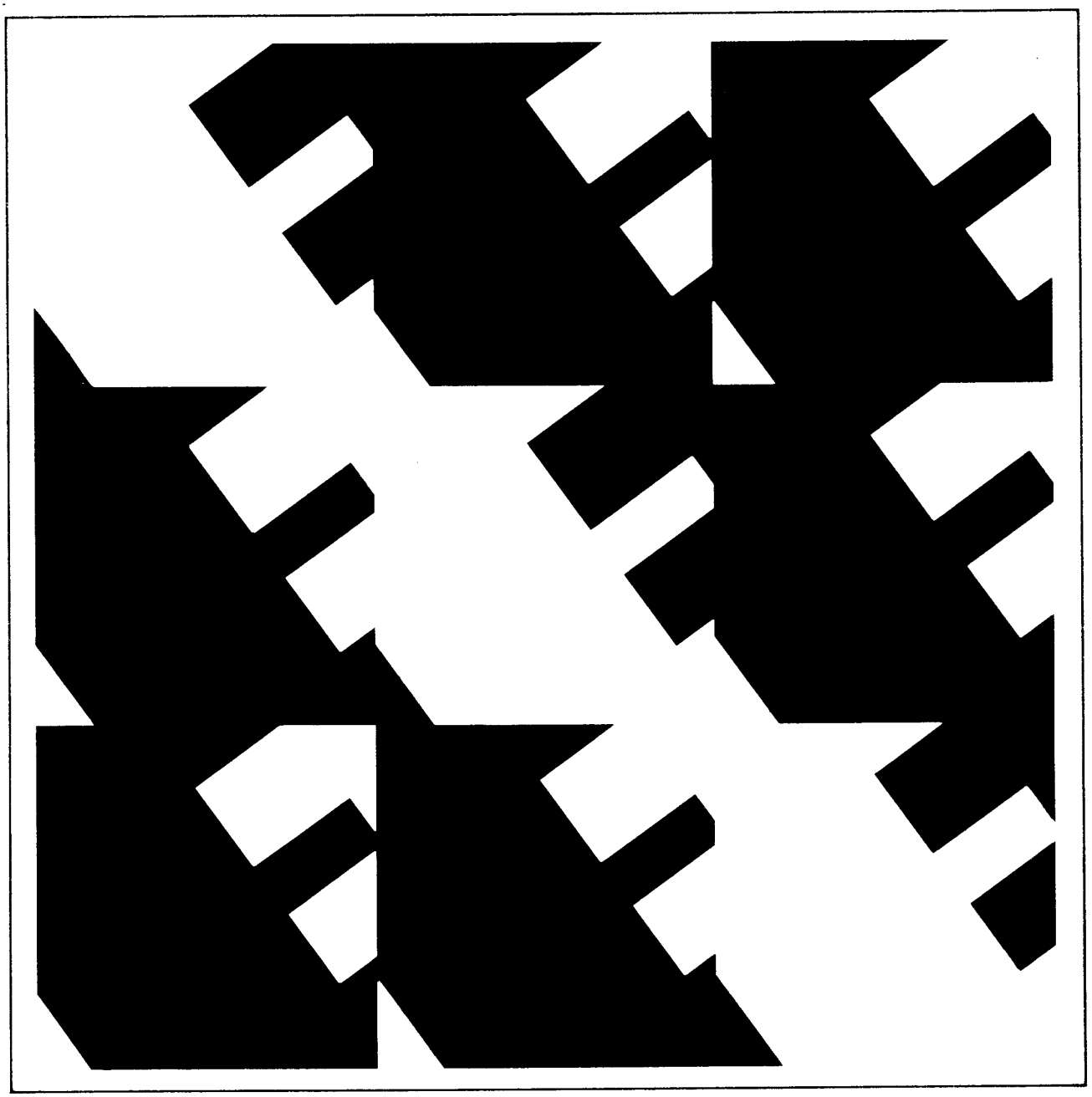
AMERICAN NATIONAL STANDARD

ANSI/IEEE Std 21-1976
(Supersedes ANSI/IEEE Std 21-1964)

IEEE Standard General Requirements and Test Procedure for Outdoor Apparatus Bushings



ANSI/IEEE Std 21-1976

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

November 30, 1976

SH06452

ANSI
C76.1-1976
IEEE
Std 21-1976
(Supersedes ANSI
C76.1-1964, IEEE
Std 21-1964)

An American National Standard

IEEE General Requirements and Test Procedure for Outdoor Apparatus Bushings

Approved June 3, 1976

IEEE Standards Board

Secretariat

Institute of Electrical and Electronics Engineers, Inc

Approved July 23, 1976

American National Standards Institute

Published by

The Institute of Electrical and Electronics Engineers, Inc

American National Standard

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Foreword

[This foreword is not part of IEEE Std 21-1976, IEEE General Requirements and Test Procedure for Outdoor Apparatus Bushings (ANSI C76.1-1976).]

This document is based on the standard practices in the United States for outdoor apparatus bushings. It is the result of joint efforts of professional engineers, manufacturers, and users working together in an American National Standards Committee C76 under the auspices of the American National Standards Institute (ANSI). The work was initially carried out under the auspices of the American Institute of Electrical Engineers (AIEE) [now the Institute of Electrical and Electronics Engineers (IEEE)] and the National Electrical Manufacturers Association (NEMA). The original standard, approved in 1942 as AIEE Standard 21 (which became American National Standard for Apparatus Bushings, ANSI C76.1-1943) was prepared by the Joint Committee on Bushing Standardization of the Electric Machinery, Power Transmission and Distribution, and Protection Devices Committees of the AIEE.

A supplement and partial revision, ANSI C76.1a-1958, Electrical and Dimensional Characteristics of Outdoor Apparatus Bushings (used with Power Circuit Breakers and Outdoor Transformers), was prepared by the NEMA Joint Sections Committee on Outdoor Apparatus Bushings (composed of representatives of the High Voltage Insulator Section, Power Circuit Breakers Group, Switchgear Section, and the Transformers Section. It resulted from work by the regional associations of electrical utilities and filled the user's needs for dimensional interchangeability.

At the time of this supplement, ANSI Sectional Committee C76 foresaw the need for a general revision and updating of the standard and asked AIEE and NEMA to submit recommendations. In NEMA implementation of this request was undertaken by a Subcommittee of the Joint Sections Committee on Outdoor Apparatus Bushings and resulted in a proposal which was approved in February 1960 by the Codes and Standards Committee for submission to C76 as the NEMA recommendation. In the AIEE a Joint Working Group consisting of members of the Transformer and Dielectric Test Committee of the Transformer Committee and of the Power Circuit Breaker Committee was established and developed a recommendation which was submitted to ANSI Committee C76 in July 1960. The AIEE proposal was subsequently reviewed by the West Coast Subcommittee of the AIEE Transformers Committee which developed additional recommendations and submitted them to ANSI Committee C76 in November 1960. ANSI Committee C76 appointed a special Working Group for Revision of ANSI C76.1-1943 to consolidate the several proposals and recommendations. This became IEEE Std 21-1964 and was approved June 9, 1964, as ANSI C76.1-1964, Standard Requirements and Test Code for Outdoor Apparatus Bushings; it was reaffirmed in 1970.

Work on a revision was initiated in Committee C76 in August 1968. A decision was made to separate the standard into three parts: the first (C76.1) to cover the general requirements and test procedures, the second (C76.2) to cover explicit ratings and dimensions, and the third to be an application guide. The latter is still under consideration. Other changes in this revision included: (1) test procedure updating, (2) adding 362 through 800 kV maximum system voltage bushing electrical ratings with wet switching impulse test values and coordination with switching surge sparkover values of arresters, and (3) establishing dual current ratings for 115 through 196 kV insulation class bushings, since circuit breakers have a lower temperature rise, permitting a larger current rating for a given maximum ambient temperature compared to transformers.

At the time it approved this standard, American National Standards Committee C76 on Apparatus Bushing Standardization had the following personnel:

W. F. Giles, *Chairman* **C. R. Muller,** *Secretary*

Organization Represented	*Name of Representative*
Electric Light and Power Group	R. L. Lindsey R. E. Minkwitz G. J. Paul K. G. Adgate (*Alt*) F. W. Rempe (*Alt*) D. O. Craghead W. G. Patton (*Alt*)

Organization Represented	*Name of Representative*
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National Electrical Manufacturers Association	J. K. Easley
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	F. W. Benke (*Alt*)
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Bonneville Power Administration	W. F. Rakel
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Ohio Brass Company	F. R. Stockum
Lapp Insulator Division, Interpace Corporation	G. L. Atkinson

When the IEEE Standards Board approved this standard on June 3, 1976, it had the following membership:

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An American National Standard

IEEE General Requirements and Test Procedure for Outdoor Apparatus Bushings

1. Scope and Purpose

1.1 Scope. This standard applies to outdoor power class apparatus bushings which have basic impulse insulation levels of 110 kV and above for use as components of oil-filled transformers, oil-filled reactors, and oil circuit breakers.

This standard does not apply to the following:

(1) High-voltage-cable terminations (potheads)

(2) Bushings for instrument transformers

(3) Bushings for test transformers

(4) Bushings in which the major insulation is provided by a gas

(5) Bushings applied with gaseous insulation (other than air at atmospheric pressure) external to the bushing

(6) Bushings for distribution class circuit breakers and transformers

(7) Bushings for automatic circuit reclosers and line sectionalizers

(8) Bushings for oil-less and oil-poor apparatus

1.2 Purpose. This standard defines the special terms used, service conditions, rating, general requirements, and test procedure. See IEEE Std 24-1976, Electrical, Dimensional, and Related Requirements for Outdoor Apparatus Bushings (ANSI C76.2-1976), for specific listings of values of electrical and mechanical characteristics, dimensions, and other related test and quality control requirements which are described in this standard.

2. Referenced Documents

The following standards form a part of this standard to the extent specified herein.

Institute of Electrical and Electronics Engineers (IEEE)

IEEE Std 100-1972, Dictionary of Electrical and Electronics Terms (ANSI C42.100-1972)

IEEE Std 4-1969, Techniques for Dielectric Tests [ANSI C68.1-1968 (R1973)]

IEEE Std 332-1972, Techniques for Switching Impulse Testing (ANSI C68.2-1972)

IEEE Std 24-1976, Electrical, Dimensional, and Related Requirements for Outdoor Apparatus Bushings (ANSI C76.2-1976)

When the preceding standards are superseded by a revision approved by the IEEE, the revision shall apply.

National Electrical Manufacturers Association (NEMA)

Publication 107-1964 (R1971), Methods of Measurement of Radio Influence Voltage of High Voltage Apparatus

3. Definitions

For terms not specifically defined in this standard see IEEE Std 100-1972, Standard Dictionary of Electrical and Electronics Terms (ANSI C42.100-1972).

ambient temperature. The temperature of the surrounding air that comes in contact with the device or equipment in which the bushing is mounted.

basic impulse insulation level (BIL). A reference insulation level expressed as the impulse crest voltage of the 1.2 × 50 μs wave which the bushing will withstand when tested in accordance with specified conditions.

bushing. An insulating structure, including a through conductor or providing a central passage for such a conductor, with provision for

mounting on a barrier, conducting or otherwise, for the purpose of insulating the conductor from the barrier and conducting current from one side of the barrier to the other.

bushing potential tap. An insulated connection to one of the conducting layers of a bushing providing a capacitance voltage divider to indicate the voltage applied to the bushing.

bushing test tap. An insulated connection to one of the conducting layers of a bushing for the purpose of making insulation power factor tests.

capacitance (of bushing). (1) The main capacitance, C_1, of a condenser bushing is the value in picofarads between the high-voltage conductor and the potential tap or the test tap. (2) The tap capacitance, C_2, of a condenser bushing is the value in picrofarads between the potential tap and mounting flange (ground). (3) The capacitance, C, of a bushing without a potential or test tap is the value in picofarads between the high-voltage conductor and the mounting flange (ground).

composite bushing. A bushing in which the major insulation consists of several coaxial layers of different insulation materials.

compound-filled bushing. A bushing in which the space between the inside surface of the weather casing and the major insulation (or conductor where no major insulation is used) is filled with insulating compound.

condenser bushing. A bushing in which cylindrical conducting layers are arranged coaxially with the conductor within the insulating material for the purpose of controlling the electric field of the bushing.

creep distance. The distance measured along the external contour of the weather casing separating the metal parts which have the operating line-to-ground voltage between them.

insulation class (bushing). The voltage by which the bushing is identified and which designates the level on which the electrical performance requirements are based.

interchangeable bushing. A bushing designed for use in both power transformers and circuit breakers.

ionization. The formation of limited avalanches of electrons developed in insulation due to an electric field. **Ionization current** is the result of capacitive discharges in an insulating medium due to electron avalanches under the influence of an electric field.

NOTE: The occurrence of such currents may cause (1) radio noise; (2) damage to insulation.

major insulation. Insulating material internal to the bushing between the line potential conductor and ground.

oil. As used in this standard, oil refers to mineral transformer oil.

oil-filled bushing. A bushing in which the space between the inside surface of the weather casing and the major insulation (or conductor where no major insulation is used) is filled with oil.

oil-impregnated paper-insulated bushing. A bushing in which the major insulation is provided by paper impregnated with oil.

power factor (of insulation). The ratio of the power dissipated in the insulation, in watts, to the product of the effective voltage and current in voltamperes, when tested under a sinusoidal voltage and prescribed conditions.

NOTE: The insulation power factor is equal to the cosine of the phase angle between the voltage and the resulting current when both the voltage and current are sinusoidal.

radio influence voltage. A high-frequency voltage generated as a result of ionization, which may be propagated by conduction, induction, radiation, or a combined effect of all three.

resin-bonded paper-insulated bushing. A bushing in which the major insulation is provided by paper bonded with resin.

solid bushing. A bushing in which the major insulation is provided by a ceramic or analogous material.

striking distance. The shortest tight string distance measured externally over the weather casing between the metal parts which have the operating line-to-ground voltage between them.

4. Service Conditions

4.1 Usual Service Conditions. Apparatus bushing conforming to this standard shall be suitable for operation at their ratings, provided:

Table 1
Altitude Correction Factors

Altitude		Current Correction Factor	Maximum Cooling Air Temperature (°C)	Dielectric Strength Correction Factor
feet	meters			
3300	1000	1.00	40	1.00
5000	1500	0.99	37.5	0.95
10000	3000	0.96	30	0.80

(1) The temperature of the ambient air is not above 40°C or below −30°C

(2) The altitude does not exceed 1000 m (3300 ft)

(3) The temperature of the insulation oil in which the lower end of the bushing is immersed does not exceed 95°C averaged over a 24 h period to obtain normal life expectancy in both 55°C and 65°C rise oil-filled transformers

(4) For bushings in oil circuit breakers, the temperature of the insulating oil in which the lower end is immersed does not exceed 80°C

(5) The external terminal and bus connections, when operated alone at rated current, does not exceed 30°C rise

(6) The bushing is mounted at an angle of inclination to the vertical not exceeding 20°

4.2 Unusual Service Conditions. Bushings complying with this standard may be applied at higher ambient temperatures or at higher altitudes than specified in Section 4.1, but their performance may be affected.[1]

4.2.1 *Applications at Altitudes Greater than 1000 m (3300 ft)*

(1) Bushings which depend upon air as a cooling medium and are designed for specified temperature rise may be used at altitudes greater than 1000 m (3300 ft) without exceeding temperature limits, provided that either or a combination of the following prevail:

(a) The current to be carried is equal to or less than the rated continous current of the bushing multiplied by the appropriate altitude correction factor as given in Table 1 in the column labeled "Current Correction Factor"

(b) The temperature of the cooling air is not likely to exceed the values given in Table 1 in the column labeled "Maximum Cooling Air Temperature" for the respective altitudes given

(2) The dielectric strength of bushings, which depend upon air for insulation, varies with altitudes; the appropriate relative dielectric strength at altitudes above 1000 m (3300 ft) is given in Table 1 in the column labeled "Dielectric Strength Correction Factor"

4.3 Other Conditions that May Affect Design and Application. Where other unusual conditions exist, they should be brought to the attention of those responsible for the design and application of the equipment. Examples of such conditions are:

(1) Damaging fumes or vapors, excessive abrasive or conducting dust, explosive mixtures of dust or gases, steam, salt spray, excessive moisture or dripping water, etc

(2) Abnormal vibration, shocks, or tilting

(3) Excessively high or low ambient temperature conditions

(4) Unusual transportation or storage conditions

(5) Unusual space limitations

(6) Abnormal temperature applications

(7) Unusual conditions or operating duty

5. Rating

A designation of performance characteristics based upon definite conditions shall include the following where applicable:

(1) Rated maximum line-to-ground voltage

(2) Rated frequency

(3) Rated dielectric strength

(4) Rated continuous current

(5) Rated short time current

[1] Details will be considered in the Application Guide, which is under consideration.

5.1 Rated Maximum Line-to-Ground Voltage. The rated maximum line-to-ground voltage is the highest rms voltage between the conductor and the mounting flange at which the bushing is designed to operate.

5.2 Rated Frequency. Rated frequency is the frequency at which the bushing is designed to operate.

5.3 Rated Dielectric Strength. The rated dielectric strength of a bushing is expressed in terms of specified values of voltage withstand tests which the bushing shall withstand without puncture or flashover of any of its parts and shall include the following.

5.3.1 *Rated Low-Frequency Test Voltage*

5.3.1.1 *Dry Test.* The test for a dry bushing is the test voltage which a new bushing shall be capable of withstanding for 1 min without flashover or puncture when tested under the conditions specified in Section 7.4.1.

5.3.1.2 *Wet Test.* The test for a wet bushing is the test voltage which a new outdoor bushing shall be capable of withstanding for 10 s without flashover or puncture when tested under the conditions specified in Section 7.3.1.1.

5.3.2 *Rated Full-Wave Lightning-Impulse (BIL) Voltage.* The rated full-wave lightning-impulse voltage is the crest value of a standard 1.2 × 50 μs impulse voltage wave which a new bushing shall be capable of withstanding without flashover or puncture when tested under the conditions specified in Section 7.3.1.2.

5.3.3 *Rated Chopped-Wave Lightning-Impulse Voltage.* The rated chopped-wave lightning-impulse voltage is the crest value of a standard 1.2 × 50 μs impulse voltage wave which a new bushing shall be capable of withstanding for a specified time from the start of the wave at virtual time zero until flashover of a rod gap or coordinating gap occurs when tested under the conditions specified in Section 7.3.1.3.

NOTE: The rated chopped-wave impulse withstand test voltages shall consist of the values shown in IEEE Std 24-1976 (ANSI C76.2-1976), Tables 1 and 2.

5.3.4 *Rated Switching-Impulse Voltage.* The rated switching-impulse voltage is the crest value of the voltage wave which a new bushing shall be capable of withstanding without puncture or damage when tested under the conditions specified in Section 7.3.1.4.

5.4 Rated Continuous Current. The rated continuous current is the rms current at rated frequency which a bushing shall be required to carry continuously under specified conditions without exceeding the permissible temperature limitations when tested under the conditions specified in Section 7.3.3.

5.4.1 *Temperature Limitations.* The hottest spot temperature rise of the current-carrying parts in contact with temperature index 105 insulation shall not exceed 65°C over ambient air. The temperature of noncurrent-carrying metal parts in contact with temperature index 105 insulation shall not exceed 105°C:

(1) When the lower end of the bushing is immersed in oil having a rise of 55°C over the ambient air and the bushing is carrying the rated current for transformer applications

(2) When the lower end of the bushing is immersed in oil having a rise of 40°C over ambient air and the bushing is carrying the rated current for circuit breaker applications

6. General Requirements

This standard includes a number of general requirements which are applicable to certain classes and ratings of outdoor power apparatus bushings. Specific values for these requirements are listed elsewhere in this standard or in IEEE Std 24-1976 (ANSI C76.2-1976) under corresponding headings.

6.1 Electrical Requirements

(1) Voltage withstand tests.
(2) Radio influence voltage.
(3) Ionization.
(4) Power factor.
(5) Creep distance.

6.2 Mechanical Requirements

(1) Dimensions.
(2) Cantilever strength.
(3) Internal Pressure.
(4) Draw lead bushing cap pressure.
(5) Bushing potential tap. All bushings 115 kV and above insulation class shall be provided with a bushing potential tap. These taps shall be either normally grounded or normally ungrounded. Refer to IEEE Std 24-1976 (ANSI C76.2-1976), Fig 1, where type A shows normally grounded tap outlet dimensions and type B shows normally ungrounded tap outlet dimensions.

6.3 Nameplate Markings. The following information where applicable shall appear on all bushing nameplates. On small 15 kV bushings, each bushing shall be marked in a conspicuous place with the manufacturer's specific identification.

(1) Manufacturer's name, identification number, type, year of manufacture, and serial number

(2) Insulation class for Table 1 and rated maximum line-to-ground voltage for Table 2 bushings of IEEE Std 24-1976 (ANSI C76.2-1976)

(3) Rated continuous current (see the following note)

NOTE: Where bushings have a dual continuous current rating, the nameplate shall indicate the rating for (1) oil circuit breaker application, (2) power transformer application.

(4) Rated full-wave impulse withstand voltage (BIL)

(5) Capacitance, C_1 and C_2, on all bushings equipped with a potential tap

(6) Power factor referred to 25°C

(7) Length of bushing below mounting gasket (L)

7. Test Procedure

This test procedure summarizes the various tests which are made on power apparatus bushings, describes accepted methods used in making the tests, and specifies the tests which will demonstrate ratings in this standard. It does not preclude the use of other equivalent or more effective methods of demonstrating ratings. These tests are divided into the following classifications:

(1) Design tests

(2) Production tests

7.1 Preparation of Bushings for Tests. The test specimen shall comply with the following requirements.

(1) Except for mechanical tests, bushings shall be mounted on a supporting structure and in the position approximating that for which they were designed and with their ends in media of the type in which they are intended to operate

(2) Bushings shall be completely assembled with all elements normally considered essential parts of the bushings

(3) The bushing shall be dry and clean

(4) Voltage withstand tests shall be made with the bushing mounted on a relatively flat metallic grounded plate so as to prevent an arc from striking any grounded object other than the grounded parts of the bushing or the relatively flat mounting plate; the test connection to the bushing shall be made so that it does not appreciably affect the test results

(5) For internal ionization tests suitable external shielding may be applied to eliminate the adverse effects of external corona on the air end terminal.

7.2 Standard Test Conditions and Equipment

7.2.1 *General Requirements.* All bushings for dielectric tests shall be prepared and measurements and corrections for conditions made in accordance with appropriate sections of this standard. The following shall be in accordance with applicable sections of IEEE Std 4-1969, Techniques for Dielectric Tests [ANSI C68.1-1968 (R1973)], and IEEE Std 332-1972, Techniques for Switching Impulse Testing (ANSI C68.2-1972):

(1) Definitions of tests

(2) General test procedures

(3) Characteristics and tolerances of waveshapes

(4) Method of measurement

(5) Standard atmospheric and precipitation conditions (United States and Canadian practice)

(6) Rate and duration of voltage application for low-frequency tests

7.2.2 *Test Equipment.* Test equipment for measuring radio influence voltage and ionization test equipment and measurements of radio influence voltage of ionization shall conform to NEMA Publication 107-1964 (1971), Methods of Measurement of Radio Influence Voltage of High Voltage Apparatus, or any equivalent method which permits accurate observation of the applied voltage and ionization measurement.

7.2.3 *Correction Factors*

7.2.3.1 *Applicability.* When actual test conditions vary from standard test conditions, correction factors d for variation in relative air density and k for variation in humidity may be applied to correct applied withstand voltages to withstand voltages at standard conditions. Correction factors shall be determined in accordance with IEEE Std 4-1969 (ANSI

C68.1-1968) and shall be applied as follows:

(1) Dry 1 min low-frequency withstand tests: No corrections

(2) Wet 10 s low-frequency withstand tests: Correction factor *d* may be applied

(3) Impulse withstand tests: Correction factors *d* and *k* may be applied at either positive or negative polarity, but not at both

(4) Wet switching-impulse withstand tests: At the present time, atmospheric correction factors for switching-impulse have not been standardized; during the interim period, reference should be made to the literature

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

7.2.3.3 *Humidity Vapor Pressure.* The vapor pressure at the time of test should preferably be between 7.6 and 15.2 mmHg (0.3 and 0.6 in) (1.0 and 2.0 kPa).

7.2.3.4 *Water Resistivity.* If water of the resistivity falling within standard conditions is not readily available, water of other resistivity may be used if suitable and agreed upon correction factors are applied.

7.2.3.5 *Standard Atmospheric Conditions and Correction Factors Used in Previous Tests.* Retest of existing equipment designs shall not be required when ANSI C68[2] adopts the standard atmospheric conditions given in IEC Publication 60-1962, High-Voltage Test Techniques,[3] or when it redefines correction factors from time to time in the future.

7.3 Design Tests. Design tests are those made to determine the adequacy of the design of a particular type, style, or model of power apparatus bushing to meet its assigned ratings and to operate satisfactorily under normal service conditions or under special conditions, if specified. Design tests are made only on representative bushings to substantiate the ratings assigned to all other bushings of basically the same design. These tests are not intended to be made as a part of normal production testing.

The applicable portions of these design tests may also be used to evaluate modifications of a previous design and to assure that performance has not been adversely affected. Test data from previous similar designs may be used for current designs where appropriate.

The following design tests shall apply.

7.3.1 *Dielectric Withstand Voltage Tests*

(1) Low-frequency wet withstand voltage

(2) Full-wave lightning-impulse withstand voltage

(3) Chopped-wave lightning-impulse withstand voltage

(4) Switching-impulse withstand voltage (only for applications on maximum system voltage 362 kV and above)

7.3.1.1 *Low-Frequency Wet Withstand Voltage.* Tests for wet bushings shall be made in accordance with IEEE Std 4-1969 (ANSI C68.1-1968). If the bushing withstands the specified test voltage for the specified time, it shall be considered as having passed the test. If a single flashover occurs, the test may be repeated. If the repeat test also results in flashover, the bushing shall be considered to have failed.

7.3.1.2 *Full-Wave Lightning-Impulse Withstand Voltage.* A standard 1.2 × 50 μs wave as described in IEEE Std 4-1969 (ANSI C68.1-1968) shall be used. At least three positive and three negative impulses having crest values of the specified value shall be applied to the bushing. If flashover occurs on only one test during any group of three consecutive tests, three more tests shall be made. If the bushing successfully withstands all three tests of the second group of tests, the single flashover in the one group shall be considered as a random flashover and the bushing shall be considered as having successfully passed the test. If an additional flashover occurs, the bushing shall be considered to have failed.

7.3.1.3 *Chopped-Wave Lightning-Impulse Withstand Voltage.* The specified waves shall be obtained by flashover of the bushing or by flashover of a rod gap in parallel with the bushing so as to chop the wave on its tail. A minimum of three impulses shall be applied to the bushing. If permanent damage results, the bushing shall be considered to have failed.

7.3.1.4 *Switching-Impulse Withstand Voltage.* This test shall apply only to transformer bushings intended for use at maximum system

[2] American National Standards Committee C68, Techniques for Dielectric Tests.

[3] Atmospheric conditions:

Standard	Temperature (°C)	Humdity (absolute) ($g/m^3 H_2O$ vapor)	Barometric Pressure (mmHg)
US Std	25	15	760
IEC Publ 60 (62)	20	11	760

voltages of 362 kV and above. A positive polarity standard 250/2500 impulse, as described in IEEE 332-1972 (ANSI C68.2-1972) shall be applied under wet conditions described as United States and Canadian practice in IEEE Std 4-1969 (ANSI C68.1-1968). At the rated withstand voltage, a statistical evaluation of the test data must establish the probability of the withstand value to be 90 percent or greater.

7.3.2 *Mechanical Tests.*

(1) Draw lead bushing cap pressure test

(2) Cantilever strength tests

7.3.2.1 *Draw Lead Bushing Cap Pressure Test.* The bushing cap assembly shall be capable of withstanding an internal pressure test (gage) of 20 lbf/in^2 (138 kPa) without leakage.

7.3.2.2 *Cantilever Strength Test.* The bushing shall be rigidly mounted with load applied normal to the longitudinal axis of the bushing and at the midpoint of the thread or threaded terminals and at the lower terminal plate on bushings so equipped. Tests shall be applied to the top and bottom terminals of the bushing but not simultaneously.

During the cantilever test the bushing internal pressure (gage) shall be 10 lbf/in^2 (69 kPa). The temperature shall be approximately 25°C. The specified load shall be applied for a period of 1 min. Permanent deformation, measured at the bottom end 1 min after removal of the load, shall not exceed 0.03 in (0.76 mm). There shall be no leakage at either end at any time either during or within 10 min after removal of the load.

7.3.3 *Thermal Tests.* Thermal tests shall apply to bottom connected bushings only. The bushing shall be tested in the following manner:

(1) The connections to the bushings shall be made in such a manner that they will not appreciably affect the bushing temperature rise. The lower end of the bushing shall be immersed to the minimum oil level at test ambient temperature.

(2) Rated continuous current at rated frequency shall be applied continuously until thermal conditions become constant or until the measured temperature does not increase by more than 1°C per hour. Operating voltage need not be applied during the test.

(3) The temperatures during the test shall be measured with mercury or alcohol thermometers, or thermocouples, in sufficient number to detect the hottest accessible part.

The temperature of the hottest point on the conductor of the bushing shall be determined by thermocouples soldered or suitably fixed along the length of the conductor or imbedded in the insulation.

(4) The bulbs of thermometers used for taking temperature shall be covered by felt pads secured to the apparatus by oil putty or adhesive tape. This protection shall not interfere with cooling of the surface being measured. Dimensions of felt pads shall be approximately 1 by 1 by 1/8 in thick (25 by 25 by 3 mm thick).

(5) The ambient temperature shall be determined as that of the surrounding air by taking the average reading of three thermometers, placed at least 2 ft (610 mm) away from any part of the bushing on test. The thermometers shall be located at heights corresponding to the top, middle, and lower end of the bushing. The temperature of the surrounding air shall not be less than 10°C nor more than 40°C. No corrections for variations of the ambient temperature within this range shall be applied.

(6) The temperature of the lower end (oil bath) shall be measured by a thermocouple or thermometer immersed approximately 2 in (50 mm) below the oil surface and located approximately 6 in (150 mm) from the surface of the bushing.

(7) Requirements, as outlined in Section 5.4.1, shall be fulfilled or the bushing shall be considered to have failed.

7.4 **Production Tests.** Production tests are those tests made to check the quality and uniformity of the workmanship and materials used in the manufacture of power apparatus bushings.

The following tests, where applicable shall be made on each bushing:

7.4.1 *Low-Frequency Dry Withstand Voltage.* The bushing shall withstand the specified test voltage for the specified time. If a single flashover occurs, the test may be repeated. If the repeat test also results in flashover, the bushing shall be considered to have failed.

7.4.2 *Capacitance, C_1 and C_2, Measurement.* Capacitance C_1 between the bushing high-voltage conductor and the potential or test tap, and capacitance C_2 between the potential tap and ground shall be measured.

7.4.3 *Power Factor.* The power factor between the bushing conductor and the bush-

ing potential tap, test tap, or grounded flange shall be measured.

7.4.4 *Insulation Quality.* Tests shall be made to determine that potentially damaging ionization does not occur in the major insulation either at rated line-to-ground voltage or during the low-frequency dry withstand voltage test. The manufacturer may select one or more of the following methods to obtain a measurement that is meaningful:

(1) Radio influence voltage test at rated line-to-ground voltage and ambient temperature to the limits specified in IEEE Std 24-1976 (ANSI C76.2-1976)

NOTE: This test is most meaningful for resin-bonded paper insulated bushings.

(2) Power factor and capacitance measurement of the C_1 component of the major insulation at rated maximum line-to-ground voltage after the low-frequency dry withstand voltage test.

NOTE: This test is most meaningful for oil-impregnated paper bushings.

(3) Ionization detection which can be demonstrated to produce accurate observation of the applied voltage and the resultant ionization measurement

7.4.5 *Potential Tap Withstand Voltage.* A low-frequency withstand test of 20 kV in oil, or in air, shall be applied to or induced at the potential tap for 1 min with the bushing mounting flange grounded.

7.4.6 *Mechanical Tests.* An internal pressure test (gage) shall be applied at 20 lbf/in^2 (138 kPa) without resultant leakage.