INTERNATIONAL

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Standard Test Method for D-C Resistance or Conductance of Moderately Conductive Materials[1]

This standard is issued under the fixed designation D4496; 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 This test method covers the determination of electrical resistance and electrical resistivity of materials that are generally categorized as moderately conductive and are neither good electrical insulators nor good conductors.

1.2 This test method applies to the materials that exhibit volume resistivity in the range of 10^0 to 10^7 Ω-cm or surface resistivity in the range of 10^3 to 10^7 Ω (per square).

1.3 This test method is designed for measurements at standard conditions of ~~23°C~~ 23 °C and 50 % relative humidity, but its principles of operation can be applied to specimens measured at lower or higher temperatures and relative humidities.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in 8.3.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D257 Test Methods for DC Resistance or Conductance of Insulating Materials
~~D374~~D374/D374M Test Methods for Thickness of Solid Electrical Insulation ~~(Metric) D0374_D0374M~~
D618 Practice for Conditioning Plastics for Testing
D991 Test Method for Rubber Property—Volume Resistivity Of Electrically Conductive and Antistatic Products
D1711 Terminology Relating to Electrical Insulation
~~D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]~~

2.2 *ASTM Adjuncts:*

Carbon black test cell (two drawings)[3]

3. Terminology

3.1 *Definitions:*

[1] This test method is under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from ASTM International Headquarters. Order Adjunct ~~No.~~ No. ADJD4496. Original adjunct produced in 2015. Adjunct last revised in 2015.

3.1.1 *moderately conductive*—a solid material having volume resistivity between 10^0 and 10^7 Ω·cm.

3.1.2 For definitions of the terms used, but not defined in this standard, refer to Terminology D1711.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *steady state*—for the purpose of this test method, steady-state is attained if any rate of change in the observed resistance (or conductance) averages less than 0.25 %/s.

4. Summary of Test Method

4.1 Specimens of the test material are conditioned at prescribed conditions and subjected to direct-voltage stress. Resistance or conductance is measured and used with the dimensional aspects of the specimen to compute the resistivity of the material. The apparatus and techniques used in this test method are selected in accordance with the general principles set forth in Test Methods D257 and D991.

5. Significance and Use

5.1 This test method is useful for the comparison of materials, as a quality control test, and for specification purposes.

5.2 This test method is useful in the selection and use of materials in wires, cables, bushings, high-voltage rotating machinery, and other electrical apparatus in which shielding or the distribution of voltage stress is of value.

5.3 Commercially available "moderately conductive" materials frequently are comprised of both conductive and resistive components (that is, cellulose fibers with colloidal carbon black particles attached to portions of the surfaces of those fibers, or discrete conductive particles adhered to the surfaces of electrical insulating polymers). Such commercially available materials are often manufactured in a manner that results in anisotropy of electrical conduction. Hence, the significance of tests using this test method depends upon the orientation of the specimen tested to the direction of the electric field and the relationship between this orientation and the orientation of the material in the electrical apparatus, which uses these materials.

6. Apparatus

6.1 Use apparatus conforming to the general requirements set forth in Test Methods D257 and D991.

6.2 *Power Source*—Capable of limiting the magnitude of the direct voltage applied to the specimen. (See Appendix X1 for discussion of voltage stress and specimen heating.)

6.3 *Test cells,* that have been found to be satisfactory are depicted in ~~Fig. 1~~Figs. 1-3~~, Fig. 2, and Fig. 3~~.[3]

NOTE 1—Conductive paint is a suitable electrode material for specimens of certain materials and testing such specimens does not require test cell assemblies similar to ones shown in Fig. 1, Fig. 2, and Fig. 3 (see Annex A1 for additional information).

7. Specimen Preparation and Selection

7.1 Take specimens from a sample of material that has been obtained in a random manner. Take care to protect the sample and the specimens from any contamination, which will affect the results of the resistance or conductance tests. Such contamination can include, in particular, salts or moisture from human hands. Be aware of elevated temperatures, extremes of high or low humidity, and the presence of chemical vapors, etc.

7.2 Prior to testing, condition all specimens to equilibrium in the standard laboratory atmosphere prescribed in Practice ~~D6054~~D618. For many materials the time of conditioning to equilibrium will require only a few hours (that is, less than 24 h). Equilibrium with standard laboratory conditions is declared attained if two consecutive volume resistance measurements on the same specimen agree within ±1 %. The two consecutive measurements are to be made at the intervals separated at least by 4 h.

7.3 Determine the dimensions of the test specimens to ~~within± 2 %~~within ±2 % on material in equilibrium with the standard

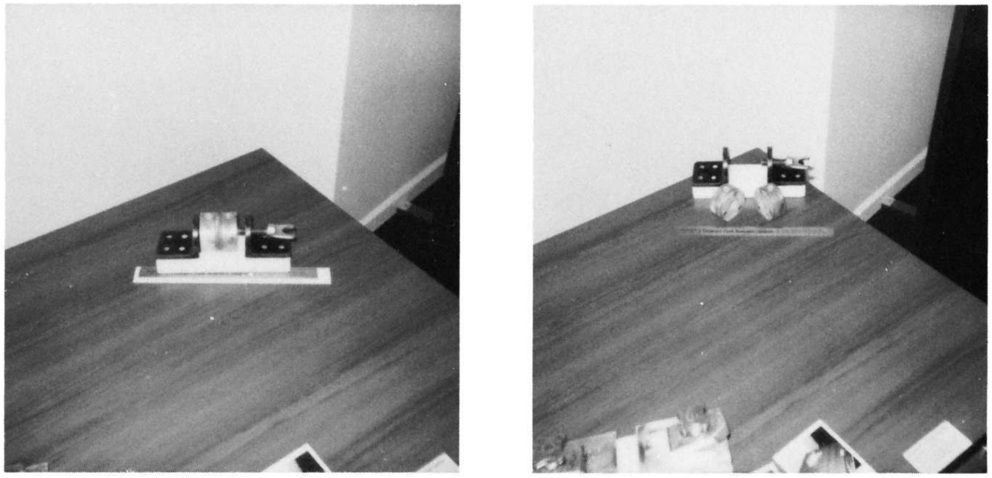
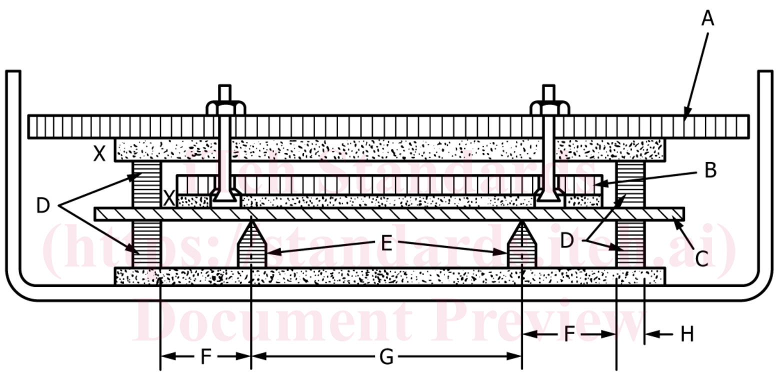


FIG. 1 Cell ~~For~~for Volume Resistivity ~~1-in.~~With[2] ~~Electrode (Mercury)~~Electrodes Made With Metal Foil, Conductive Paint or Similar High Conductivity Material as Described in Test Method D257



A—Mass for applying contact force between current electrodes and the specimen (300 N/m times the specimen width in metres) (Note 1).
B—Mass for applying contact force between potential electrodes and the specimen (60 N/m times specimen width in metres) (Note 2).
C—The specimen.
D—Current electrodes.
E—Potential electrodes.
F—Distance between the current and potential electrodes (20 mm minimum).
G —Distance between potential electrodes depends on specimen size.
H—Width of current electrode, 5 to 8 mm (0.2 to 0.3 in.).
X—Electrical insulating material (10 tera Ω·cm volume minimum resistivity).

Note 1—For a specimen 150 mm (6 in.) wide, mass is approximately 4.5 kg (10 lb).

Note 2—For a specimen 150 mm (6 in.) wide, mass is approximately 0.9 kg (2 lb).

~~Note 3—Fig. 2 is taken from Test Method D991.~~

The electrode assembly (Fig. 2) shall consist of a rigid base made from an electrical insulating material having a volume resistivity greater than 10 T Ω·cm (for example, hard rubber, polyethylene, polystyrene, etc.) to which a pair of potential electrodes are fastened in such a manner that the four electrodes are parallel and their top surfaces are in the same horizontal plane. Another pair of current electrodes identical with the first pair shall be fastened to a second piece of insulating material so that they can be superimposed on the specimen directly above the first pair. The current electrodes shall have a length at least 10 mm (0.4 in.) greater than the specimen width, a width between 5 and 8 mm (0.2 and 0.3 in.), and a height uniform with 0.05 mm (0.002 in.) between 10 and 15 mm (0.4 and 0.6 in.). The potential electrodes shall have a length and height equal to the current electrodes, and shall be tapered to an edge having a radius of 0.5 mm (0.02 in.) maximum at the top surface. The distance between the potential electrodes shall be not less than 10 mm (0.4 in.) nor more than 66 mm (2.6 in.) and shall be known ~~within + 2 %.~~within +2 %. The current electrodes shall be equidistant outside the potential electrodes by at least 20 mm (0.8 in.). The electrodes shall be made from a corrosion-resistant metal such as brass, nickel, stainless steel, etc. Insulation resistance between electrodes shall be greater than 1 TΩ.

FIG. 2 Electrode Assembly as described in Test Method D991

laboratory atmosphere. Make all thickness measurements in accordance with Method D of Test Methods ~~D374~~D374/D374M using the appropriate procedure for the material being tested.

7.4 For specimens incorporating conductive paint electrodes see Annex A1.

7.5 For anisotropic materials, label and prepare specimens for testing in each of the principal directions of anisotropy. This may require using more than one type of test fixture depending on sample shape and orientation.

FIG. 3 Cell ~~For~~for Surface Resistance Assembly Photo

NOTE 2—Moderately conductive paper exhibits three axes of anisotropy. The principal axes in paper are machine direction (MD); cross-machine direction (CMD); and thickness direction (TD). Extruded polymeric materials frequently show anisotropy with the axis of extrusion (direction of flow) compared to the axis of the material at right angles to that direction of flow.

8. Procedure

8.1 Unless otherwise specified, make all measurements using an electrification time of less than 1 min. The electrification time shall be long enough to attain a "steady state" and the magnitude of the voltage shall not be so great as to cause heating of the test specimen. See Appendix X1 for discussion of time effects of voltage application and specimen heating.

8.2 Do not apply to the test specimen a power input exceeding 1 W. For very conductive materials it is useful to increase the size of a specimen or to decrease the test voltage by one or more orders of magnitude below 500 V in order to avoid the specimen overheating.

8.3 Test a minimum of five specimens from each sample in each of the principal directions of anisotropy. Use caution in handling the specimens to avoid contaminating the surfaces.

8.4 Place the specimen in the test cell or attach the leads to the painted-on electrodes. ~~If mercury electrodes are used, take special care in handling the mercury.~~Mercury electrodes shall not be used due to the health hazards associated with exposure to mercury vapor.

~~8.4.1 **Warning—**Mercury metal-vapor poisoning has long been recognized as a hazard in the industry. The maximum exposure limits are set by the American Conference of Governmental Industrial Hygienists.[5] The concentration of mercury vapor over spills from broken thermometers, barometers, or other instruments using mercury can easily exceed these exposure limits. Mercury, being a liquid and quite heavy, will disintegrate into small droplets and seep into cracks and crevices in the floor. The use of a commercially available emergency spill kit is recommended whenever a spill occurs. The increased area of exposure adds significantly to the mercury vapor concentration in the air. Mercury vapor concentration is easily monitored using commercially available sniffers. Spot checks are to be made periodically around operations where mercury is exposed to the atmosphere. Thorough checks are to be made after spills.~~

8.5 Measure the conductance, resistance, or ~~voltagecurrent~~ voltage and current values, depending upon the type of apparatus shown in Test Methods D257~~,~~ or D991 that is being used. Record each observed measurement.

8.6 Calculate the resistivity in accordance with Section 9.

9. Calculation

9.1 If the voltmeter-ammeter method of Test Methods D257 is used in 8.5, calculate the resistance for each specimen using the equation:

$$R = V \div I \quad (1)$$

where:

R = resistance, Ω,
V = applied direct voltage, V, and
I = magnitude of the direct current, A.

where:

R = resistance, Ω,
V = applied direct voltage, V, and
I = magnitude of the direct current, A.

9.2 If the direct method of resistance of Test Methods D257 is used, use the values observed and calculate the resistivity as follows:

9.2.1 Volume Resistivity = presistivity = ρ_v (in Ω·cm)Ω·cm).

$$\rho_v = R_v \frac{A}{t} \quad (2)$$

where:

R_v = volume resistance, Ω,
A = area of the electrodes, cm^2, and
t = distance between the electrodes, cm.

9.2.2 Surface Resistivityresistivity in Ω (per square) ρ_s:

$$\rho_s = R_s(W/L) \quad (3)$$

where:

R_s = surface resistance, Ω
L = length of the specimen between electrodes, and
W = width of the specimen.

where:

R_s = surface resistance, Ω
L = length of the specimen between electrodes, and
W = width of the specimen.

NOTE 3—The ratio (*W/L*) is analogous to the (*P/g*) ratio shown in Test Methods D257.

NOTE 4—*L* and *W* must be measured in the same units of distance. The unit of surface resistivity is ohms (or megohms). It is common practice to refer to surface resistivity as ohms per square.

9.3 If the electrode assembly shown in Fig. 2 is used, the calculation to determine volume resistivity shall be that described in Test Method D991:

$$\rho_v = Vwd/Il$$

where:

ρ_v = volume resistivity,
V = voltage difference across potential electrodes,
I = current through current electrodes,
w = width of specimen,
d = thickness of specimen, and
l = length of specimen.