IEEE Std 48-1990
(Revision of IEEE Std 48-1975)

IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations

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Sponsored by the
Insulated Conductors Committee of the
IEEE Power Engineering Society

Industrial Applications

Signals and Applications

Standards Coordinating Committees

IEEE Std 48-1990
(Revision of IEEE Std 48-1975)

Published by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017, USA.

April 25, 1990 *SH13300*

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Sponsor

**Insulated Conductors Committee of the
IEEE Power Engineering Society**

Approved January 25, 1990

IEEE Standards Board

Abstract: IEEE Std 48-1990, *IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations*, applies to all indoor and outdoor cable terminations used on ac cables having laminated or extruded insulation rated 2.5 kV through 500 kV except separable insulated connectors.

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Foreword

(This foreword is not a part of IEEE Std 48-1990, IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations.)

This standard supersedes IEEE Std 48-1975, Standard Test Procedures for High-Voltage Alternating-Current Cable Terminations.

Table 1 (IEEE Std 48-1975), showing the Standard Dielectric Tests for High-Voltage Cable Terminations Assembled and Ready for Service, has been divided into two tables, Table 1 for Laminated Dielectric Cable Terminations, and Table 2 for Extruded Dielectric Cable Terminations.

A Cyclic Aging test (7.4.2) requirement has been added to the Dielectric Tests (6.1.1(8)).

The 6 h dry withstand test voltages for Laminated Cable Terminations 69 kV and above were revised to agree with current cable specifications.

This standard requires wet tests to be made in accordance with IEEE Std 4-1978. Test data obtained by the old wet test standard (IEEE Std 48-1975 and IEEE Std 29-1941) is considered valid test data. Tests on new terminations should be run in accordance with IEEE Std 4-1978. Refer to IEEE Std 4-1978 for additional information.

The number of consecutive Lightning or Switching Surge impulses applied to a test specimen has increased from three to ten.

Some Class 1 and Class 2 terminations have external leakage insulation made of polymeric material. It is recognized that there is some concern about the ability of such insulations to withstand weathering, ultraviolet radiation, contamination, and leakage currents, and that a test capable of evaluating the various materials would be desirable. There are available today a number of test procedures for this purpose. However, none of them has been recognized and adopted by the industry as a standard. Consequently this standard cannot and does not include such a test.

This standard was drawn up by a working group of the Accessories Subcommittee of the Insulated Conductors Committee having the following membership:

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The final conditions for approval of this standard were met on January 25, 1990. This standard was conditionally approved by the IEEE Standards Board on November 9, 1989, with the following membership:

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Contents

IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations

1. Scope and References

1.1 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 500 kV except separable insulated connectors, which are covered by IEEE Std 386-1985, Separable Insulated Connectors for Power Distribution Systems Above 600 V (ANSI).

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

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

[1] IEEE S-135-1, 1962 (IPCEA P-46-426), Power Cable Ampacities—vol. I: Copper Conductors.[1]

[2] IEEE S-135-2, 1962 (IPCEA P-46-426), Power Cable Ampacities—vol. II: Aluminum Conductors.

[3] IEEE Std 4-1978, IEEE Standard Techniques for High Voltage Testing (ANSI).

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

2. Service Conditions

2.1 Standard Service Conditions. Devices conforming to this standard shall be capable of successful operation under the following service conditions. Refer to IEEE Std 97-1969 [B13][3] for more information.

2.1.1 Physical Conditions

(1) Temperature

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

(b) 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 maxiumum temperature of 85 °C.

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

2.1.2 System Conditions. The nominal power system frequency is not less than 25 Hz nor more than 60 Hz.

2.2 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.

2.2.1 Physical Conditions

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

(2) Altitude exceeding 1000 m (3300 ft) where atmospheric air is part of the thermal or dielectric system or both (See Section 8, Application Guide.)

[1] IEEE (ANSI) publications are available from the Service Center, The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, or from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

[2] IEC publications are available from ANSI.

[3] The numbers in brackets correspond to those of the references listed in 1.2; when preceded by B, they correspond to the bibliography in Section 9.

(3) Damaging fumes or vapors, excessive or abrasive dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture or dripping water, etc.
(4) Unusual mechanical conditions such as vibration, shock, cantilever loading, wind loading, icing, etc.
(5) Unusual transportation or storage conditions
(6) Unusual space limitations
(7) Unusual internal pressures
(8) Unusual maintenance difficulties

3. Definitions

NOTE: The definitions and terminology used herein apply specifically to cable terminations treated in this standard. For additional definitions, see IEEE Std 100-1988 [B14].

apparatus termination. A termination intended for use in apparatus where the ambient temperature of the medium immediately surrounding the termination may reach 55 °C.

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.

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

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

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.

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:

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 pressure, if any, of the cable system.

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.

Class 3 Termination. Provides electric stress control for the cable insulation shield terminus.

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

indoor termination. A termination intended for use where it is protected from direct exposure to both solar radiation and precipitation. Terminations designed for use in sealed enclosures where the external dielectric strength is dependent upon liquid or special gaseous dielectrics are also included in this category.

outdoor termination. A termination intended for use where it is not protected from direct exposure to either solar radiation or precipitation.

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.

pressure-type termination. A Class 1 termination intended for use on positive pressure cable systems.
(1) Single-pressure zone termination — a pressure-type termination intended to operate with one pressure zone.
(2) Multipressure zone termination — a pressure-type termination intended to operate with two or more pressure zones.

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.

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.

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.

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. Rating

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

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.

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.

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.

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.

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.

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.

rated internal pressure. The nominal internal pressure for which it 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 S-135-1 [1] and IEEE S-135-2, 1962 [2], including any additions and amendments published by IEEE, 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 cable conductor to the surrounding air or other medium. The types and amounts of dielectric or other materials required for achieving the desired cable termination 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.

5. Nameplate Markings

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

(1) Manufacturer's name, type, designation number, manufacturing date, or date code
(2) IEEE termination class number
(3) Insulation class
(4) Maximum design voltage to ground
(5) Maximum and minimum cable conductor size
(6) Maximum and minimum cable insulation diameter
(7) BIL
(8) Rated internal pressure (gauge)

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

6. Test Requirements

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

6.1.1 Dielectric Tests. [See Note (10), under Table 1 or 2.]

(1) Power frequency voltage 1 min dry withstand test in accordance with Column 3 of Table 1 or 2 and 7.4.1.1 (all classes).

(2) Power frequency voltage 10 s wet withstand test in accordance with Column 4 of Table 1 or 2 and 7.4.1.2. This test is made on outdoor terminations only (Classes 1 and 2 when applicable).

(3) Power frequency voltage 6 h dry withstand test in accordance with Column 5 of Table 1 or 2 and 7.4.1.3 (all classes).

(4) Power frequency partial discharge (corona) extinction voltage test in accordance with Column 8 of Table 1 or 2 and 7.4.1.5, if the termination is used on cable that requires discharge tests (all classes), or power frequency RIV test in accordance with Column 7 of Table 1 or 2 and 7.4.1.4 if the termination is for use on all other cable (all classes).

(5) Lightning impulse voltage withstand test in accordance with Column 9 of Table 1 or 2 and 7.4.1.6 (all classes).

(6) Switching impulse voltage wet withstand test (if applicable) in accordance with Column 10 of Table 1 and 7.4.1.7 (all classes).

(7) Direct voltage 15 min dry withstand test in accordance with Column 11 of Table 1 or 2 and 7.4.1.8 (all classes).

(8) Cyclic Aging test in accordance with 7.4.2 (all classes).

6.1.2 Pressure Leak Tests. Class 1 terminations without a rated internal pressure shall be given pressure leak tests in accordance with 7.4.3, (1) and (2). Class 1 terminations with rated internal pressure shall be given pressure leak tests in accordance with 7.4.3, (2) and (3).

6.2 Routine Tests

NOTE: Because of the variety of termination designs and materials, each manufacturer generally specifies and performs his own particular routine and quality assurance tests, and 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.

6.2.1 Dielectric Tests. [See Note (10), Table 1 or 2.] A dielectric test on the termination insulator in accordance with 7.5.1 (all classes).

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

6.2.2 Pressure Leak Tests. A pressure leak test on all pressure-tight parts and factory-assembled seals in accordance with 7.5.2 (Class 1).

6.3 Dielectric Field Tests. [See Note (10), Table 1 or 2.] Field tests are tests that may be made in accordance with 7.6 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 insulations 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.

7. Test Procedures

7.1 Preparation of Test Specimen. The test specimen shall comply with the requirements as specified in 7.4 through 7.6.

7.1.1 It shall be clean.

7.1.2 It shall be dry and clean.

7.1.3 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 premolded 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.

Table 1
Standard Dielectric Tests for High-Voltage Laminated Dielectric Cable Terminations Assembled and Ready for Service

		Power Frequency Voltage Tests (1)						Impulse Voltage Tests (4)		
Insulation Class (kV) Column 1	Max Design Voltage to Ground (kV) 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	3	50	2.0	60	—	40
5.0	3.2	25	25	15	6	50	4.5	75	—	50
8.7	5.5	35	30	25	10	50	7.5	95	—	65
15	9.5	50	45	35	17	50	13	110	—	75
25	16.0	65	60	55	29	100	21.5	150	—	105
34.5	22.0	90	80	75	40	150	30	200	—	140
46	29.5	120	100	100	53	200	40	250	—	170
69	44.0	175	145	120	80	300	60	350	—	245
115	73.0	205	190	160	133	400	80	450	—	275
120	73.0	260	230	190	140	450	100	550	—	320
138	88.0	310	275	210	160	500	120	650	—	355
161	102.0	365	315	250	186	500	140	750	—	395
230	146	390	380	320	265	500	—	900	—	450

NOTES:

(1) Power frequency includes any frequency from 25 Hz to 60 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. See 7.4.1.7.

(4) The required lightning and switching impulse voltage 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 voltages shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in this table.

(9) The direct voltage test shall be made with negative polarity on the conductor. Refer to 6.3 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 3.0 pC. Values have not been established at 230 kV, 345 kV, and 500 kV.

Table 1 (Continued)
Standard Dielectric Tests for High-Voltage Laminated Dielectric Cable Terminations Assembled and Ready for Service

		Power Frequency Voltage Tests (1)						Impulse Voltage Tests (4)		
Insulation Class (kV) Column 1	Max Design Voltage to Ground (kV) 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
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	[1110]	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

NOTES:
(1) Power frequency includes any frequency from 25 Hz to 60 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. See 7.4.1.7.
(4) The required lightning and switching impulse voltage 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 voltages shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in this table.
(9) The direct voltage test shall be made with negative polarity on the conductor. Refer to 6.3 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 3.0 pC. Values have not been established at 230 kV, 345 kV, and 500 kV.

Table 2
Standard Dielectric Tests for High-Voltage Extruded Dielectric Cable Terminations Assembled and Ready for Service

		Power Frequency Voltage Tests (1)						Impulse Voltage Tests (4)		
Insulation Class (kV) Column 1	Max Design Voltage to Ground (kV) 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	2.0	60	—	40
5.0	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	16.0	65	60	55	43	100	21.5	150	—	105
34.5	22.0	90	80	75	60	150	30	200	—	140
46	29.5	120	100	100	53	200	40	250	—	170
69	44.0	175	145	120	80	300	60	350	—	245
115	73.0	205	190	145	133	400	80	450	—	275
120	73.0	260	230	175	140	450	100	550	—	320
138	88.0	310	275	200	160	500	120	650	—	355
161	102.0	365	315	230	186	500	140	750	—	395

NOTES:

(1) Power frequency includes any frequency from 25 Hz to 60 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. See 7.4.1.7.

(4) The required lightning and switching impulse voltage 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 voltages shall be determined by the tests required for the equipment or apparatus if these voltages are lower than the values listed in this table.

(9) The direct voltage test shall be made with negative polarity on the conductor. Refer to 6.3 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 3.0 pC. Extinction voltages have not been established at 230 kV, 345 kV, and 500 kV.

7.1.4 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-sealing material against the mandrel.

7.1.5 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.

7.1.6 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.

7.1.7 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.

7.2 Standard Test Conditions

7.2.1 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 component		mm/min	1.0 to 1.5
Horizontal component		mm/min	1.0 to 1.5
Limits for any individual measurement vertical or horizontal component		mm/min	0.5 to 2.0
Temperature of collected water		°C	ambient Temp. ±15
Resistivity of collected water corrected to 20 °C			
(See note below.)		Ω m	100 ± 15

NOTE: For switching impluses, 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 4-1978 [3].

Where test conditions differ from those above, suitable corrections shall be made as outlined in 7.3.

7.2.2 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.

7.2.3 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.

7.2.4 Testing Equipment and Voltage Measurements. The character of the test equipment and the method of measuring voltage shall conform to IEEE Std 4-1978 [3].

7.3 Correction Factors

7.3.1 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 7.2.1. Correction factors shall be used for only the following tests:

7.3.1.1 Power Frequency Voltage 10 s Wet Withstand Test. The applied test voltage shall be the specified test voltage multiplied by D as determined by 7.3.3.

7.3.1.2 Lightning Impulse Voltage Withstand Test. The applied test voltage shall be the specified test voltage multiplied by D/H as determined by 7.3.3 and 7.3.4 respectively.

7.3.1.3 Switching Impulse Voltage Wet Withstand Test. The applied test voltage shall be the specified test voltage multiplied by D as determined by 7.3.3.

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

7.3.3 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:

$$D = A \frac{P}{t_0 \pm t} \qquad \text{(Eq 1)}$$

where

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

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

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

7.4 Design Tests

7.4.1 Dielectric Tests

7.4.1.1 Power Frequency Voltage 1 min Dry Withstand Test. The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 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.

7.4.1.2 Power Frequency Voltage 10 s Wet Withstand Test. The test specimen shall be prepared for test in accordance with 7.1.1, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 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 4-1978 [3].

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.

7.4.1.3 Power Frequency Voltage 6 h Dry Withstand Test. The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 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.

7.4.1.4 RIV (Radio Influence Voltage) Test. The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 and IEC 270-1981 [4].

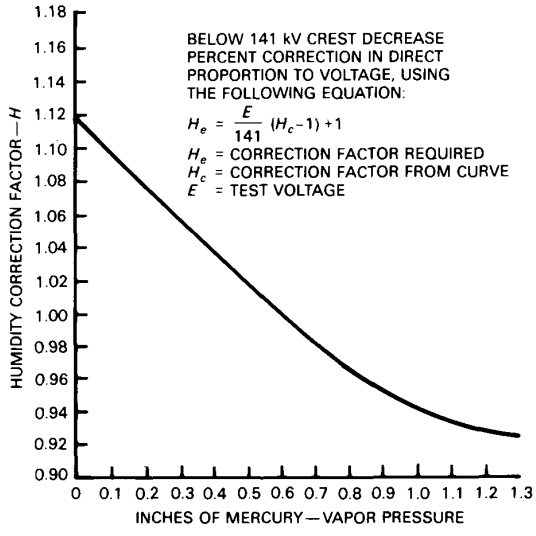


Fig 1
Humidity Correction Factor,
1.2 × 50 μs Impulse

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 radio influence voltage does not exceed the value indicated in Column 7 of Table 1 or 2 measured at 1 MHz.

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

7.4.1.5 Partial Discharge (Corona) Extinction Voltage Test. The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 and IEC 270-1981 [4].

The partial discharge detecting apparatus shall be adjusted to have a sensitivity that will permit detection of discharge pulses of at least 3.0 pC. The test voltage shall be raised to at least 120% of the value listed in Column 8 of Table 1 or 2. If partial discharge exceeds 3.0 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 3.0 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.

7.4.1.6 Lightning Impulse Voltage Withstand Test. The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 and Column 9 of Table 1 or 2.

(1) 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 4-1978 [3], 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.

(2) 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 impluses 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. As a consequence, the initial impulse of opposite polarity may give erratic results and may damage the test piece. It is suggested, therefore, that each set of impulses with a given polarity be preceded by several impulses of that polarity at approximately 50% of the required value in Table 1 or 2. This procedures will neutralize the polarization effects of any previous tests.

7.4.1.7 Switching Impulse Voltage Wet Withstand Test. The test specimen shall be prepared for test in accordance with 7.1.1, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 and Column 10 of Table 1. This test is required on certain classes of terminations only (see note), under standard wet test conditions as defined in IEEE Std 4-1978 [3].

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

(2) 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 Section 3, Definitions), a switching impulse test must be made, dry; the test values are referred to in Column 10 of Table 1 in brackets.

7.4.1.8 Direct Voltage 15 min Dry Withstand Test. The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with 7.2 and Column 11 of Table 1 or 2.

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

(2) 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.

7.4.2 Cyclic Aging Test

7.4.2.1 The test specimen shall be prepared for test in accordance with 7.1.2, 7.1.3, 7.1.5, and 7.1.6.

7.4.2.2 Each test specimen shall be assembled as follows:

(1) For single-phase terminations in insulation classes up to and including 46 kV, a total of four (4) 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 (2) terminations shall be tested with one on each end of a power cable. A minimum of two (2) m [six (6) ft] of cable shall be used between terminations.

NOTE: A typical load cycle test circuit for single-phase terminations is shown in Fig 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 two (2) m [six (6) ft] of cable shall be used between terminations.

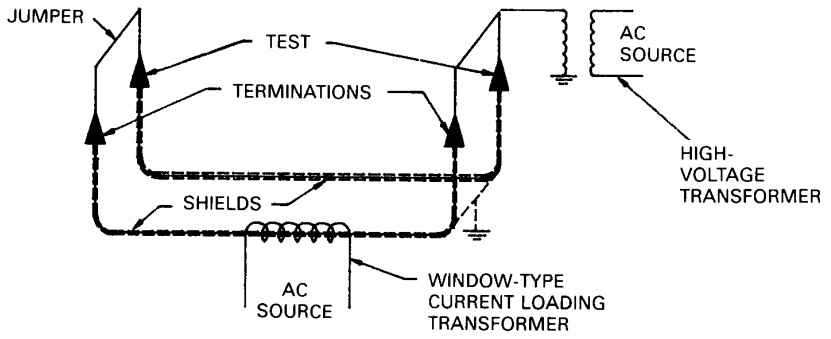
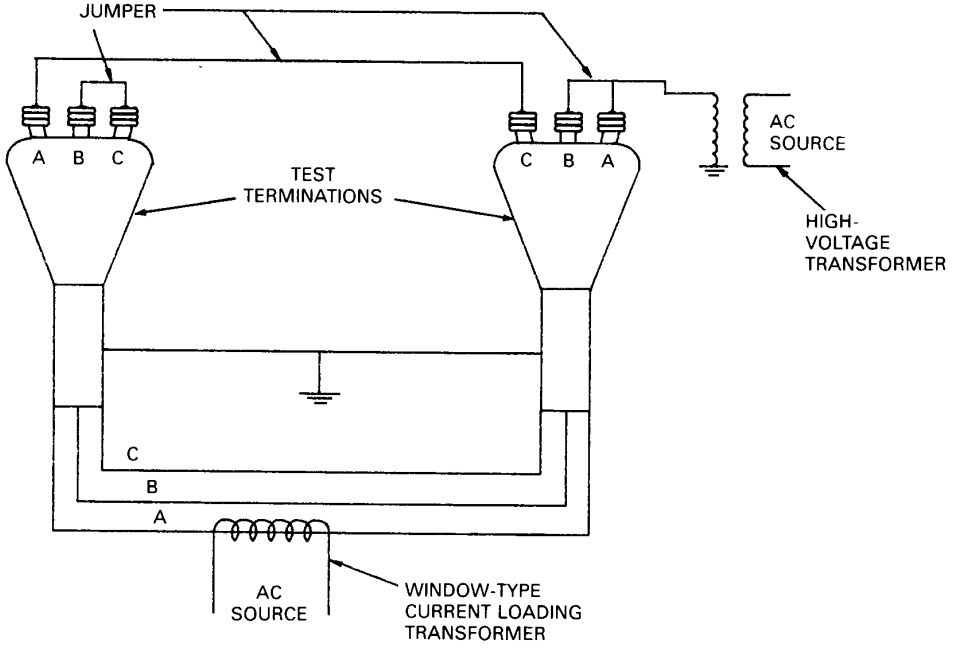


Fig 2
Single-Phase Terminations



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.

Fig 3
One-Piece Three-Phase Terminations

NOTE: A typical load cycle test circuit is shown in Fig 3. In this 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.

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 Figs 2 and 3 are only examples of how the test may be performed. Other test setups may be used to obtain the same goal.

7.4.2.3 Testing shall be in accordance with 7.2 and the following:

(1) Applied test voltage for Extruded Dielectric Cable Terminations shall be in accordance with Column 6 of Table 2.

(2) Applied test voltage for 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 7.4.2.3, (1) or (2).]

(4) Load current, in addition to voltage (3), 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 (5) 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.

(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 7.4.1.5.

(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 7.2, 7.4.1.6, and Column 9 of Table 1 or 2.

If the two specimens (one specimen for 46 kV and above or for a three-phase specimen) withstand all the specified test conditions (1-6) 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 Section 4, Rating).

7.4.3 Pressure Leak Tests. The test specimen shall be prepared at room temperature in accordance with 7.1.2, 7.1.4, and 7.1.7 and tested in accordance with (1) and (2) or (2) and (3) below. See 6.1.2 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 (2).

(1) Apply 200 kPa (30 lb/in^2) for 1 h at room temperature. If gas pressure is used, the test specimen shall be immersed in a liquid bath or the exterior surface 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 lb/in^2) for 2 h or 50 kPa (7 lb/in^2) for 6 h when specified and agreed upon.

(2) 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), 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).

(3) Fill the test specimen with a liquid that has a viscosity no greater than 125 s (Saybolt Universal) at 25 °C. Apply 2 1/2 times rated internal pressure for terminations rated up to 2000 kPa (300 lb/in^2) [consult manufacturer for test on terminations with rated internal pressure greater than 2000 kPa (300 lb/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 oil 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 low-pressure zone of a multipressure zone termination.

7.5 Routine Tests

7.5.1 Dielectric Tests. Dielectric tests shall be made on termination insulators prepared in accordance with 7.1.2 and tested in accordance with 7.2. Any of the following procedures may be used at the manufacturer's option:

(1) 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.

(2) 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.

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.

(3) Using a conducting member passing through the insulator (see note) 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 7.5.1 (4).

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.

(4) 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.

7.5.2 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. In addition to these tests, terminations having a rated internal pressure greater than 100 kPa (15 lb/in^2) shall be subjected to an internal pressure of 2 1/2 times the nominal rating for terminations rated up to 2000 kPa (300 lb/in^2) in accordance with the following:

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

(2) Twenty-four (24) 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.

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

7.6 Dielectric Field Tests. The tests are to be conducted in accordance with 7.1.2 and 7.1.6.

Direct voltage test values up to the maximums listed in Table 1 or 2 may be used with the test set

Table 3
Altitude-Ampacity Correction Factors

Altitude (m)	Altitude (f)	Altitude-Ampacity Correction Factor	Maximum Temperature of the Cooling Air (°C)	(°F)
1000	3300	1.00	40	104
2000	6600	0.99	35	95
3000	9900	0.96	30	86

Table 4
Altitude-Dielectric Strength Correction Factors

Altitude (m)	Altitude (f)	Altitude Correction Factor for Dielectric Strength
1000	3300	1.00
1500	5000	0.95
2100	7000	0.89
3000	9900	0.80

connected for negative polarity. Refer to 6.3 for comments regarding the direct voltage test values.

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

8. Application Guide

8.1 Application at Altitudes Greater Than 1000 m (3300 ft)

8.1.1 Effect on Ampacity. An high-voltage cable termination that depends on air for its cooling medium and is designed for standard temperature rise may be used at altitudes greater than 1000 m provided that the ampacity is reduced by the correction factors listed in Table 3.

The temperature of the cooling air is not likely to exceed the values for the respective altitudes given in Table 3.

8.1.2 Effect on Dielectric Strength. The dielectric strength of a high-voltage cable termination that depends on air for its insulation varies with altitude. Table 4 shows the approximate relative dielectric strength for altitudes above 1000 m at any given temperature.

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