



Designation: D 4566 – 90

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St., Philadelphia, Pa. 19103
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Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable¹

This standard is issued under the fixed designation D 4566; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 These test methods cover procedures for electrical testing of thermoplastic insulations and jackets used on telecommunications wire and cable and for the testing of electrical characteristics of completed products. To determine the procedure to be used on the particular insulation or jacket compound, or on the end product, reference should be made to the specification for that product.

1.2 The test methods appear in the following sections of this standard:

Test Method	Sections
Electrical Tests of Insulation—In Process:	4–8
D-C proof test	8
Insulation defect or fault rate	7
Spark test	6
Electrical Tests of Completed Wire and Cable:	9–37
Attenuation	26
Capacitance deviation	19
Capacitance difference	20
Capacitance unbalance—pair-to-ground	22
Capacitance unbalance—pair-to-pair	21
Capacitance unbalance—pair-to-support wire	23
Coaxial capacitance (capacitance to water)	17
Conductor continuity	11
Conductor resistance	13
Conductor resistance unbalance (pairs)	15
Continuity of other metallic cable elements	12
Crosses test (continuity between wires of different pair)	30
Crosstalk loss—far end	25
Crosstalk loss—near end	24
D-C proof test—core-to-internal shield (screen)	35
D-C proof test—core-to-shield	33
D-C proof test—core-to-support wire	34
D-C proof test—internal shield (screen)-to-shield	36
D-C proof test—other required isolations	37
D-C proof test—wire-to-wire	32
Fault rate test (air core only)	28
Insulation resistance	27
Jacket voltage breakdown rating test	31
Mutual capacitance	18
Mutual conductance	16
Resistance of other metallic cable elements	14
Shorts test (continuity between wires of a pair)	29
Voltage surge test	38

1.3 The values stated in inch-pound units are to be regarded as the standard. SI units are for information only.

1.4 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish*

appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific hazard statements are given in Sections 6 and 32.

2. Referenced Documents

2.1 ASTM Standards:

B 193 Test Method for Resistivity of Electrical Conductor Materials²

D 150 Test Methods for A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials³

D 1711 Definitions of Terms Relating to Electrical Insulation³

D 3426 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Using Impulse Waves³

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specification⁴

2.2 ANSI Standard:

ANSI/IEEE Standard 100 IEEE Standard Dictionary of Electrical and Electronics Terms⁵

3. Terminology

3.1 Descriptions of Terms Specific to This Standard:

3.1.1 *air core*—refers to products in which the air spaces between cable core components (pairs, etc.) remain in their unfilled or natural state.

3.1.2 *armored wire or cable*—wire or cable in which the shielded or jacketed or shielded and jacketed wire or cable is completely enclosed by a metallic covering designed to protect the underlying telecommunications elements from mechanical damage.

3.1.3 *cable, telecommunications*—products of six or more pair.

3.1.4 *filled core*—those products in which air spaces are filled with some materials intended to exclude air or moisture, or both.

3.1.5 *pair*—two insulated conductors combined with a twist.

3.1.6 *sheath*—the jacket and any underlying layers of shield, armor, or other intermediate material down to but not including the core wrap.

3.1.7 *shielded wire or cable*—wire or cable in which the

¹ These test methods are under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.18 on Solid Insulations, Non-Metallic Shieldings, and Coverings for Electrical and Telecommunications Wires and Cables.

Current edition approved March 5, 1990. Published May 1990. Originally published as D 4566 – 86. Last previous edition D 4566 – 86 ϵ 1.

² Annual Book of ASTM Standards, Vol 02.03.

³ Annual Book of ASTM Standards, Vol 10.02.

⁴ Annual Book of ASTM Standards, Vol 14.02.

⁵ Available from the Institute of Electrical and Electronic Engineers, Inc., 135 E. 47th St., New York, NY 10017.

core (or inner jacket) is completely enclosed by a metallic covering designed to shield the core from electrostatic or electromagnetic interference, or both.

3.1.8 *wire, telecommunications*—products containing less than six pair.

ELECTRICAL TESTS OF INSULATION— IN-PROCESS

4. Scope

4.1 In-process electrical tests are used primarily as process control tools in an attempt to minimize the number and magnitude of problems detected at final test of completed cable.

5. Significance and Use

5.1 Electrical tests, properly interpreted, provide information with regard to the electrical properties of the insulation. The electrical test values give an indication as to how the insulation will perform under conditions similar to those observed in the tests. Electrical tests may provide data for research^c and development, engineering design, quality control, and acceptance or rejection under specifications.

6. Spark Test

6.1 The spark test is intended to detect defects in the insulation of insulated wire conductors. Spark testers are commonly used to detect insulation defects (faults) at conductor insulating operations, at pair twisting operations, and (occasionally) at operations for assembly or subassembly of conductors. In selected instances, spark tests may be used to detect defects in the jackets of shielded wire and cable, and in such cases, spark testers appear on cable jacketing lines. The basic method calls for a voltage to be applied between a grounded conductor and an electrode that is in mechanical contact with the surface of the material being tested. The wire or cable under test usually moves continuously against the electrode. When the dielectric medium is faulty (for example, excessively thin or missing, as in a pin-hole or when mechanically damaged), the impressed voltage will produce an arc to the grounded conductor. This arcing or sparking will usually activate one or more indicators (such as, warning buzzers or lights, counters, etc.) and, when appropriately interlocked, may halt the production or movement of the item through the sparker. For telecommunications products, the number of faults are usually only counted while production continues. Jacket defects may be flagged when detected. Jacket defects and units of insulated wire containing an excessive number of faults may be repaired or disposed of.

6.2 **Caution:**—Lethal voltages may be present during this test. It is essential that the test apparatus and all associated equipment that may be electrically connected to it be properly designed and installed for safe operation. Solidly ground all metal parts that any person might come into contact with during the test. Thoroughly instruct all operators in the proper way to conduct the test safely. When making tests at high voltage with electrodes, particularly in compressed gas or in oil, the energy released at breakdown may be sufficient to result in fire, explosion or rupture of the test chamber. Design of test equipment, test chambers, and

test specimens shall be such as to minimize the possibility of such occurrences, and to eliminate the possibility of personal injury.

6.3 Unless otherwise limited by detailed specification requirements, spark testers used may generate either an a-c or d-c test voltage; if a-c, various frequencies may be used. For safety to personnel, spark test equipment is usually current-limited to levels normally considered to be nonlethal. Unless otherwise specified, the test voltage level employed shall be at the discretion of the manufacturer.

6.4 Unless otherwise limited by detailed specification requirements, various types of electrodes may be used, at the discretion of the manufacturer. Bead chains, water, ionized air and spring rods are among electrode types that have been successfully employed. The length of the electrode is also variable; unless otherwise limited by detailed specification requirements, electrode size and length shall be such that the tester will operate successfully for any particular rate of travel of the product through the tester that is used. In spite of current limitations, electrodes are normally provided with grounded metallic screens or shields to guard against accidental personnel contact.

6.5 Both ends of the conductor of insulated wire, or both ends of the metallic shield under a cable jacket are grounded, and then attached to the ground side of the tester. Attach the high voltage side of the tester to the sparker electrode. Set the test voltage at the level specified. Unless otherwise specified, energize the spark tester whenever the product to be tested is moving through the electrode. Take appropriate action (for example, flag defects, count defects, adjust the process, etc.) when and if defects are detected.

6.6 *Report:*

6.6.1 The report shall include the following information recorded on suitable forms (that is, production reports):

6.6.1.1 Machine number and type (that is, extruder, twister, etc.),

6.6.1.2 Date of production test,

6.6.1.3 Insulation type (air core or filled core), conductor gage and footage,

6.6.1.4 Voltage level, and

6.6.1.5 Number of indicated faults.

6.7 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this spark test since the result merely states whether there is conformance to the criteria for success specified in the product specification.

7. Insulation Defect or Fault Rate—In-Process

7.1 For purposes of in-process control, it may be desirable to monitor and record in-process faults at a particular operation (such as, extruders, twisters, etc.) and relate the number of defects found to the quantity of product produced.

7.2 When appropriate, and using records of the quantity of product produced versus the number of insulation defects counted, a fault rate may be established as a ratio as follows:

$$\text{Fault Rate} = \frac{\text{faults detected}}{\text{quantity (ft or m) produced}} = \frac{1}{X} \quad (1)$$

7.3 Fault rates may be determined for any particular time frame as desired; however, minimum industry practice is to

keep fault rate records covering periods approximating 1 month, with cumulative records kept for 6-month periods (for example, for the first 6 months of the year, the fault rate was 1/40 000 ft, meaning 1 fault/40 000 conductor ft.)

7.4 *Report*—The report shall be in accordance with 6.6.

7.5 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for insulation defect or fault rate since the result merely states whether there is conformance to the criteria for success specified in the product specification.

8. D-C Proof Test—In-Process

8.1 For purposes of in-process control, it may be desirable to d-c proof test product at one or more stages of processing prior to the final test operation. Such testing is normally at the discretion of the manufacturer.

8.2 Conduct wire-to-wire d-c proof tests in accordance with Section 32 following, at whatever stage of production may be appropriate and designated by the factory management.

8.3 *Report*—The report shall be in accordance with Section 39 except that 39.1.5 does not apply.

8.4 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this d-c proof test since the result merely states whether there is conformance to the criteria for success specified in the product specification.

ELECTRICAL TESTS OF COMPLETED WIRE AND CABLE

9. Scope

9.1 Electrical tests of completed wire and cable may include verification of some or all of the properties in accordance with Sections 11 through 38.

10. Significance and Use

10.1 Electrical tests, properly interpreted, provide information with regard to the electrical properties of the insulation or of the jacket, or both. The electrical test values give an indication as to how the wire or cable, or both, will perform under conditions similar to those observed in the tests. Electrical tests may provide data for research and development, engineering design, quality control, and acceptance or rejection under specifications.

11. Conductor Continuity

11.1 Continuity of the conductors of a telecommunications wire and cable is a critical characteristic.

11.2 Unless otherwise specified or agreed upon, conductor continuity shall be verified using a d-c potential of 100 V or less. Manual continuity checkers commonly take the form of a battery voltage source of 9 V, in series with a visible or audible indicator with hand-held test leads. Automatic test equipment, also available to test properly terminated wire and cable, normally provides an indication (lights or printout) when continuity does not exist.

11.3 Prepare each end of the wire or cable for test. This usually involves stripping some insulation from each conductor at each end and separating the conductors at one or both ends. When automatic test equipment is used, terminate the individual conductors at a test fixture (both ends are

normally terminated since this automatic test is often performed in conjunction with other tests). When manual continuity checking is performed, it is usually suitable to connect all conductors to a common termination (for example, wrap stripped ends with a length of copper wire, immerse one end in an electrically conductive liquid, etc.) at one end of the wire or cable.

11.4 In succession, apply the voltage source to one end of each conductor. Using test equipment indicators, verify the continuous circuit paths or detect the discontinuities.

11.5 After defective conductors are repaired, continuity checks must be repeated.

11.6 *Report*—The report shall be in accordance with Section 39.

11.7 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for conductor continuity since the result merely states whether there is conformance to the criteria for success specified in the product specification.

12. Continuity of Other Metallic Cable Elements

12.1 In addition to the metallic conductors intended for information transmission, telecommunications wire and cable may contain one or more additional metallic elements in the form of a shield, an armor, or an internal shield or screen that separates a cable into compartments, etc. Depending upon the particular product design, these elements may or may not be in contact with each other (cross-continuity). The continuity of each of these elements is normally considered to be a critical parameter.

12.2 Unless otherwise specified or agreed upon, verify the individual continuity of each shield, armor, screen (internal shield), or other metallic cable element of the cable construction using a d-c potential of 100 V or less, in accordance with Section 11. When metallic elements under test are insulated, the insulation is normally removed to the extent necessary for testing. If continuity between any of these metallic elements is required, it shall be verified; if such continuity is expected but not required, it may be verified at the discretion of the manufacturer. If continuity between any of these metallic elements is not permitted, verify isolation in accordance with Section 37.

12.3 *Report*—The report shall be in accordance with Section 39.

12.4 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for continuity of other metallic cable elements since the result merely states whether there is conformance to the criteria for success specified in the product specification.

13. Conductor Resistance

13.1 The resistance of each of the conductors used in telecommunications wire and cable is usually a key characteristic; however, conductor resistance is normally verified only on a quality assurance sampling basis for finished products. Complete shipping units (full reels or other) of wire or cable, or both (not specimen lengths) shall constitute the basic sample. When the selected sample reel is a cable containing a great many conductors, the conductors of the

sample cable are also checked on a sampling basis (that is, sampling of the sample).

13.2 Unless otherwise specified or agreed upon, measure the d-c resistance of conductors at or correct to 68°F (20°C). Temperature correction shall be performed as described in Test Method B 193. The d-c resistance is considered to vary directly with cable length.

13.3 Conductor resistance measurements are commonly made using volt/ohm meters or Wheatstone bridges having an accuracy of $\pm 0.5\%$. Various types of automatic or semiautomatic equipment may also be used.

13.4 Follow the general procedures of 11.3 through 11.5 except that the voltage source shall be the test instrument, and instrument readings obtained for each tested conductor shall be recorded. Note that data for resistance unbalance testing (Section 15) is normally obtained during this procedure; consequently, care must usually be taken to record data separately in pair groupings. See Section 15 for details.

13.5 Upon completion of measurements, manipulate the recorded data as appropriate (for example, determine averages, adjust for temperature and length, etc.) and compare with the requirements of detailed specifications.

13.6 Report:

13.6.1 The report shall be in accordance with Section 39 and shall include the following:

13.6.1.1 Minimum, maximum and average values, and

13.6.1.2 Ambient temperature.

13.7 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for conductor resistance since the result merely states whether there is conformance to the criteria for success specified in the product specification.

14. Resistance of Other Metallic Cable Elements

14.1 It is occasionally important to know the resistance of other metallic elements (most often shield resistance) within telecommunications wire and cable. When required, this information may be obtained following 13.2 through 13.4, measuring cable construction elements as appropriate.

14.2 *Report*—The report shall be in accordance with Section 39 and shall include the ambient temperature.

14.3 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for resistance of other metallic cable elements since the result merely states whether there is conformance to the criteria for success specified in the product specification.

15. Conductor Resistance Unbalance (Pairs)

15.1 The difference in resistance between two conductors of any pair can be a key characteristic in telecommunications; however, resistance unbalance is normally verified only on a quality assurance sampling basis for finished products.

15.2 The Conductor Resistance Unbalance is usually determined at the same time that conductor resistance measurements are made; consequently, 13.2 through 13.5 apply and resistance data is recorded in pair groupings.

15.3 The absolute difference in resistance unbalance is calculated by subtracting the lesser resistance from the greater resistance. Absolute resistance unbalance is normally

expressed in $\Omega/1000$ ft or Ω/km . A more useful and generally used expression for resistance unbalance is percent resistance unbalance, where

% Resistance Unbalance =

$$\frac{(\text{max resistance} - \text{min resistance})}{(\text{min resistance})} \times 100 \quad (2)$$

15.4 Telecommunications wire and cable users are generally interested in two resistance unbalance values: cable average and maximum individual pair unbalance. Cable average in absolute or percentage terms is determined by standard averaging techniques, while the maximum individual pair unbalance in absolute or percentage terms is determined by simple inspection of the data. Data values are then compared with detailed specification requirements to verify conformance.

15.5 *Report*—The report shall be in accordance with Section 39 and shall include the average and maximum values.

15.6 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for conductor resistance unbalance (pairs) since the result merely states whether there is conformance to the criteria for success specified in the product specification.

16. Mutual Conductance

16.1 The mutual conductance of a pair in a wire or cable is proportional to the mutual capacitance, the average value of the effective dissipation factor of the insulating system, and the frequency. Although it is one of the primary transmission characteristics, mutual conductance is the least consistent; the conductance of an individual pair may vary as much as 10 to 15 % from the nominal values at carrier frequencies. Fortunately, the effect of conductance on the secondary parameters is negligible at voice frequency, and contributes less than 1 % to the secondary parameters at 1 MHz, so the inconsistency is of little consequence. Although conductance also varies with temperature, the correction is insignificant in comparison with other sources of variation, so it is usually neglected.

16.2 Because of the factors mentioned in 16.1, mutual conductance is normally measured only infrequently, and readings are usually taken on short specimen lengths (an exact 32-ft specimen is convenient). When an impedance bridge is used for measurements, conductance and capacitance may be read directly from the instrument balance settings. Various types of automatic or semiautomatic equipment may also be used.

16.3 Unless otherwise specified, obtain mutual conductance readings at $23 \pm 3^\circ\text{C}$ and 1000 ± 100 Hz. Measured values are normally converted to a standard length value (normally one mile or one km). For conductance in microsiemens per mile, the values would be:

$$G_0 = \frac{G \times 5280}{L} \quad (3)$$

where:

G_0 = mutual conductance, $\mu\text{S}/\text{mile}$,

G = conductance reading, μS , and

L = specimen length, ft.



Documents

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16.4 *Report*—The report shall be in accordance with Section 39 and shall include the maximum value.

16.5 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for mutual conductance since the result merely states whether there is conformance to the criteria for success specified in the product specification.

17. Coaxial Capacitance (Capacitance to Water)

17.1 Coaxial capacitance for insulated wire is defined as the capacitance existing between the outer surface of the round metallic conductor and the outer surface of the insulating dielectric applied over that conductor.

NOTE 1—For a more general definition, refer to Test Methods D 150 or to Definitions D 1711.

17.2 In-process measurements of coaxial capacitance are made by passing the insulated conductor through a water bath while measurements are made between the grounded conductor and the water. Automatic feedback of data is then used to control the insulating equipment. Such measurements are generally not suitable for product acceptance.

17.3 For purposes of measuring coaxial capacitance in completed wire, a sample length of insulated wire is immersed in a water bath and the direct capacitance is measured between the conductor and the water. Unless otherwise specified, a minimum specimen length of 1000 ft (305 m) shall be used. Unless otherwise specified, perform measurements at a water temperature of $20 \pm 2^\circ\text{C}$ and a test frequency of 1000 ± 100 Hz using capacitance or impedance bridges, capacitance meters, etc. Unless otherwise prohibited, other equipment yielding equivalent results may be used.

17.4 *Report*—The report shall be in accordance with Section 39 and shall include the minimum, maximum, and average values.

17.5 *Precision and Bias*—The precision of this test has not been determined. No statement can be made about the bias of this test for coaxial capacitance (capacitance to water) since the result merely states whether there is conformance to the criteria for success specified in the product specification.

18. Mutual Capacitance

18.1 Mutual capacitance is defined as the effective capacitance between the two wires of a pair. In a multi-pair cable,

AC mutual capacitance is defined as:

$$C_M = C_{AB} + \frac{(C_{AG})(C_{BG})}{C_{AG} + C_{BG}} \quad (4)$$

where:

C_{AB} , C_{AG} and C_{BG} are as illustrated in Fig. 1.

18.2 Mutual capacitance is a critical characteristic in telecommunications wire and cable; consequently, unless otherwise specified or agreed upon between the producer and the user, each lot of product is checked to verify this parameter.

18.3 Before measuring, cable to be tested must be prepared by removing the jacket(s) and shield or armor, when present, from both ends of the cable to expose approximately 2 ft (600 mm) of the cable core. Conductors at one end of the cable are then fanned out to ensure that no conductors are shorted or grounded. Insulation is then stripped for approximately 1 to 3 in. (25 to 75 mm) from the conductors at the other end of the cable. All conductors are then shorted together and to ground to dissipate any static charge that may have accumulated.

18.4 Unless otherwise specified, mutual capacitance is understood to mean capacitance at an a-c frequency of 1000 ± 100 Hz, and this test frequency shall be used if measurement is made using a bridge technique. Other test methods yielding comparable results shall be considered as acceptable if not specifically prohibited.

18.5 Mutual capacitance readings are commonly made manually using impedance bridges or capacitance meters; various types of automatic or semiautomatic equipment may also be used.

18.6 Specification limits are generally placed on the cable average mutual capacitance and on the individual pair mutual capacitance. Limits for individual pairs can be verified only by making measurements of individual pairs, and such measurements are normally made for cables of 25 or fewer pairs; for larger cables, individual measurements are often made only on a quality assurance sampling basis. Cable averages can be obtained by averaging individual pair readings. Average mutual capacitance can also be measured by grouping a number of pairs together (electrically in parallel circuits), measuring the capacitance of the group and dividing the total capacitance by the number of pairs tested to obtain a grouped average. When grouped readings are made, no more than 25 pairs should be grouped for any one

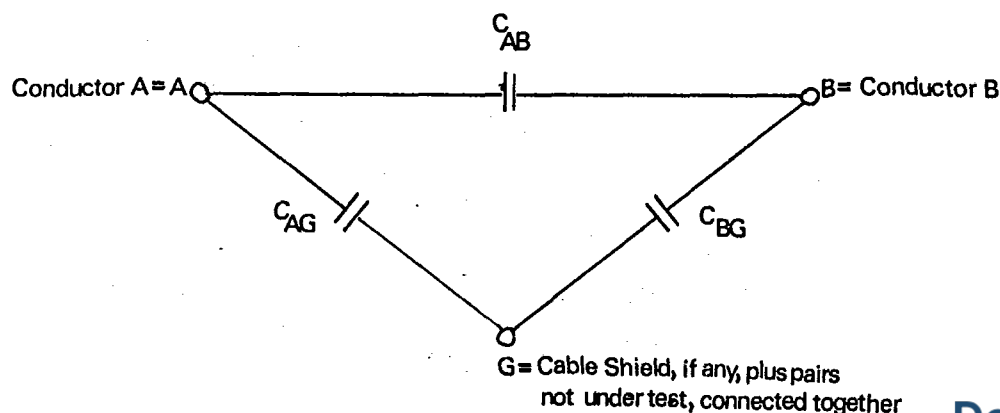


FIG. 1 Mutual Capacitance Relationships