American National Standard

for electrical power insulators – test methods

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American National Standard for Electrical Power Insulators – Test Methods

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American National Standard

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Foreword

(This Foreword is not part of American National Standard C29.1-1988.)

This standard comprises a manual of procedures to be followed in making tests to determine the characteristics of insulators used on electric power systems. This standard is not an insulator specification, but rather a test method to be used in conjunction with insulator specifications.

American National Standard C29.1-1988 is a revision of American National Standard Test Methods for Electrical Power Insulators, ANSI C29.1-1972. The present revision was prepared by Accredited Standards Committee on Insulators for Electric Power Lines, C29, which is in charge of this work.

Suggestions for improvement of this standard will be welcome. They should be sent to The Manager of Engineering, National Electrical Manufacturers Association, 2101 L St, NW, Washington, DC 20037, Attn: Secretary, ASC C-29.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee C29. Committee approval does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C29 Committee had the following members:

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Contents

American National Standard

for Electrical Power Insulators – Test Methods

1. Scope

This standard comprises a manual of test methods to be followed in making tests to determine the characteristics of electrical power insulators, as defined herein. Individual tests shall be made only when specified.

2. Definitions

NOTE: Definitions as given herein apply specifically to the subject treated in this standard. For additional definitions see American National Standard Dictionary of Electrical and Electronics Terms, ANSI/IEEE 100-1988.

2.1 Insulators and Parts

2.1.1 Insulator. An insulator is a device intended to give flexible or rigid support to electric conductors or equipment and to insulate these conductors or equipment from ground or from other conductors or equipment.

An insulator comprises one or more insulating parts to which connecting devices (metal fittings) are often permanently attached.

2.1.2 Shell. A shell is a single insulating member, having a skirt or skirts without cement or other connecting devices, intended to form a part of an insulator or an insulator assembly.

2.1.3 Pin Insulator. A pin insulator is an insulator having means for rigid mounting on a separable pin.

2.1.4 Post Insulator. A post insulator is an insulator of generally columnar shape, having means for direct and rigid mounting.

2.1.5 Cap and Pin Insulator. A cap and pin insulator is an assembly of one or more shells with metallic cap and pin, having means for direct and rigid mounting.

2.1.6 Line Insulator (Pin, Post). A line insulator is an assembly of one or more shells, having means for semirigidly supporting line conductors.

2.1.7 Apparatus Insulator (Cap and Pin, Post). An apparatus insulator is an assembly of one or more apparatus-insulator units, having means for rigidly supporting electric equipment.

2.1.7.1 Unit. An apparatus-insulator unit is an assembly of one or more shells with attached metal parts, the function of which is to support rigidly a conductor, bus, or other conducting elements on a structure or base member.

2.1.7.2 Stack. An apparatus-insulator stack is a rigid assembly of two or more apparatus-insulator units.

2.1.8 Suspension Insulator. A suspension insulator is an insulator with attached metal parts having means for nonrigidly supporting electric conductors.

2.1.8.1 Unit. A suspension-insulator unit is an assembly of a shell and hardware, having means for nonrigid coupling to other units or terminal hardware.

2.1.8.2 String. A suspension-insulator string is an assembly of two or more suspension insulators in tandem.

2.1.9 Strain Insulator. A strain insulator is an insulator generally of elongated shape, with two transverse holes or slots.

2.1.10 Spool Insulator. A spool insulator is an insulator of generally cylindrical form having an axial mounting hole and a circumferential groove or grooves for the attachment of a conductor.

2.1.11 Wire Holder. A wire holder is an insulator of generally cylindrical or pear shape, having a hole for securing the conductor and a screw or bolt for mounting.

2.2 Low-Frequency Voltages

2.2.1 Low Frequency. Low frequency, as used in this standard, means any frequency between 15 and 100 hertz.

2.2.2 Low-Frequency Flashover Voltage. A low-frequency flashover voltage of an insulator is the root-mean-square value of the low-frequency voltage that, under specified conditions, causes a sustained disruptive discharge through the surrounding medium.

2.2.2.1 Dry flashover voltage tests are tests as described in 4.2.

2.2.2.2 Wet flashover voltage tests are tests as described in 4.3.

2.2.3 Low-Frequency Withstand Voltage. A low-frequency withstand voltage of an insulator is the root-mean-square value of the low-frequency voltage that, under specified conditions, can be applied without causing flashover or puncture.

2.2.3.1 Dry withstand voltage tests are tests as described in 4.4.

2.2.3.2 Wet withstand voltage tests are tests as described in 4.5.

2.2.3.3 Dew withstand voltage tests are tests as described in 4.6.

2.2.4 Low-Frequency Puncture Voltage. A low-frequency puncture voltage of an insulator is the root-mean-square value of the low-frequency voltage that, under specified conditions, causes disruptive discharge through any part of the insulator.

Puncture tests are tests as described in 4.11.

2.3 Impulse Voltages

2.3.1 Impulse Wave. An impulse wave is a unidirectional surge generated by the release of electrical energy into an impedance network.

2.3.2 Impulse Flashover Voltage. An impulse flashover voltage of an insulator is the crest value of the impulse wave that, under specified conditions, causes flashover through the surrounding medium.

2.3.3 Critical Impulse Flashover Voltage. The critical impulse flashover voltage of an insulator is the crest value of the impulse wave that, under specified conditions, causes flashover through the surrounding medium on 50% of the applications.

Impulse flashover voltage tests are tests as described in 4.7.

2.3.4 Impulse Withstand Voltage. The impulse withstand voltage of an insulator is the crest value of an applied impulse voltage that, under specified conditions, does not cause a flashover, puncture, or disruptive discharge on the test specimen.

Impulse withstand voltage tests are tests as described in 4.8.

2.4 Mechanical Strength

2.4.1 Ultimate Mechanical Strength. The ultimate mechanical strength of an insulator is the load at which any part of the insulator fails to perform its function of providing a mechanical support without regard to electrical failure.

Ultimate mechanical-strength tests are tests as described in 5.1.

2.4.2 Combined Mechanical and Electrical Strength (Suspension Insulator). The combined mechanical and electrical strength of a suspension insulator is the mechanical load at which the insulator fails to perform its function either electrically or mechanically, when voltage and mechanical stress are applied simultaneously.

A combined mechanical- and electrical-strength test is a test as described in 5.2.

2.4.3 Time-Load Withstand Strength. The time-load withstand strength of an insulator is the mechanical load that, under specified conditions, can be continuously applied without mechanical or electrical failure.

A time-load withstand test is a test as described in 5.3.

2.4.4 Mechanical-Impact Strength. The mechanical-impact strength of an insulator is the impact which, under specified conditions, the insulator can withstand without damage.

A mechanical-impact strength test is a test as described in 5.1.2.2.

2.5 Miscellaneous

2.5.1 Test Specimen. A test specimen is an insulator which is representative of the product being tested; it is a specimen that is undamaged in any way which would influence the result of the test.

2.5.2 Leakage Distance. The leakage distance of an insulator is the sum of the shortest distances measured along the insulating surfaces between the conductive parts, as arranged for dry flashover test. (Surfaces coated with semiconducting glaze shall be considered as effective leakage surfaces, and leakage distance over such surfaces shall be included in the leakage distance.)

2.5.3 Dry-Arcing Distance. The dry-arcing distance of an insulator is the shortest distance through the surrounding medium between terminal electrodes, or the sum of the distances between intermediate electrodes, whichever is the shorter, with the insulator mounted for dry flashover test.

2.5.4 Radio-Influence Voltage. The radio-influence voltage of an insulator is the radio-frequency voltage measured under specified conditions.

Radio-influence voltage tests are tests as described in 4.9.

3. Test-Specimen Mounting for Electrical Tests

3.1 Suspension Insulators

3.1.1 Mounting Arrangement. Unless otherwise specified, the test specimen (unit or string) shall be suspended vertically at the end of a grounded conductor so that the vertical distance from the uppermost point of the insulator hardware to the supporting structure shall be not less than 3 feet (914 mm).

3.1.2 Energized Electrode. The energized or bottom electrode or conductor shall be a straight, smooth rod or tube having an outside diameter not less than 3/4 inch (19 mm) nor more than 1-1/2 inches (38 mm). It shall be coupled to the lower integral fitting of the test specimen so that the distance from the lowest edge of the insulator shell to the upper surface of the electrode shall be between 0.5 and 0.7 of the diameter of the lowest insulator. The conductor shall be horizontal and at right angles to the axis of the test specimen. The conductor shall be of such length that flashover will not be initiated at the electrode ends.

3.1.3 Proximity of Other Objects. No objects, other than parts of the test assembly, shall be nearer the test specimen or energized electrodes than 1-1/2 times the test-specimen dry-arcing distance, with a minimum allowable distance of 3 feet (914 mm).

3.2 Line Insulators (Pin, Post)

3.2.1 Mounting Arrangement (Crossarm). Unless otherwise specified, the supporting crossarm shall be a horizontal, straight, smooth, grounded, metallic tube or structural member having a horizontal width not less than 3 inches (76 mm) nor more than 6 inches (152 mm). It shall be of such length that flashover will not be initiated at its ends.

3.2.2 Mounting Pin (If Required). When a separable pin is required, the test specimen shall be mounted vertically on a 1-inch (25-mm) diameter metal pin of such length that the shortest dry-arcing distance from the upper electrode and connected metallic parts to the supporting crossarm shall be 25% greater than the similar distance to the pin. The pin shall be coaxial with the test specimen. Insulators having integrally assembled means for mounting on a crossarm shall be mounted vertically and directly on the test crossarm.

3.2.3 Energized Electrode. The energized or top electrode or conductor shall be a horizontal round rod or tube placed at right angles to the supporting crossarm, and of a diameter not less than 1/2 inch (13 mm). It shall be of such length that flashover will not be initiated at its ends. The conductor shall be placed in the top conductor groove of the test specimen. When there is no top conductor groove, the conductor shall be placed in the other means provided for the conductor support. If a tie wire is to be used, the conductor shall be secured by means of at least two turns of wire not smaller than No. 8 AWG (American Wire Gage), the ends being closely wrapped around the conductor on each side of the insulator.

3.2.4 Proximity of Other Objects. No objects, other than parts of the test assembly, shall be nearer the test specimen or energized electrodes than 1-1/2 times the test-specimen dry-arcing distance, with a minimum allowable distance of 3 feet (914 mm).

3.3 Apparatus Insulators (Cap and Pin, Post)

3.3.1 Mounting Arrangement. Unless otherwise specified, the test specimen shall be mounted vertically upright on a horizontal, grounded 10-inch (254-mm) channel, with the channel flanges projecting down. A subbase shall be used if the insulator characteristics are predicated on its use. The supporting channel shall be of such length that flashover will not be initiated at its ends, and its top surface shall be not less than 3 feet (914 mm) above the ground.

3.3.2 Energized Electrode. The energized or top electrode or conductor shall be a horizontal round rod or tube at right angles to the supporting channel, and of a diameter approximately 5% of the test-specimen dry-arcing distance within the limits of 4-1/2 inches (114 mm) maximum and 1/2 inch (13 mm) minimum. The length of the conductor shall be such that flashover will not be initiated at its ends. It shall be mounted directly in contact with the top integral fitting of the test specimen, and with its horizontal axis in the same vertical plane as the vertical axis of the test specimen.

3.3.3 Proximity of Other Objects. No objects, other than parts of the test assembly, shall be nearer the test specimen or energized electrodes than 1-1/2 times the test-specimen dry-arcing distance, with a minimum allowable distance of 3 feet (914 mm).

3.4 Strain Insulators

3.4.1 Mounting Arrangement. Unless otherwise specified, the test specimen shall be mounted in a position with its major axis at 45 degrees from the vertical (for wet flashover test, the major axis shall be at right angles to the spray direction, and the axis of the upper conductor hole or slot shall be horizontal), using flexible metal conductors of approximately 50% of the hole diameter. The conductors shall be clamped with guy clamps, spaced from the test specimen at a distance not less than the test-specimen length. Mechanical tension sufficient to avoid appreciable sag in the setup shall be applied to the test specimen. The lower conductor shall be grounded.

3.4.2 Proximity of Other Objects. No objects, other than parts of the test assembly, shall be nearer the test specimen or energized electrodes than 1-1/2 times the dry-arcing distance of the test specimen, with a minimum allowable distance of 1 foot (305 mm).

3.5 Spool Insulators

3.5.1 Mounting Arrangement. The test specimen shall be mounted horizontally or vertically [as specified in Fig. 1 through 5 of American National Standard for Wet-Process Porcelain Insulators (Spool Type), ANSI C29.3-1986], and in contact with two smooth metallic straps 1-1/2 inches (38 mm) wide and of any suitable thickness. A rod of suitable diameter shall pass through the axial hole of the test specimen and one end of each of the straps. The straps shall extend horizontally in one direction from the rod and remain parallel to each other for a distance from the test specimen of not less than the height of the test specimen. The other ends of the straps shall be suitably connected to a grounded support.

3.5.2 Energized Electrode. The energized electrode shall consist of one turn of No. 8 AWG conductor placed around the wire groove and served back on itself. This conductor shall be carried away from the test specimen parallel to and in a direction opposite to the supporting straps.

3.5.3 Proximity of Other Objects. No objects, other than parts of the test assembly, shall be nearer to the test specimen or energized electrodes than 1 foot (305 mm).

4. Electrical Tests

4.1 General. Test specimens used for the tests in this section shall have clean insulating surfaces.

4.2 Low-Frequency Dry Flashover Voltage Tests

4.2.1 Mounting Arrangement. The test-specimen mounting for dry flashover voltage tests shall be in accordance with Section 3.

4.2.2 Voltage Application. The initial applied voltage may be quickly raised to approximately 75% of the expected average dry flashover voltage value. The continued rate of voltage increase shall be such that the time to flashover will be not less than 5 seconds nor more than 30 seconds after 75% of the flashover value is reached.

4.2.3 Dry Flashover Voltage Value.[1] The dry flashover voltage value of a test specimen shall be the arithmetical mean of not less than five individual flashovers taken consecutively. The period between consecutive flashovers shall be not less than 15 seconds nor more than 5 minutes.

4.2.4 Corrections

4.2.4.1 Standard Conditions. Dry flashover voltage values shall be corrected in accordance with American National Standard Techniques for High-Voltage Testing, ANSI/IEEE 4-1978, except the following standard conditions shall apply:

Barometric pressure:	29.92 inches of mercury (10.086×10^4 pascals)
Temperature:	77°F (25°C)
Vapor pressure:	0.6085 inch of mercury (2.051×10^3 pascals)

[1] Probable variation: Due to inaccuracies of correction methods, difficulties of precise calibrations, and other uncontrollable conditions, a variation of ± 5% from the probable true average dry flashover voltage value may occur in tests conducted in one laboratory. Values obtained by tests conducted in different laboratories may vary by ± 8%.

Humidity and relative air density corrections shall be calculated in accordance with 4.2.4.2 and 4.2.4.3.

4.2.4.2 Humidity. The dry flashover voltage value shall be corrected to standard humidity conditions in accordance with the curves in Fig. 1. (Humidity correction curves are not available for spool and strain insulators.)

The vapor pressure shall be determined by the following procedure:

Humidity shall be measured with wet- and dry-bulb thermometers, the air being circulated past the thermometers at a velocity of 3 meters (9.84 feet), or more, per second, or with the sling psychrometer. The measurements shall be reduced to vapor pressure with the assistance of the Smithsonian Meteorological Tables or by the following formulas:

For U.S. customary units:

$$P_h = P_s - 0.000367b(t - t')\left(1 + \frac{t' - 32}{1571}\right)$$

where

P_h = vapor pressure, in inches of mercury
P_s = pressure, in inches of mercury, of saturated aqueous vapor at temperature t'
b = barometric pressure, in inches of mercury
t = temperature of air, in degrees Fahrenheit
t' = wet-bulb temperature of air, in degrees Fahrenheit

For SI units:

$$P_h = P_s - 0.0876b(t - t')(1 + 0.00115t')$$

where

P_h = vapor pressure, in pascals
P_s = pressure, in pascals, of saturated aqueous vapor at temperature t'
b = barometric pressure, in pascals
t = temperature of air, in degrees Celsius
t' = wet-bulb temperature of air, in degrees Celsius

4.2.4.3 Air Density. The dry flashover voltage value shall be corrected to standard atmospheric temperature and pressure conditions. To do so, divide the measured voltage value by the relative air density correction factor, K_d, calculated in one of the following ways:

For U.S. customary units:

$$K_d = 17.95 \frac{P}{(460 + T)}$$

where

P = barometric pressure in inches of mercury
T = air temperature in degrees Fahrenheit

For SI units:

$$K_d = 0.002955 \frac{P}{(273 + T)}$$

where
P = barometric pressure in pascals
T = air temperature in degrees Celsius

or

$$K_d = 0.392 \frac{P}{(273 + T)}$$

where
P = barometric pressure in millimeters of mercury
T = air temperature in degrees Celsius

4.3 Low-Frequency Wet Flashover Voltage Tests

4.3.1 Mounting Arrangement. The test specimen mounting for wet flashover voltage tests shall be in accordance with Section 3.

4.3.2 Precipitation. The precipitation shall be applied in accordance with subsection 1.3.3.2 and Table 1.2 (Practice in USA) of ANSI/IEEE 4-1978.

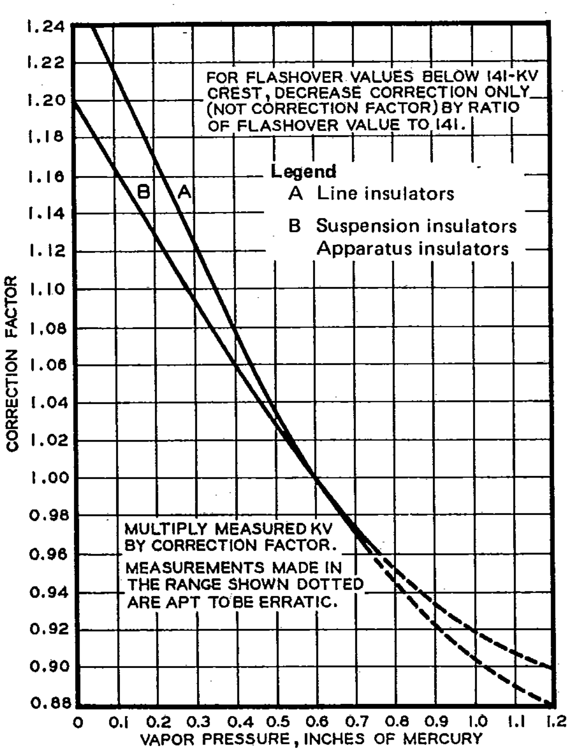


Fig. 1
Low-Frequency Humidity Correction Factors

4.3.3 Preparation of Test Specimen. The preparation of the test specimen shall be in accordance with subsection 1.3.3.2 of ANSI/IEEE 4-1978.

4.3.4 Voltage Application. At not less than 1 minute after the final adjustment of the spray, the applied voltage may be raised quickly to approximately 75% of the expected average wet flashover voltage value. The continued rate of voltage increase shall be such that the time to flashover will be not less than 5 seconds nor more than 30 seconds after 75% of the wet flashover voltage value is reached.

4.3.5 Wet Flashover Voltage Value.[2] The wet flashover voltage value of a test specimen shall be the arithmetical mean of not less than five individual flashovers taken consecutively. The period between consecutive flashovers shall be not less than 15 seconds nor more than 5 minutes.

4.3.6 Corrections. Corrections shall be made in accordance with 4.2.4, except that no correction for humidity shall be made.

4.4 Low-Frequency Dry Withstand Voltage Tests

4.4.1 Mounting Arrangement. The test-specimen mounting for dry withstand voltage tests shall be in accordance with Section 3.

4.4.2 Voltage Application. 75% of the rated dry withstand voltage may be applied in one step and gradually raised to the required value in not less than 5 nor more than 30 seconds.

4.4.3 Test Voltage and Time. The test voltage, which is the rated dry withstand voltage with appropriate atmospheric corrections applied, shall be held on the test specimen for 1 minute.

4.4.4 Corrections. Corrections shall be made in accordance with 4.2.4. The test voltage applicable to existing atmospheric conditions is obtained from the rated withstand voltage, as given for standard atmospheric conditions, by use of the following equation:

$$V = V_s \times \frac{\delta}{H}$$

where
V = test voltage, in kilovolts, applied to test specimen
V_s = rated withstand voltage, in kilovolts
δ = relative air density
H = humidity correction factor applicable for the particular test specimen

[2] Probable variation: Due to variations in water spray, inaccuracies of correction methods, difficulties of precise calibrations, and other uncontrollable conditions, a variation of ± 8% from the probable true average wet flashover voltage value may be expected in tests conducted in one laboratory. Values obtained by tests conducted in different laboratories may vary by ± 12%.

4.5 Low-Frequency Wet Withstand Voltage Tests

4.5.1 Mounting Arrangement. The test-specimen mounting for wet withstand voltage tests shall be in accordance with Section 3.

4.5.2 Precipitation. The precipitation shall be applied in accordance with subsection 1.3.3.2 and Table 1.2 (Practice in USA) of ANSI/IEEE 4-1978.

4.5.3 Preparation of Test Specimen. The preparation of the test specimen shall be in accordance with subsection 1.3.3.2 of ANSI/IEEE 4-1978.

4.5.4 Voltage Application. 75% of the rated wet withstand voltage may be applied in one step and gradually raised to the required value in not less than 5 nor more than 30 seconds.

4.5.5 Test Voltage and Time. The test voltage, which is the rated wet withstand voltage, with appropriate atmospheric corrections applied, shall be held on the test specimen for 10 seconds.

4.5.6 Corrections. Corrections shall be in accordance with 4.2.4, except that no correction shall be made for humidity. The test voltage applicable to existing atmospheric conditions is obtained from the rated withstand voltage, as given for standard atmospheric conditions, by use of the following equation:

$$V = V_s \times \delta$$

where

V = test voltage, in kilovolts, applied to test specimen

V_s = rated withstand voltage, in kilovolts

δ = relative air density

4.6 Low-Frequency Dew Withstand Voltage Tests

4.6.1 Preparation of Test Specimen. The test specimen shall be placed in a chamber having a temperature of from -10°C to -15°C (14°F to 5°F) until the specimen is thoroughly cooled. (Cooling may take 10 to 12 hours.)

4.6.2 Mounting Arrangement. The test specimen shall be mounted in accordance with Section 3 in a test chamber having a temperature of approximately 77°F (25°C). The relative humidity in the test chamber shall be approximately 100%. This may be obtained by passing live steam at atmospheric pressure into the chamber.

4.6.3 Voltage Application. The voltage shall be raised rapidly to dew withstand test voltage, while the test specimen is completely covered with dew. The time to raise the voltage shall be not more than 20 seconds.

4.6.4 Test Voltage and Time. The test voltage, which is the rated dew withstand voltage with appropriate atmospheric corrections applied, shall be held on the test specimen for 10 seconds.

4.6.5 Corrections. Corrections shall be made in accordance with 4.5.6.

4.7 Impulse Flashover Voltage Tests

4.7.1 General. Impulse flashover voltage tests are made under dry conditions only.

4.7.2 Mounting Arrangement. The test-specimen mounting for impulse flashover voltage tests shall be in accordance with Section 3.

4.7.3 Impulse Voltage Wave. All tests shall be made with a 1.2 × 50-microsecond wave, in accordance with ANSI/IEEE 4-1978.

4.7.4 Critical Impulse Flashover Voltage Value.[3] The critical impulse flashover voltage shall be determined in accordance with ANSI/IEEE 4-1978.

4.7.5 Volt-Time Flashover Curves.[3] The volt-time flashover curves shall be determined in accordance with ANSI/IEEE 4-1978.

4.7.6 Corrections

4.7.6.1 Critical Impulse Flashover Voltage. The critical impulse flashover voltage value shall be corrected to standard conditions in accordance with 4.2.4, except that the curves in Fig. 2 shall be used.

4.7.6.2 Volt-Time Curves. The full air-density corrections shall be applicable. The humidity correction shall be made as follows:

(1) When the critical flashover voltage value occurs at more than 10 microseconds, full corrections shall be applied to all values with time lags of 10 microseconds or more. When flashover above critical voltage occurs at less than 10 microseconds, the correction shall be reduced in the direct ratio that the time to flashover bears to 10 microseconds.

(2) When the critical flashover voltage value occurs at less than 10 microseconds, the correction shall be reduced in the direct ratio that the time to flashover bears to the time at the critical flashover.

4.8 Impulse Withstand Voltage Tests

4.8.1 General. Impulse withstand voltage tests are made to determine that the test specimen is capable of withstanding a specified impulse voltage.

4.8.2 Mounting Arrangement. The test-specimen mounting for impulse withstand voltage tests shall be in accordance with Section 3.

4.8.3 Corrections. Corrections shall be made in accordance with 4.4.4, except that the curves in Fig. 2 shall be used.

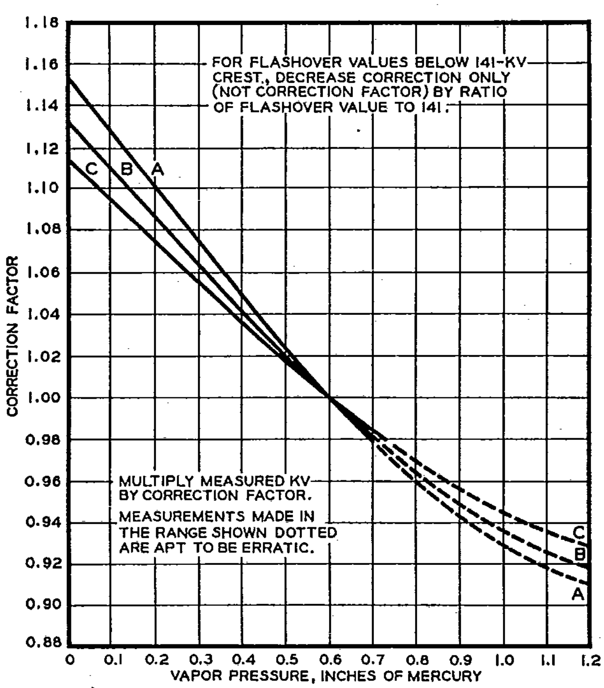
[3] Probable variation: Due to inaccuracies of correction methods, difficulties of precise calibrations, and other uncontrollable conditions, a variation of ± 5% from the probable true average impulse critical flashover voltage value may be expected in tests conducted in one laboratory. Values obtained by tests conducted in different laboratories may vary by ± 8%. In volt-time curves, similar variations are to be expected at points near the impulse critical flashover voltage value, with considerably larger variations involved as the time to breakdown decreases.

4.8.4 Voltage Application. Impulse withstand voltage tests shall be made with an impulse of that polarity which produces the lower flashover voltage on the test specimen. Three consecutive impulses shall be applied to the test specimen. The crest voltage of each shall be not less than the specified impulse withstand voltage, with appropriate atmospheric corrections.

4.9 Radio-Influence Voltage Tests

4.9.1 Mounting Arrangement. The test-specimen mounting shall be in accordance with Section 3, except that the clearance to objects, other than parts of the test assembly, shall in no case be less than 3 feet (914 mm) per 100 kilovolts of test voltage.

All hardware associated with the test circuit shall be relatively free of radio influence at a voltage 10% higher than the voltage at which the tests are to be performed.



Legend

A Suspension insulators, positive wave

B Line insulators, positive wave
Suspension insulators, negative wave
Apparatus insulators, positive wave

C Line insulators, negative wave
Apparatus insulators, negative wave

Fig. 2
Impulse Humidity Correction Factors

4.9.2 Equipment. The equipment used in making the radio-influence voltage tests shall be in accordance with NEMA 107-1964 (R1987), Methods of Measuring Radio Noise.[4]

4.9.2.1 Wave Shape. The wave shape of the applied voltage shall be a sine wave of acceptable commercial standards in accordance with ANSI/IEEE 4-1978.

4.9.2.2 Supply-Voltage Frequency. The frequency of the supply voltage shall be 60 hertz ± 5%.

4.9.3 Atmospheric Conditions. Tests shall be conducted under atmospheric conditions prevailing at the time and place of test, but it is recommended that tests be avoided when the vapor pressure exceeds 0.6 inch of mercury (2.02×10^3 pascals). Since the effects of humidity and air density upon the radio-influence voltage are not definitely known, no correction factors are recommended for either at the present time. However, it is recommended that barometric pressure and dry- and wet-bulb thermometer readings be recorded so that if suitable correction factors should be determined, they could be applied to previous measurements.

4.9.4 Precautions in Making Radio-Influence Voltage Tests. The following precautions should be observed when making a radio-influence voltage test on a test specimen:

(1) The test specimen should be at approximately the same temperature as the room in which the test is made.

(2) The test specimen should be clean.

(3) In some cases it may be found that the radio-influence voltage falls off rapidly after the 60-hertz voltage has been applied for a short time. In such cases it is permissible to stabilize conditions by preexciting the test specimen at normal operating voltage for a period not to exceed 5 minutes before proceeding with the tests.

4.9.5 Methods of Making Tests

4.9.5.1 Radio-Influence Voltage. The specified voltage shall be applied to the test specimen, and the radio-influence voltage shall be measured in microvolts at the specified radio frequency. It is considered impractical to read radio-influence test voltages that are less than 10 microvolts.

4.9.5.2 Radio-Influence Characteristics. The radio-influence characteristics are determined by plotting the test voltage against the corresponding radio-influence voltage.

4.10 Visual Corona Test

4.10.1 General. To assist in locating a source of

[4] Available from National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, D.C. 20037.

radio-influence voltage, a corona test may be performed. The test shall be made in a thoroughly darkened room.

4.10.2 Mounting Arrangement. The test-specimen mounting shall be in accordance with 4.9.1.

4.10.3 Procedure. A voltage well above the corona point shall be applied and slowly lowered until all discharges disappear from the test specimen. The point of disappearance shall be the corona voltage. The observer's eyes shall be thoroughly accustomed to the darkened room before making visual observations.

4.11 Puncture Tests

4.11.1 Mounting Arrangement. Puncture tests shall be performed on fully assembled insulators only. The test specimen shall be inverted and immersed in insulating oil having a sufficient dielectric strength to prevent external flashover of the specimen. The oil shall be at least 6 inches (152 mm) deep over all parts of the test specimen.

Voltage shall be applied between the integrally assembled electrode (cap and pin) on all units having these parts. In the case of pin insulators having no conducting electrodes at one or both terminals, electrodes shall be provided as follows:

An electrode in the pinhole shall be provided by setting a metallic thimble, with suitable conducting material, such as cement or alloy. The thimble shall be provided with a close-fitting pin for attaching the conductor. The top of the test specimen shall be coated with conducting material to a diameter of approximately 1 inch (25 mm) larger than the test-specimen head.

4.11.2 Voltage Application. Voltage shall be applied between the electrodes, as described in 4.11.1. The initial applied voltage may be raised quickly to the rated dry flashover voltage of the test specimen. The voltage shall then be raised at the rate of approximately 10 000 volts every 15 seconds to the value at which puncture occurs.

4.11.3 Percent Average Variation of Puncture Voltage.[5] The percent average variation of the puncture voltage is determined as follows:

Let

$V_1, V_2, V_3, \ldots, V_n$ = individual puncture voltage values, in kilovolts

V = average puncture voltage, in kilovolts

then

$$V = \frac{(V_1 + V_2 + V_3 + \ldots + V_n)}{n}$$

Let

$a_1 = V - V_1$
$a_2 = V - V_2$
$a_3 = V - V_3$
$A_n = V - V_n$

NOTE: Consider all these values of a as positive; that is, neglect the signs.

Let

a = average variation, in kilovolts
A = percent average variation

then

$$a = \frac{(a_1 + a_2 + a_3 + \ldots + a_n)}{n}$$

$$A = \frac{100a}{V}$$

[5] If test-equipment limitations are such that the test specimen cannot be punctured, the puncture value shall be considered to be the maximum available applied test voltage, provided this value exceeds 150% of the puncture rating.

5. Mechanical Tests

5.1 Ultimate Mechanical-Strength Tests

5.1.1 General. Mechanical load shall be applied to the test specimen in the manner prescribed in 5.1.1 through 5.3.2. The load shall be started at zero and smoothly brought up in a practically stepless variation to the failure point. The load may be increased rapidly to approximately 75% of rated strength of the insulator. The rate of increase of load from 75% of rating to failure is given in Table 1.

5.1.2 Suspension Insulators

5.1.2.1 Tensile Strength. Mechanical-tensile load shall be applied between terminal fittings in line with the axis of the test specimen.

Table 1
Rate of Increase of Load

Class of Insulator	Type of Test	Increase in Load per Minute in Percentage of Rated Strength	
		Min	Max
Suspension	Tensile	15	30
Line	Cantilever	30	60
Apparatus	Cantilever	30	60
Apparatus	Torsion	30	60
Apparatus	Tensile	15	30
Apparatus	Compression	15	30

5.1.2.2 **Mechanical-Impact Strength.** The test specimen shall be mounted in the specified test machine in the specified manner under a tensile load of approximately 2000 pounds-force (8896 N). The bearing point of the pendulum shall be so adjusted that, when released, the copper nose will strike the outer rim of the shell squarely in a direction parallel to the axis of the unit and towards the cap. The test specimen shall receive an impact of the specified severity by releasing the pendulum when its shaft is opposite the corresponding mark on the indicating scale. The pendulum shall be released with no imparted acceleration. After receiving the specified impact, the test specimen shall be tested for soundness by momentary flashover.

5.1.3 **Line Insulators (Pin, Post) (Cantilever Strength).** Mechanical load shall be applied in line with the side groove of the test specimen and normal to the axis of the pinhole. The load at the tie-wire groove may be applied by means of a loop of flexible stranded cable or the equivalent. The mounting pin, connecting hardware, and linkages between the test specimen and the testing machine shall be such that no appreciable deflection takes place at values up to the failure point of the test specimen. Insulators whose design incorporates self-contained metal caps, mounting bases, pins, or conductor clamps, shall be tested with this hardware, using a suitable rigid support.

5.1.4 **Apparatus Insulators (Cap and Pin, Post)**

5.1.4.1 **Cantilever Strength.** Cantilever-strength tests shall be made with the test specimen adequately secured to the testing machine. The load shall be applied normal to the axis of the test specimen at the specified point of application. In demonstrating stack ratings, one insulator unit may be used. The equivalent lever arm may be obtained by bolting a bar or pipe of proper length and stiffness to the test specimen.

5.1.4.2 **Torsional Strength.** Torsional-strength tests shall be made with the test specimen adequately secured to the testing machine. The torsional load shall be applied to the test specimen through a torque member so constructed that the test specimen is not subjected to any cantilever stress.

5.1.4.3 **Tensile Strength.** Tensile-strength tests shall be made with the test specimen adequately secured to the testing machine. The load shall be applied in line with the axis of the test specimen.

5.1.4.4 **Compression Strength.** Compression-strength tests shall be made by applying load in compression in line with the axis of the test specimen.

5.1.5 **Strain Insulators (Tensile Strength).** Mechanical load shall be applied in line with the main axis of the test specimen, using flexible, stranded, steel cable. Each cable loop shall be secured with clamps so positioned that the distance between the edge of the nearest clamp and the end of the test specimen is the same as the length of the test specimen. The diameter of the cable used should not exceed 50% of the diameter of the hole in the test specimen.

5.1.6 **Spool Insulators (Transverse Strength).** The test specimen shall be mounted between close-fitting parallel straps, using a through bolt of the same diameter as that for which the test specimen is designed. The straps and connecting linkage shall be such that no appreciable deflection will take place. Mechanical load shall be applied in the plane of the external wire groove. The load shall be applied by means of a loop of flexible, stranded, steel cable. The diameter of the cable shall not exceed the radius of the wire grooves.

5.1.7 **Wire Holders**

5.1.7.1 **Tensile Strength.** The mounting screw or bolt shall be installed in such a manner that the mounting surface of the test specimen does not touch the support. Load shall be applied in line with the axis of the mounting screw or bolt, using a loop of flexible, stranded, steel cable, the diameter of which shall not exceed the radius of the wire hole in the insulator. The loop shall be clamped, with the inside edge of the nearest clamp placed 9 inches (229 mm) from the end of the insulator.

5.1.7.2 **Cantilever Strength.** The mounting screw or bolt shall be held rigidly in such a manner that the mounting base of the test specimen seats squarely against the face of the plate. Load shall be applied in a plane parallel to the mounting surface, passing through the center of the wire groove, using the flexible loop arrangement described in 5.1.7.1.

5.2 Combined Mechanical- and Electrical-Strength Test (Suspension Insulators).

Load shall be applied as described in 5.1.1 and 5.1.2.1. Simultaneously, a low-frequency voltage of not less than 75% of the rated dry flashover voltage shall be applied to the test specimen.

5.3 Time-Load-Withstand-Strength Test

5.3.1 **Mounting Arrangement.** The test-specimen mounting shall be in accordance with the pertinent provisions in 5.1.

5.3.2 **Loading.** The specified load shall be applied smoothly, without undue vibration or shock, and maintained for the specified period. After the load has been removed, the test specimen shall be checked for electrical soundness by being subjected to momentary flashover. Test specimens having more than one shell shall have each shell checked individually for electrical soundness.

5.4 Porosity Test

5.4.1 **Preparation of Test Specimens.** Freshly broken fragments of the insulator, having clean surfaces exposed, shall be used for this test. At least 75% of the surface area shall be free from glaze or other treatment. Fragments approximately 1/4 inch (6 mm) in the smallest dimension up to 3/4 inch (19 mm) in the largest dimension are recommended.

5.4.2 Testing Solution. For this test, a solution consisting of 1 gram of basic fuchsine dye dissolved in 1 liter of 50% alcohol shall be used. If a denatured alcohol is used, one should be selected which does not react with the dye to cause fading of the color.

5.4.3 Procedure. The test specimens shall be completely immersed in the testing solution within a pressure chamber. A minimum pressure of 4000 pounds-force per square inch (27 600 kN/m^2) shall be applied for not less than 5 hours, or an optional test at minimum 10 000 pounds-force per square inch (68 900 kN/m^2) for not less than 2 hours may be used. At the conclusion of the pressure application, the test specimens shall be thoroughly dried and broken for examination.

5.4.4 Interpretation of Results. Penetration into small fissures formed in preparing the test specimens shall be disregarded. Porosity is indicated by penetration of the dye into the test specimen to an extent visible to the unaided eye.

5.5 Thermal Test

5.5.1 General. The thermal test shall consist of alternate immersions of the test specimen in hot and cold water.

5.5.2 Testing Arrangement. The test specimens shall be arranged so that they are not in contact with each other and so that air shall not be entrapped during immersion. Free circulation of water shall be provided. Test specimens shall be at least 2 inches (51 mm) from the walls of the tank.

5.5.3 Equipment. Each bath shall have a weight of water at least 10 times the weight of the test specimen immersed. Either natural or forced circulation may be used to maintain the temperature of all parts of the bath within ± 4°F (2°C) of the specified value. The recorded temperature shall be measured at least 4 inches (102 mm) from the heating or cooling elements.

5.5.4 Method of Making Test. The test specimen shall first be immersed in a hot water bath for 10 minutes. It shall then be withdrawn and immersed in a cold water bath for 10 minutes. Not more than 5 seconds shall elapse in transferring the test specimen from one bath to another. After the specified number of hot and cold cycles, the test specimen shall be tested for electrical soundness by momentary flashover.

5.6 Pinhole-Gaging Test

5.6.1 General. When the threaded pinholes of pin insulators are gaged, the specified pinhole gage shall be used.

5.6.2 Test Procedure. The gage shall be screwed into the test specimen until the gage is tight. The distance from the bottom of the pinhole to the point where the gage stops, as indicated by the plunger and scale on the gage, shall be read.

The gage shall be removed from the test specimen, and the number of revolutions of the gage required to release it from the pinhole shall be counted.

6. Galvanizing Test

Test for thickness of coating shall be in accordance with Standard Measurement of Coating Thickness by the Magnetic Method: Nonmagnetic Coatings of Magnetic Base Metals, ASTM B 499-75 (1987).

7. Routine Tests

7.1 Electrical Tests. Flashover tests on shells or insulators may be made in accordance with either the procedure in 7.1.1 or in 7.1.2.

7.1.1 High-Frequency Test

7.1.1.1 Method 1. The shells or insulators shall be subjected to a damped high-frequency voltage sufficient to cause flashover for from 3 to 5 seconds. The frequency shall be approximately 200 kilohertz in damped trains.

7.1.1.2 Method 2. The shells or insulators shall be subjected to a high-frequency discharge from a transformer adjusted to a no-load voltage of not less than 115% of the low-frequency dry flashover of the shells or insulators, this test to be continued for a period of from 3 to 5 seconds. The frequency superimposed upon the low-frequency voltage shall be higher than 100 kilohertz.

7.1.2 Low-Frequency Test. The shells or insulators shall be subjected to vigorous dry flashover for from 3 to 5 minutes. The voltage control shall be such that a continual flashover occurs and divides uniformly over the shells or insulators under test.

7.2 Mechanical Tests

7.2.1 Suspension Insulators. Prior to or simultaneous with the final electrical test, the assembled suspension insulators shall be given a tensile-strength test 3 seconds in duration, at the specified value, applied in line with the axis of the insulator.

7.2.2 Apparatus Insulators. Prior to or simultaneous with the final electrical test, the assembled apparatus insulators shall be given a tensile-strength test 3 seconds in duration, at the specified value, applied in line with the axis of the insulator.

8. Revision of American National Standards Referred to in This Document

When the following American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, Inc, the revision shall apply:

ANSI C29.3-1986, Wet-Process Porcelain Insulators (Spool Type)

ANSI/IEEE 4-1978, Techniques for High-Voltage Testing

ANSI/IEEE 100-1988, Dictionary of Electrical and Electronics Terms

American National Standards

The standard in this booklet is one of 8000 standards approved to date by the American National Standards Institute.

The Standards Institute provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation "American National Standards."

Each standard represents general agreement among maker, seller, and user groups as to the best current practice with regard to some specific problem. Thus the completed standards cut across the whole fabric of production, distribution, and consumption of goods and services. American National Standards, by reason of Institute procedures, reflect a national consensus of manufacturers, consumers, and scientific, technical, and professional organizations, and governmental agencies. The completed standards are used widely by industry and commerce and often by municipal, state, and federal governments.

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