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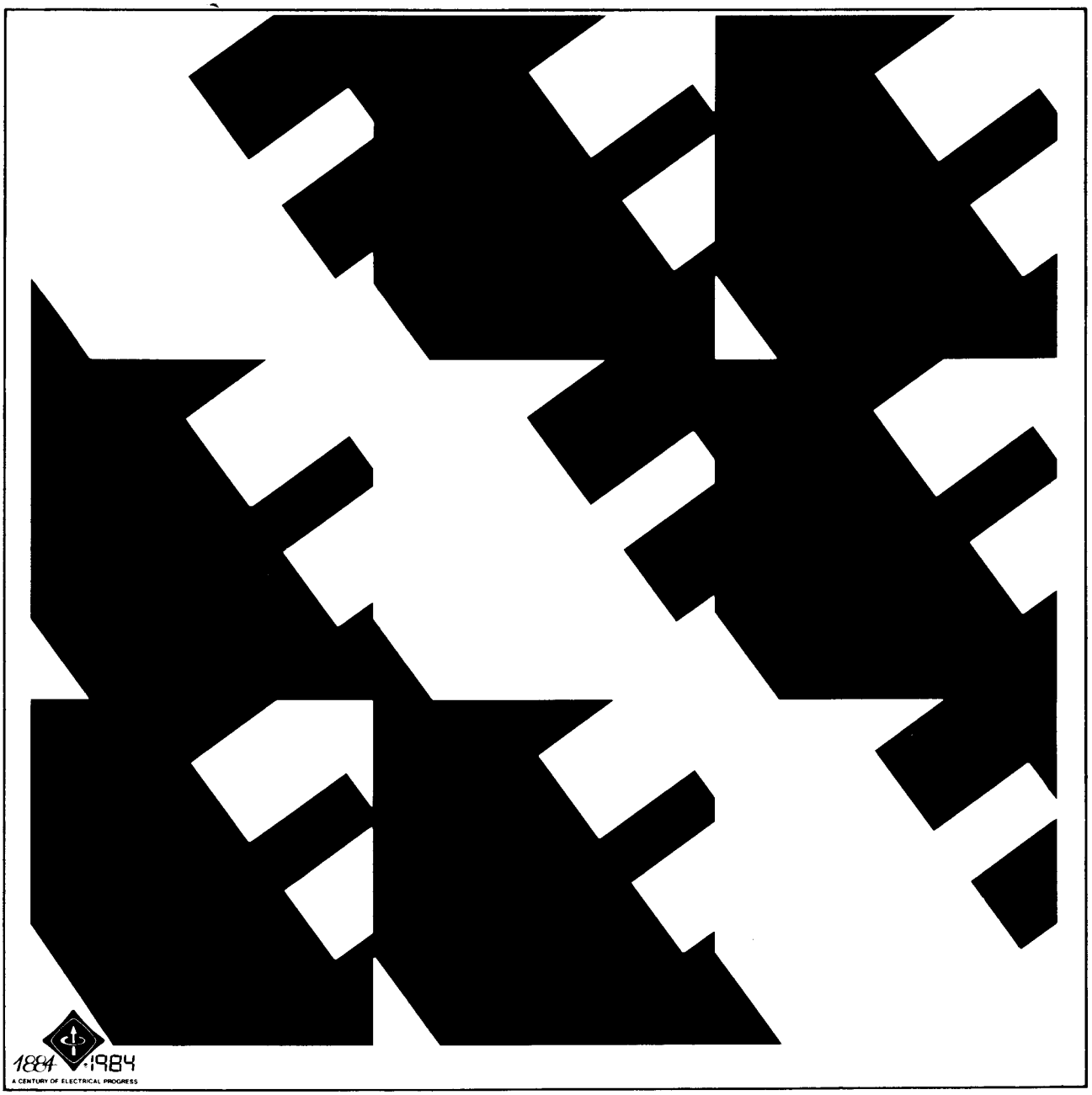
IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations



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

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 [1].

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

2. Service Conditions

2.1 Standard Service Conditions. Devices conforming to this standard shall be capable of successful operation under the following service conditions.

2.1.1 ***Physical Conditions***

(1) Temperature:

(a) The temperature of the cooling medium (ambient temperature) is not less than −30 °C nor more than +40 °C.

(b) The temperature of the cooling medium (ambient inside enclosure) does not exceed 55 °C for apparatus terminations. The devices designed for this service will be connected to the equipment bus which may, at full load, reach a total temperature of 85 °C.

NOTE: IEEE Std 55-1953, Guide for Temperature Correlation in the Connection of Insulated Wire and Cables to Electric Equipment has been prepared for such applications. It is recommended that this guide, as well as the limiting cable conductor temperatures established by AEIC,[1] IPCEA,[2] and other industry accepted committees be reviewed before selecting the size and type of cable and the associated apparatus cable termination. See Section 9, Bibliography.

(2) The altitude does 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 the design or application of the cable terminations, and should be called to the attention of the manufacturer.

2.2.1 ***Physical Conditions***

(1) Ambient temperatures 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.)

(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.

2.2.2 ***System Conditions***

(1) Nominal power system frequency less than 25 Hz or more than 60 Hz.

(2) Poor system voltage waveforms having voltage crest (peak instantaneous) to rms ratios in excess of 2.12.

(3) Unbalanced voltages.

(4) Magnetic forces associated with high momentary currents that may cause abnormal physical strain or internal forces.

3. Definitions

NOTE: The definitions and terminology used herein apply specifically to the cable terminations treated in this standard. For additional definitions see the latest issue of IEEE Std 100-1972 (ANSI C42.100-1972), Dictionary of Electrical and Electronics Terms.

[1] The Association of Edison Illuminating Companies standards are obtainable from Edison Electric Institute, 90 Park Avenue, New York, NY 10016.

[2] The Insulated Power Cable Engineers Association, 192 Washington Street, Belmont, Mass 02178.

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 other current-carrying parts of a cable termination.

field tests. Tests which 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. Terminations for such cables would not be required to provide electric stress control. In such cases, this requirement 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 be operated with two or more pressure zones

RIV (radio influence voltage). 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 the purpose 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 electric 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, and 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 the 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.

Reference IEEE S-135-1, 1962 (IPCEA P-46-426), Power Cable Ampacities — Vol I: Copper Conductors and IEEE S-135-2, 1962 (IPCEA P-46-426), Power Cable Ampacities — Vol II: Aluminum Conductors 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 increases 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 materials should be consulted for the ampacity rating of the design for the intended application with a specific type and size of cable.

It is recommended that the ampacity rating 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

5.1 Class 1 Terminations. The following information shall appear on all Class 1 Termination nameplates, where applicable:

(1) Manufacturer's name, type, and designation number
(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: Some models of Class 1 Terminations may be too small to accommodate a complete nameplate. In such cases, the unit shall be marked in some conspicuous location with at least the designation number and the manufacturer's name or trademark.

5.2 Class 2 Terminations. Some Class 2 Terminations may be field fabricated and, as

such, will not normally carry a nameplate. Preassembled Class 2 Termination nameplates should contain items (1) through (7) inclusive of Section 5.1 unless the termination is too small to feasibly embody a nameplate. In such cases, the unit shall be marked in some conspicuous location with at least the designation number and the manufacturer's name or trademark.

5.3 Class 3 Terminations. Some Class 3 Terminations may be field fabricated and, as such, will not normally carry a nameplate. Preassembled Class 3 Terminations shall be marked in some conspicuous location with at least the designation number and the manufacturer's name or trademark.

6. Test Requirements

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

6.1.1 ***Dielectric Tests*** [see Note (10), Table 1]

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

(2) Power frequency voltage 10 s wet withstand test in accordance with Column 4 of Table 1 and Section 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 and Section 7.4.1.3 (all classes).

(4) Power frequency partial discharge (corona) extinction voltage test in accordance with Columns 7 and 8 of Table 1 and Section 7.4.1.5 if the termination is for use on cable which requires partial discharge tests (all classes), or power frequency RIV test in accordance with Column 6 of Table 1 and Section 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 and Section 7.4.1.6 (all classes).

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

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

6.1.2 ***Pressure Leak Test.*** Class 1 Terminations without a rated internal pressure shall be given pressure leak tests in accordance with Section 7.4.2, Paragraphs (1) and (2). Class 1 Terminations with rated internal pressure shall be given pressure leak tests in accordance with Section 7.4.2, Paragraphs (2) and (3).

6.2 Routine Tests

NOTE: Because of the varieties 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 which will be applicable to every situation. Therefore, other routine tests may be performed as agreed upon by the manufacturer and the user in addition to those listed herewith.

6.2.1 ***Dielectric Test*** [see Note (10), Table 1]. A dielectric test on the termination insulator in accordance with Section 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 Test.*** A pressure leak test on all pressure tight parts and factory assembled seals in accordance with Section 7.5.2 (Class 1).

6.3 Dielectric Field Tests [see Note (10), Table 1]. Field tests are tests which may be made in accordance with Section 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 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 which 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 IPCEA cable specifications. The cable termination manufacturer shall be consulted before conducting any field tests which exceed the values listed in Table 1.

NOTE: Transformers, regulators, and other equipment which 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 such of the following requirements as specified in Section 7.4–7.6.

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 the cable, and the test assembly shall include the standard types of external connectors (aerial lugs).

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.

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-vapor pressure	2.06 kPa	15.45 mmHg	0.6085 inHg
Water resistivity	17 800 Ω · cm	17 800 Ω · cm	7000 Ω · in
Rate of precipitation	5.08 mm/min	5.08 mm/min	0.2 in/min
Angle of precipitation	45°	45°	45°

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

7.2.2 ***Rate of Voltage Application for Power Frequency and Direct Voltage Tests.*** The initial applied voltage shall not be greater than 20 percent of the test voltage. The applied voltage may be quickly raised to 75 percent 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 5 s and 30 s after the 75 percent 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) 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 4-1968 (ANSI C68.1-1968), Techniques for Dielectric Tests.

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 made vary from the standard test conditions given in Section 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

Table 1
Standard Dielectric Tests for High-Voltage Cable Terminations Assembled and Ready for Service (2), (5), (6), (7), (8), (10)

		Power Frequency Voltage Tests (1)						Impulse Voltage Tests (4)		Direct Voltage Test (9)
						Partial Discharge (Corona) Extinction Test				
Insulation Class	Max Design Voltage to Ground	1 min Dry Withstand	10 s Wet Withstand (3)	6 h Dry Withstand	Radio Influence Voltage Dry	Extinction Voltage	Minimum Detector Sensitivity	Lightning Impulse Dry Withstand (BIL)	Switching Impluse Wet (Dry) (3) Withstand (BSL)	15 min Dry Withstand
(kV) Column 1	(kV) Column 2	(kV rms) Column 3	(kV rms) Column 4	(kV rms) Column 5	(μV) Column 6	(kV rms) Column 7	(pC) Column 8	(kV crest) Column 9	(kV crest) Column 10	(kV average) Column 11
2.5	1.6	20	20	10	50	2.0	3.0	60	-	40
5.0	3.2	25	25	15	50	4.5	3.0	75	-	50
8.7	5.5	35	30	25	50	7.5	3.0	95	-	65
15	9.5	50	45	35	50	13	3.0	110	-	75
25	16.0	65	60	55	100	21.5	3.0	150	-	105
34.5	22.0	90	80	75	150	30	3.0	200	-	140
46	29.5	120	100	100	200	40	3.0	250	-	170
69	44.0	175	145	120	300	60	3.0	350	-	245
115	73.0	205	190	145	400	80	3.0	450	-	275
115	73.0	260	230	175	450	100	3.0	550	-	320
138	88.0	310	275	200	500	120	3.0	650	-	355
161	102	365	315	230	500	140	3.0	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 must withstand dry switching impulse voltage tests as noted in brackets in Column 10. See Section 7.4.1.7.

(4) The required lightning and switching impulse voltage values must be met with both positive and negative polarity tests.

(5) On assembled multiple conductor cable terminations the tests are to 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 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 is to be made with negative polarity on the conductor. Refer to Section 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 testing overvoltages 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.

Table 1 (Continued)
Standard Dielectric Tests for High-Voltage Cable Terminations Assembled and Ready for Service (2), (5), (6), (7), (8), (10)

		Power Frequency Voltage Tests (1)						Impulse Voltage Tests (4)		Direct Voltage Test (9)
						Partial Discharge (Corona) Extinction Test				
Insulation Class	Max Design Voltage to Ground	1 min Dry Withstand	10 s Wet Withstand (3)	6 h Dry Withstand	Radio Influence Voltage Dry	Extinction Voltage	Minimum Detector Sensitivity	Lightning Impulse Dry Withstand (BIL)	Switching Impluse Wet (Dry) (3) Withstand (BSL)	15 min Dry Withstand
(kV) Column 1	(kV) Column 2	(kV rms) Column 3	(kV rms) Column 4	(kV rms) Column 5	(μV) Column 6	(kV rms) Column 7	(pC) Column 8	(kV crest) Column 9	(kV crest) Column 10	(kV average) Column 11
230	146	390	380	280	500	values not established		900	-	450
230	146	460	445	310	500	values not established		1050	-	510
345	220	520	-	375	500	values not established		1175	[900]	555
345	220	575	-	375	500	values not established		1300	825	600
345	220	575	-	375	500	values not established		1300	900	600
500	318	575	-	375	500	values not established		1300	[1110]	600
500	318	690	-	440	500	values not established		1550	1050	700
500	318	750	-	475	500	values not established		1675	1110	745
500	318	750	-	475	500	values not established		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 must withstand dry switching impulse voltage tests as noted in brackets in Column 10. See Section 7.4.1.7.

(4) The required lightning and switching impulse voltage values must be met with both positive and negative polarity tests.

(5) On assembled multiple conductor cable terminations the tests are to 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 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 is to be made with negative polarity on the conductor. Refer to Section 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 testing overvoltages 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.

shall be the specified test voltage multiplied by D as determined by Section 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 Sections 7.3.3 and 7.3.4, respectively.

7.3.1.3 *Switching Impulse Voltage Withstand Test.* The applied test voltage shall be the specified test voltage multiplied by D as determined by Section 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 shall be determined as follows:

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

where:

D	= relative air density		
A	= 2.89	for	P in kilopascals
t_0	= 273	for	t in degrees Celsius
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 inHg and 0.6 inHg (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 Section 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 7.2 and Column 3 of Table 1. 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.

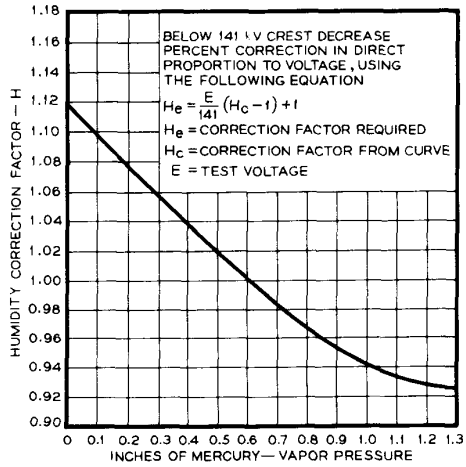

Fig 1
Humidity Correction Factor
1.2 × 50 Impulse

7.4.1.2 *Power Frequency Voltage 10 s Wet Withstand Test.* The test specimen shall be prepared for test in accordance with Section 7.1.1, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 7.2 and Column 4 of Table 1. This test is required on outdoor terminations only. Wet tests shall be made in accordance with the latest issue of IEEE Std 29-1941 (Reaff 1971), Wet Tests (out of print and under revision; reproduction available).

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.

7.4.1.3 *Power Frequency Voltage 6 h Dry Withstand Test.* The test specimen shall be prepared for test in accordance with Section 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 7.2 and Column 5 of Table 1. If the test specimen withstands the required 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 Section 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 7.2 and the latest issue of IEEE Std

454-1973, Recommended Practice for the Detection and Measurement of Partial Discharges (Corona) During Dielectric Tests.

The applied test voltage shall be the maximum design voltage to ground indicated in Column 2 of Table 1. The test specimen shall have successfully passed the test if the radio influence voltage does not exceed the value indicated in Column 6 of Table 1 measured at 1 MHz.

NOTE: Some cables may develop higher influence voltage levels than specified in Column 6. 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 Section 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 7.2 and the latest issue of IEEE Std 454-1973.

The partial discharge detecting apparatus shall be adjusted to have a sensitivity that will permit detection of discharge pulses of at least the value shown in Column 8 of Table 1. The test voltage shall be raised to at least 120 percent of the value listed in Column 7 of Table 1. If partial discharge exceeds the value in Column 8, the test voltage shall be lowered to the value listed in Column 7 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 the value in Column 8 during this period.

NOTE: Some cables may indicate a partial discharge extinction voltage lower than that 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.

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

(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 the latest issue of IEEE Std 4-1968 except that the virtual front time shall not exceed 5 μs in those cases where the capacitance of the test piece is such as to prevent attainment of the IEEE Standard 4-1968 requirement.

(2) Three 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 met the test. If two or three of the applied impulse waves cause flashover, the specimen shall be considered as having failed. If one of the applied impulses causes flashover, three additional impulses shall be applied. If flashover or other dielectric breakdown does not occur, the specimen shall be considered as having met the test.

NOTE: When voltage 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 percent of the required value in Table 1. This procedure 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 Section 7.1.1, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 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 29-1941.

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

(2) Three 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 met the test. If two or three of the applied impulse waves cause flashover, the specimen shall be considered as having failed. If one of the applied impulses causes flashover, three additional impulses shall be applied, If flashover or other dielectric breakdown does not occur, the specimen shall be considered as having met 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 Section 7.1.2, 7.1.3, 7.1.5, and 7.1.6 and tested in accordance with Section 7.2 and Column 11 of Table 1.

(1) A direct voltage of negative polarity, having a ripple of less than 3 percent 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 ***Pressure Leak Tests.*** The test specimen shall be prepared at room temperature in accordance with Section 7.1.2, 7.1.4, and 7.1.7 and tested in accordance with (1) and (2) or (2) and (3) below. See Section 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 paragraph (2).

(1) Apply 200 kPa (30 lb_f/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 which will stain if there is a leak. The test may be made at 100 kPa (15 lb_f/in^2) for 2 h or 50 kPa (7 lb_f/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 which has a viscosity no greater than 125 s (Saybolt Universal) at 25 °C. Apply 2 ½ times rated internal pressure for terminations rated up to 2000 kPa (300 lb_f/in^2) [consult manufacturer for tests on terminations with rated internal pressure greater than 2000 kPa (300 lb_f/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 the 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 Section 7.1.2 and tested in accordance with Section 7.2. Any of the following procedures may be used at the manufacturer's option:

(1) Using parts simulating external metal parts of the fully assembled cable termination apply power frequency voltage for 1 min using the value shown in Column 3 of Table 1 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 and 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 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 Section 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 and 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_f/in^2) shall be subjected to an internal pressure of 2 ½ times the nominal rating for terminations rated up to 2000 kPa (300 lb_f/in^2) in accordance with the following [for terminations with an internal pressure rating greater than 2000 kPa (300 lb_f/in^2), the test pressure should be agreed upon by the purchaser and manufacturer]:

(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 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.

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

Direct voltage test values up to the maximums listed in Table 1 may be used with the test set connected for negative polarity. Refer to Section 6.3 of this standard for comments regarding the direct voltage test values.

The field test voltage may be applied phase-to-phase or phase-to-ground.

8. Application Guide

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

8.1.1 ***Effect on Ampacity.*** A high-voltage cable termination which 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 2.

Table 2
Altitude-Ampacity Correction Factors

Altitude (m)	Altitude (f)	Altitude-Ampacity Correction Factor	Maximum Temperature of the Cooling Air (°C)
1000	3300	1.00	40
1500	5000	0.99	37.5
3000	10000	0.96	30

The temperature of the cooling air is not likely to exceed the values for the respective altitudes given in Table 2.

8.1.2 ***Effect on Dielectric Strength.*** The dielectric strength of a high-voltage cable termination which depends on air for its insulation varies with altitude. Table 3 shows the approximate relative dielectric strength for altitudes above 1000 m at any given temperature.

Table 3
Altitude-Dielectric Strength Correction Factors

Altitude (m)	Altitude (f)	Altitude Correction Factor for Dielectric Strength
1000	3300	1.00
1500	5000	0.95
3000	10000	0.80

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