressure is used, the liquid shall have a viscosity no greater than 125 s (Saybolt Universal) at 25 °C. Seal areas are to be coated with a white chalk that will stain if there is a leak. The test may be made at 100 kPa (15 lbf/in^2) for 2 h or 50 kPa (7 lbf/in^2) for 6 h when specified and agreed upon.
b) For Class 1C terminations (components) with the test specimen at a temperature not higher than 25 °C, evacuate to a pressure of not more than 67 Pa (0.5 torr or 0.01 lb/in^2 absolute), after which the valve shall be closed, separating the test specimen from the pump. During the next 30 min, the rise in pressure shall not exceed 67 Pa (0.5 torr or 0.01 lbf/in^2). For Class 1 A and 1 B terminations, the test pressure shall be not more than 670 Pa (5 torr or 0.1 lbf/in^2) using the same procedure.
c) Fill the test specimen with a liquid that has a viscosity no greater than 125 s (Saybolt Universal) at 25 °C. Apply 2.5 times rated internal pressure or 267 kPa (40 lbf/in^2), whichever is highest, for terminations up to 2000 kPa (300 lbf/in^2) [consult manufacturer for test on terminations with rated internal pressure greater than 2000 kPa (300 lbf/in^2)]. The internal pressure (or pressures) shall be observed and maintained at the test pressure until the temperature of the test specimen and filling fluid have stabilized. The temperature-pressure test shall then be continued 1 h for single-pressure zone terminations and 24 h for multipressure zone terminations. Leakage shall be detected at the end of this period by visual examination of chalk on the exterior surfaces of the test specimen and by pressure drop in the high-pressure zone or pressure rise in the low-pressure zone of a multipressure zone termination.

8.5 Routine tests

8.5.1 Dielectric tests

Dielectric tests shall be made on termination insulators prepared in accordance with 8.1 items a) and b) and tested in accordance with 8.2. Any of the following procedures may be used at the manufacturer's option:

a) Using parts simulating external metal parts for the fully assembled cable termination, apply power frequency voltage for 1 min using the value shown in column 3 of table 1 or 2 for the specified insulation classification. If flashover occurs, the test may be repeated. If puncture occurs, or if flashover occurs on the repeat test, the insulator shall be rejected.

b) Using parts simulating external metal parts of the fully assembled cable termination, maintain power frequency flashover for at least 3 min. The insulator shall be rejected if the flashover causes puncture.

c) Using a conducting member passing through the insulator (see note below) and a conducting ring surrounding the insulator at the approximate midpoint, maintain power frequency flashover for at least 3 min. Any insulator that is punctured shall be rejected. Good insulators for cable terminations rated 69 kV and higher might be punctured by this method and, therefore, these insulators should be tested as prescribed in item d) below.

NOTE—Several insulators may be tested in parallel and, when so tested, the voltage control shall be such that a continual flashover occurs and divides uniformly over the insulators under test. To meet this condition it may be necessary to insert additional impedance in the testing circuit. High-frequency test voltage may be used for these tests, in which case the test duration shall be at least 3 s. The high frequency shall be of the order of 200 000 Hz in damped trains, but not less than 100 000 Hz.

d) Using a conducting surface on the entire internal surface of the termination insulator and a series of conducting rings surrounding the insulator at each minimum diameter of corrugation or petticoat, apply a power frequency voltage for 1 min using an average puncture gradient of 28 kV/cm (70 kV/in). Any punctured insulator shall be rejected.

NOTE—Most polymeric termination designs do not lend themselves to the above tests. Consult the manufacturer(s) for specific procedures to determine insulator integrity.

8.5.2 Pressure leak tests

NOTE—The pressures indicated below are gauge.

Routine pressure leak tests on parts and on factory-assembled seals shall be made in accordance with the practice developed by the manufacturer. Class 1C components having a rated internal pressure greater than 100 kPa (15 lbf/in^2) shall be subjected to an internal pressure of 2.5 times the nominal rating for terminations rated up to 2000 kPa (300 lbf/in^2) in accordance with the following:

a) One hour on single-pressure zone terminations where the outer surface of the parts subjected to leakage are exposed for visual examination.

b) Twenty-four hours on multipressure zone terminations where the outer surface of the parts subject to leakage are not exposed for visual examination, and leakage detection must be determined by pressure drop in the high-pressure zone or pressure rise in the low-pressure zone.

c) For terminations with an internal pressure rating greater than 2000 kPa (300 lbf/in^2), the test procedure should be agreed upon by the purchaser and manufacturer.

8.6 Dielectric field tests

The tests are to be conducted in accordance with 8.1 items b) and f).

Direct voltage test values up to the maximums listed in table 1 or 2 may be used with the test set connected for negative polarity. Refer to 7.3 for comment regarding the direct voltage test values.

The field test voltage has been established for phase-to-ground tests only.

9. Application guide

9.1 Application at altitudes greater than 1000 m (3300 ft)

9.1.1 Effect on ampacity

A high-voltage cable termination that depends an air for its cooling medium and is designed for standard temperature rise may be used at altitudes greater than 1000 m (3300 ft) provided that the ampacity is reduced by the correction factors listed in table 7.

The temperature of the cooling air is not likely to exceed the values for the respective altitudes given in table 7.

Table 7—Altitude-ampacity correction factors

Altitude		Altitude ampacity correction factor	Maximum temperature of the cooling air	
(m)	(ft)		(°C)	(°F)
1000	3300	1.00	40	104
2000	6600	0.99	35	95
3000	9900	0.96	30	86

9.1.2 Effect on dielectric strength

The dielectric strength of a high-voltage cable termination that depends on air for its insulation varies with altitude. Table 8 shows the approximate relative dielectric strength for altitudes above 1000 m (3300 ft) at any given temperature.

Table 8—Altitude-dielectric strength correction factors

Altitude		Altitude correction factor for dielectric strength
(m)	(ft)	
1000	3300	1.00
1500	5000	0.95
2100	7000	0.89
3000	9900	0.80

9.2 Effect of solar radiation (ultraviolet light)

Solar radiation can cause molecular scission to occur on most polymer surfaces unless adequately protected by UV stabilizers. This degradation can shorten service life of polymers significantly.

Little has been reported to correlate ASTM weatherometer test results with anticipated 30-year service life. Solar radiation varies significantly between geographical areas (513 langleys/day in Phoenix, AZ and

352 langleys/day in Indianapolis, IN) so that a test life of 1000 h may be adequate for one area while 3000 h may be inadequate for another.

The following test methods are recommended to evaluate effects of solar radiation on polymeric terminations or exposed polymer components used with porcelain terminations:

— Operating light and water-exposure apparatus (fluorescent UV-condensation type): [B11] (UVA-340 lamp) or (UVB-313 lamp)
— Xenon arc methods: [B9] or [B10]

Surface cracking or crazing constitutes failure. Three thousand hours is recommended, but because of the above reasons, the manufacturer should be consulted.

9.3 Environmental exposure

Terminations are installed in a range of environments, from very benign to extremely severe. Airborne pollutants coupled with water can lower design electrical withstand values and cause flashover.

The following pollution severity guide is for distribution voltages and is meant to assist the user to broadly define the environment in which the termination is to be installed. Minimum termination requirements are given within the definitions of clause 3 to assist the user in consulting with the manufacturer if there is a concern on the type of environment involved.

9.3.1 Indoor terminations

a) *Dry.* Applications where the termination is protected from exposure to sunlight and precipitation, not subject to condensation or excessive (90% RH) continuous humidity, and protected from wind-driven pollutants. An example would be unit substations located inside office and industrial buildings.

   Class 1A terminations without weathersheds are often used. Class 2 and 3 terminations can be considered.

b) *Wet.* Applications where the termination is protected from exposure to sunlight and precipitation, but subject to climatic changes causing condensation on the termination surfaces and infiltration of wind-driven particles settling on these surfaces. Generally, these would be outdoor free-standing enclosures.

   Class 1 terminations are recommended. If the above conditions are frequent and/or severe, designs with weathersheds should be considered.

9.3.2 Outdoor terminations

These terminations are not protected from solar radiation, airborne pollutants, or precipitation. Environments are broadly defined as follows:

a) *Light*

   1) Areas without industries and with low-density housing
   2) Areas subjected to frequent winds and/or rainfall with low density of industries or housing
   3) Agricultural areas
   4) Mountainous areas

All of these regions should be situated at least 7–15 mi from the coast and should not be exposed to coastal winds. Distances from coast depend on the topography of the coastal area and on the extreme wind conditions.

Class 1 terminations with weathersheds are recommended.

b) *Medium*

1) Nonpolluting industrial areas subject to infrequent rainfall and/or with average-density housing
2) Areas subjected to frequent winds and/or rainfall with high-density industries and/or housing
3) Areas exposed to wind from the coast, but generally over 2 mi from the coast

Use of fertilizers by spraying, or the burning of crop residues, can lead to a higher pollution level due to dispersal by wind.

Class 1 terminations are normally used with weathersheds for these applications.

c) *Heavy*

1) High-density industrial areas and some urban areas with high-density housing, especially those with infrequent rainfall

2) Areas subjected to a moderate concentration of conductive dust, particularly industrial smoke-producing deposits

3) Areas generally close to the coast and exposed to coastal spray or to strong winds carrying sand and salt, and subjected to regular condensation

Class 1 terminations with weathersheds are often used, but the next higher voltage level or extended creepage should be considered if the general area has a known history of contamination problems.

d) *Extremely heavy*

1) Usually very limited areas having extremely heavy pollutants from industrial sites, especially those located near oceans and subjected to prevailing winds from the sea

2) Very small isolated areas where terminations are located immediately adjacent to a pollutant source, especially downwind (cement plants, paper mills, etc.)

Normally additional creepage length is required, e.g., next voltage level, and often extra maintenance such as periodic washing is needed.

9.3.3 Apparatus termination environments

Apparatus terminations must be compatible with the insulating medium, i.e., no degradation of the termination and the medium over the intended temperature operating range.

9.4 Accelerated contamination testing

While there are a number of test procedures in use, none has been adopted as an industry standard.

Investigators have found modification of a given procedure can significantly affect test time and/or failure modes, especially between material types. This has been documented in several IEEE papers.

Manufacturer(s) should be consulted concerning contamination test history of the product if there is a question for use in areas having high contamination levels.

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