ASTM D 257 â€“ Standard Test Methods for DC Resistance or Conductance of Insulating Materials

Description

[WORDPRES_PDF]
Summary of Test Methods
4.1 The resistance or conductance of a material specimen or of a capacitor is determined from a measurement of current or of voltage drop under specified conditions. By using the appropriate electrode systems, surface and volume resistance or conductance may be measured separately. The resistivity or conductivity can then be calculated when the required specimen and electrode dimensions are known.

Electrode Systems
6.1 The electrodes for insulating materials should be of a material that is readily applied, allows intimate contact with the specimen surface, and introduces no appreciable error because of electrode resistance or contamination of the specimen (5). The electrode material should be corrosion-resistant under the conditions of test. For tests of fabricated specimens such as feed-through bushings, cables, etc., the electrodes employed are a part of the specimen or its mounting. Measurements of insulation resistance or conductance, then, include the contaminating effects of electrode or mounting materials and are generally related to the performance of the specimen in actual use.

6.1.1 Binding-Post and Taper-Pin Electrodes, Fig. 1 and Fig. 2, provide a means of applying voltage to rigid insulating materials to permit an evaluation of their resistive or conductive properties. These electrodes simulate to some degree the actual conditions of use, such as binding posts on instrument panels and terminal strips. In the case of laminated insulating materials having high-resin-content surfaces, somewhat lower insulation resistance values may be obtained with taper-pin than with binding posts, due to more intimate contact with the body of the insulating material. Resistance or conductance values obtained are highly influenced by the individual contact between each pin and the dielectric material, the surface roughness of the pins, and the smoothness of the hole in the dielectric material. Reproducibility of results on different specimens is difficult to obtain.

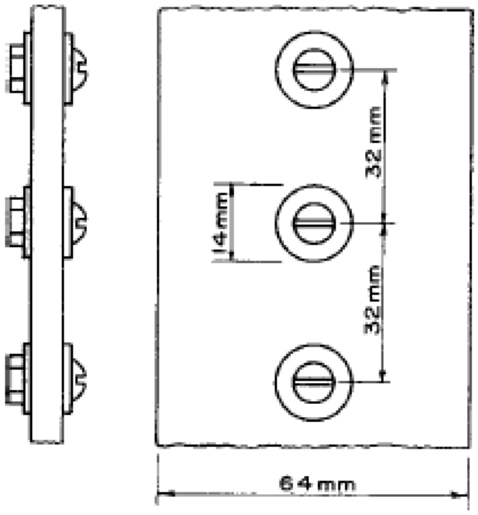


FIG. 1 Binding-Post Electrodes for Flat, Solid Specimens

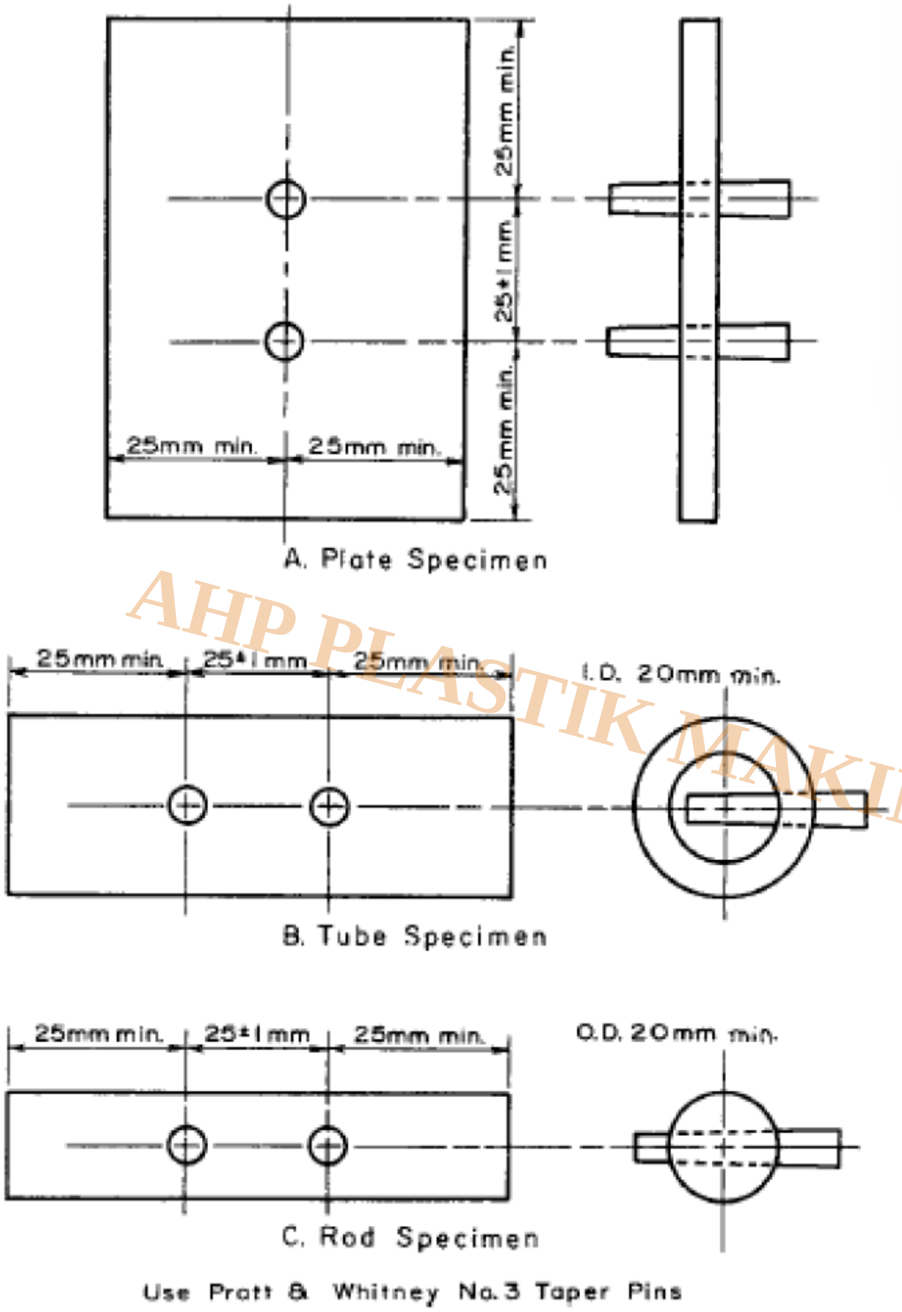


FIG. 2 Taper-Pin Electrodes

6.1.2 Metal Bars in the arrangement of Fig. 3 were primarily devised to evaluate the insulation resistance or conductance of flexible tapes and thin, solid specimens as a fairly simple and convenient means of electrical quality control. This arrangement is somewhat more satisfactory for obtaining approximate values of surface resistance or conductance when the width of the insulating material is much greater than its thickness.

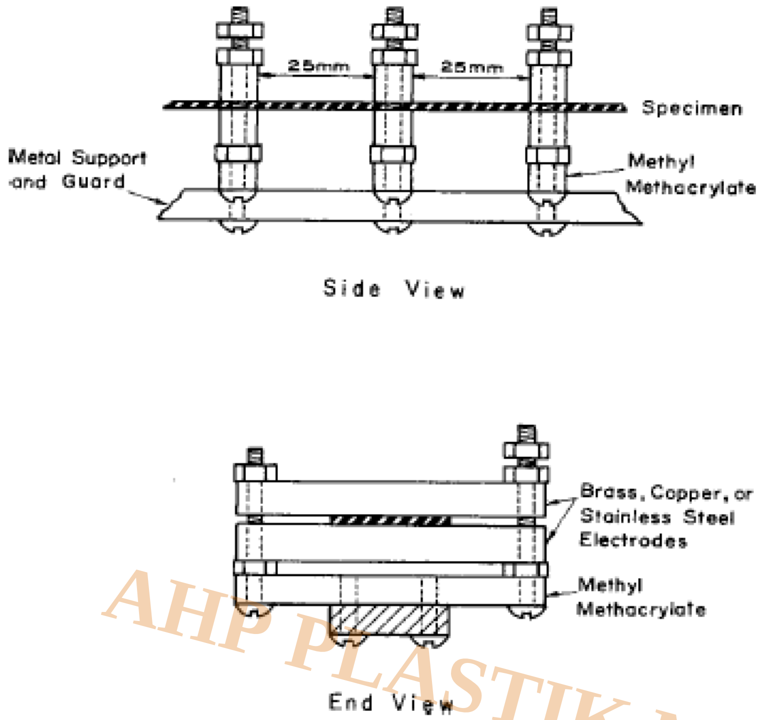


FIG. 3 Strip Electrodes for Tapes and Flat, Solid Specimens

6.1.3 Silver Paint, Fig. 4, Fig. 5, and Fig. 6, is available commercially with a high conductivity, either air-drying or low-temperature-baking varieties, which are sufficiently porous to permit diffusion of moisture through them and thereby allow the test specimen to be conditioned after the application of the electrodes. This is a particularly useful feature in studying resistance-humidity effects, as well as change with temperature. However, before conductive paint is used as an electrode material, it should be established that the solvent in the paint does not attack the material so as to change its electrical properties. Reasonably smooth edges of guard electrodes may be obtained with a fine-bristle brush. However, for circular electrodes, sharper edges can be obtained by the use of a ruling compass and silver paint for drawing the outline circles of the electrodes and filling in the enclosed areas by brush. A narrow strip of masking tape may be used, provided the pressure-sensitive adhesive used does not contaminate the surface of the specimen. Clamp-on masks also may be used if the electrode paint is sprayed on.

6.1.4 Sprayed Metal, Fig. 4, Fig. 5, and Fig. 6, may be used if satisfactory adhesion to the test specimen can be obtained. Thin sprayed electrodes may have certain advantages in that they are ready for use as soon as applied. They may be sufficiently porous to allow the specimen to be conditioned, but this should be verified. Narrow strips of masking tape or clamp-on masks must be used to produce a gap between the guarded and the guard electrodes. Use a tape that is known not to contaminate the gap surface.

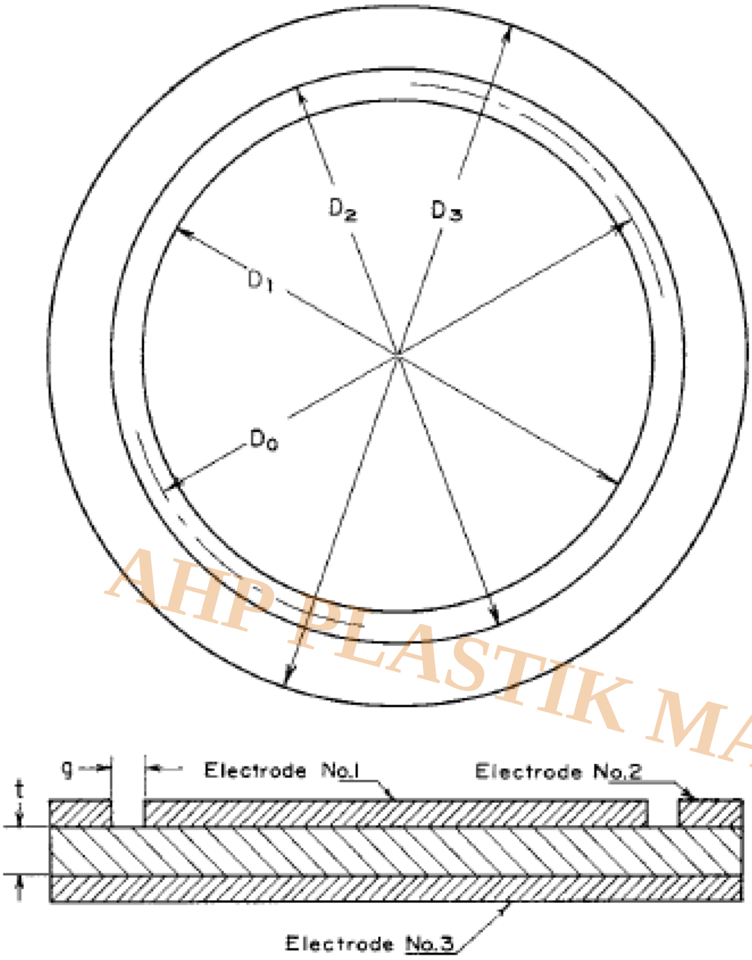


FIG. 4 Flat Specimen for Measuring Volume and Surface Resistances or Conductances

6.1.5 Evaporated Metal may be used under the same conditions given in 6.1.4.
6.1.6 Metal Foil, Fig. 4, may be applied to specimen surfaces as electrodes. The usual thickness of metal foil used for resistance or conductance studies of dielectrics ranges from 6 to 80 Î¼m. Lead or tin foil is in most common use, and is usually attached to the test specimen by a minimum quantity of petrolatum, silicone grease, oil, or other suitable material, as an adhesive. Such electrodes shall be applied under a smoothing pressure sufficient to eliminate all wrinkles, and to work excess adhesive toward the edge of the foil where it can be wiped off with a cleansing tissue. One very effective method is to use a hard narrow roller (10 to 15 mm wide), and to roll outward on the surface until no visible imprint can be made on the foil with the roller. This technique can be used satisfactorily only on specimens that have very flat surfaces. With care, the adhesive film can be reduced to 2.5 Î¼m. As this film is in series with the specimen, it will always cause the measured resistance to be too high. This error may become excessive for the lower resistivity specimens of thickness less than 250 Î¼m. Also the hard roller can force sharp particles into or through thin films (50 Î¼m). Foil electrodes are not porous and will not allow the test specimen to condition after the electrodes have been applied. The adhesive may lose its effectiveness at elevated temperatures necessitating the use of flat metal back-up plates under pressure. It is possible, with the aid of a suitable cutting device, to cut a proper width strip from one electrode to form a guarded and guard electrode. Such a three-terminal specimen normally cannot be used for surface resistance or conductance measurements because of the grease

remaining on the gap surface. It may be very difficult to clean the entire gap surface without disturbing the adjacent edges of the electrode.

6.1.7 Colloidal Graphite, Fig. 4, dispersed in water or other suitable vehicle, may be brushed on nonporous, sheet insulating materials to form an air-drying electrode. Masking tapes or clamp-on masks may be used (6.1.4). This electrode material is recommended only if all of the following conditions are met:

6.1.7.1 The material to be tested must accept a graphite coating that will not flake before testing,

6.1.7.2 The material being tested must not absorb water readily, and

6.1.7.3 Conditioning must be in a dry atmosphere (Procedure B, Practice D6054), and measurements made in this same atmosphere.

6.1.8 Liquid metal electrodes give satisfactory results and may prove to be the best method to achieving the contact to the specimen necessary for effective resistance measurements. The liquid metal forming the upper electrodes should be confined by stainless steel rings, each of which should have its lower rim reduced to a sharp edge by beveling on the side away from the liquid metal. Fig. 7 and Fig. 8 show two possible electrode arrangements.

6.1.9 Flat Metal Plates, Fig. 4, (preferably guarded) may be used for testing flexible and compressible materials, both at room temperature and at elevated temperatures. They may be circular or rectangular (for tapes). To ensure intimate contact with the specimen, considerable pressure is usually required.

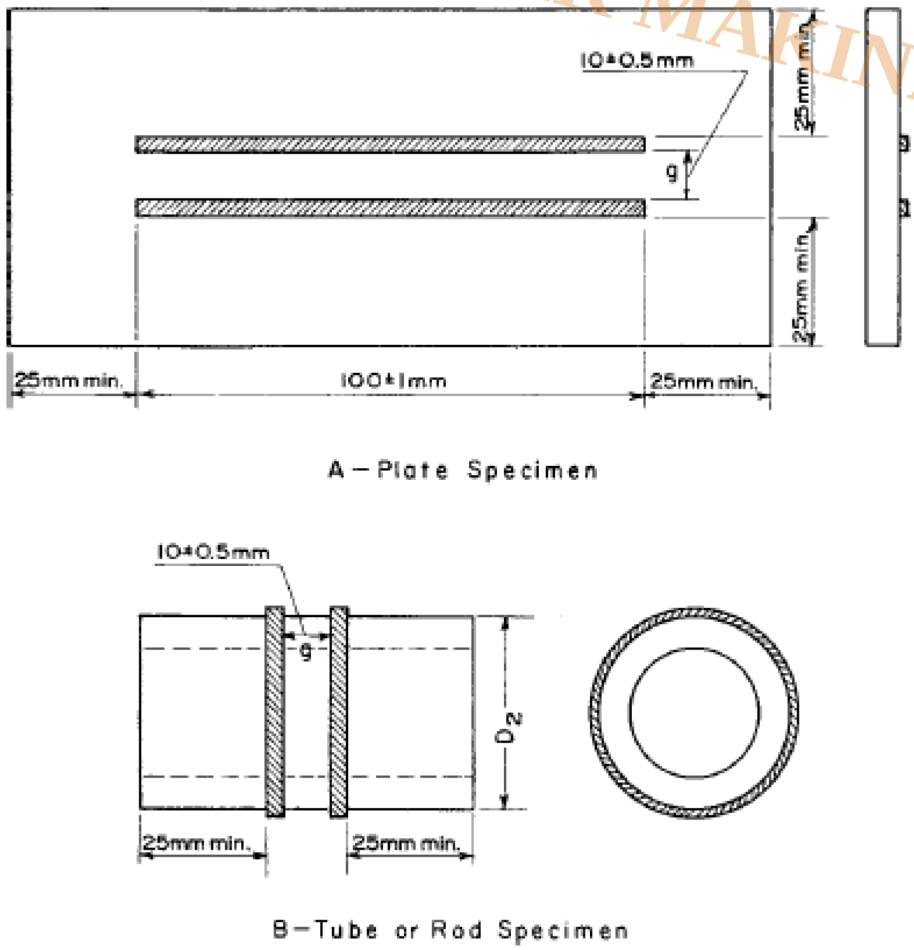


FIG. 6 Conducting-Paint Electrodes

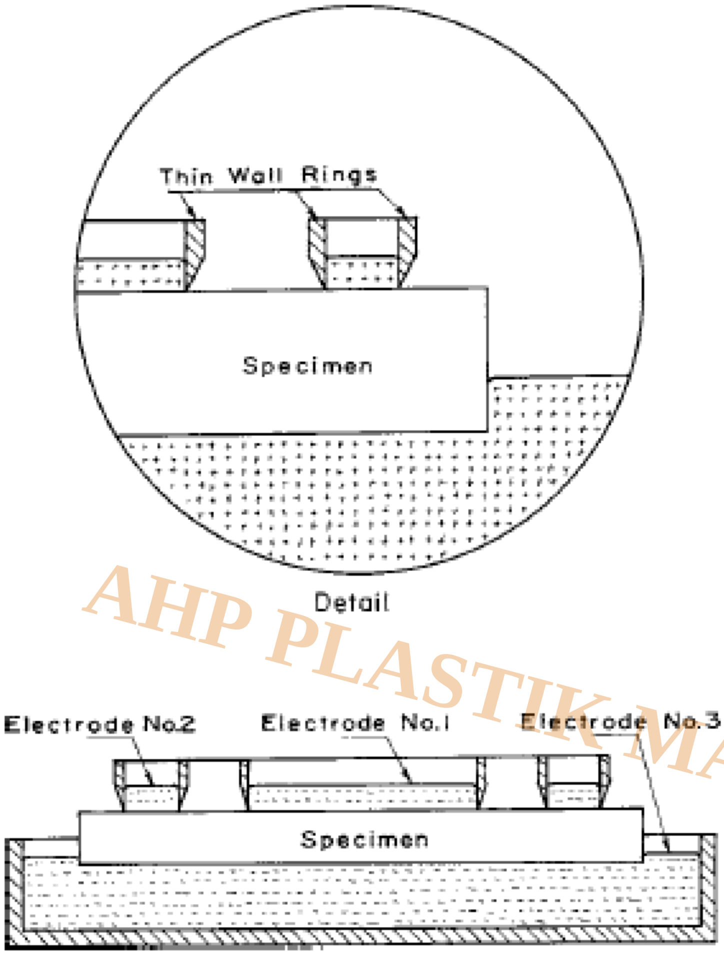


FIG. 7 Liquid Metal Electrodes for Flat, Solid Specimens

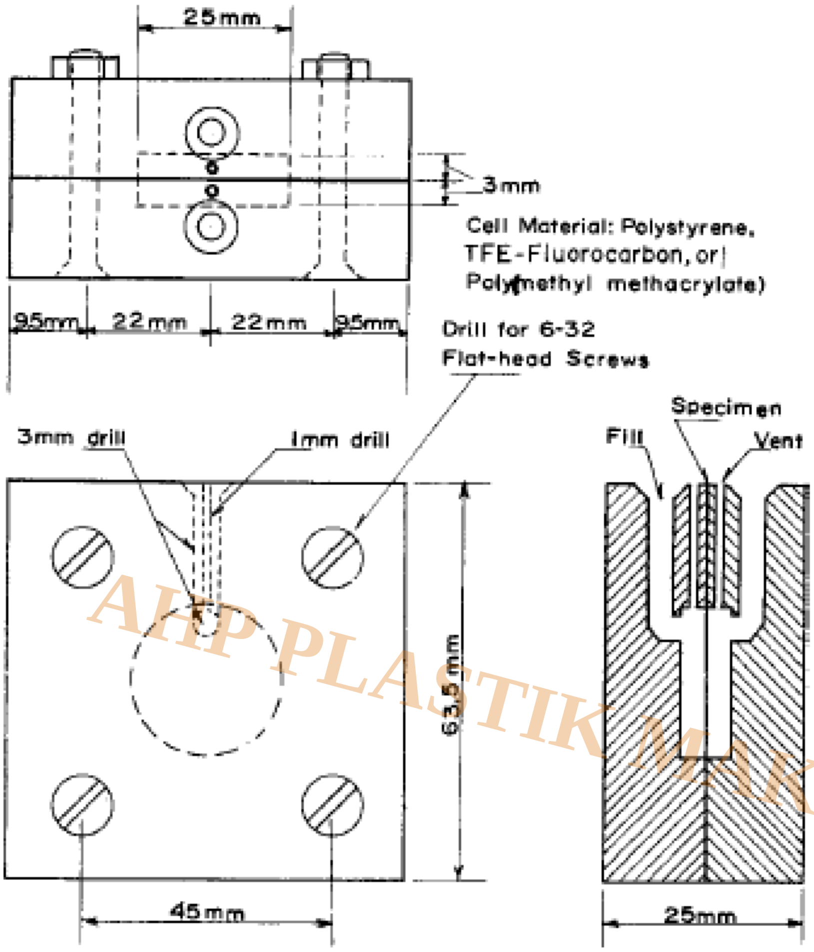


FIG. 8 Liquid Metal Cell for Thin Sheet Material

Pressures of 140 to 700 kPa have been found satisfactory (see material specifications).
6.1.9.1 A variation of flat metal plate electrode systems is found in certain cell designs used to measure greases or filling compounds. Such cells are preassembled and the material to be tested is either added to the cell between fixed electrodes or the electrodes are forced into the material to a predetermined electrode spacing. Because the configuration of the electrodes in these cells is such that the effective electrode area and the distance between them is difficult to measure, each cell constant, K, (equivalent to the A/t factor from Table 1) can be derived from the following equation:

$$K = 3.6 \pi C = 11.3 C \quad (1)$$

where:
K has units of centimetres, and
C has units of picofarads and is the capacitance of the electrode system with air as the dielectric. See Test Methods D150 for methods of measurement for C.

6.1.10 Conducting Rubber has been used as electrode material, as in Fig. 4, and has the advantage that it can quickly and easily be applied and removed from the specimen. As the electrodes are applied only during the time of measurement, they do not interfere with the conditioning of the specimen. The conductive-rubber material must be backed by proper plates and be soft enough so that effective contact with the specimen is obtained when a reasonable pressure is applied.

NOTE 1â€”There is evidence that values of conductivity obtained using conductive-rubber electrodes are always smaller (20 to 70 %) than values obtained with tinfoil electrodes (6). When only order-of-magnitude accuracies are required, and these contact errors can be neglected, a properly designed set of conductive-rubber electrodes can provide a rapid means for making conductivity and resistivity determinations.
6.1.11 Water is widely employed as one electrode in testing insulation on wires and cables. Both ends of the specimen must be out of the water and of such length that leakage along the insulation is negligible. Refer to specific wire and cable test methods for the necessity to use guard at each end of a specimen. For standardization it is desirable to add sodium chloride to the water so as to produce a sodium chloride concentration of 1.0 to 1.1 % NaCl to ensure adequate conductivity. Measurements at temperatures up to about 100 Â°C have been reported as feasible.

Choice of Apparatus and Test Method
7.1 Power Supplyâ€”A source of very steady direct voltage is required (see X1.7.3). Batteries or other stable direct voltage supplies have been proven suitable for use.
7.2 Guard Circuitâ€—Whether measuring resistance of an insulating material with two electrodes (no guard) or with a three-terminal system (two electrodes plus guard), consider how the electrical connections are made between the test instrument and the test specimen. If the test specimen is at some distance from the test instrument, or the test specimen is tested under humid conditions, or if a relatively high (10^10 to 10^15 ohms) specimen resistance is expected, spurious resistance paths can easily exist between the test instrument and test specimen. A guard circuit is necessary to minimize interference from these spurious paths (see also X1.9).
7.2.1 With Guard Electrodeâ€”Use coaxial cable, with the core lead to the guarded electrode and the shield to the guard electrode, to make adequate guarded connections between the test equipment and test specimen. Coaxial cable (again with the shield tied back to the guard) for the unguarded lead is not mandatory here (or in 7.2.2), although its use provides some reduction in background noise (see also Fig. 9).

7.2.2 Without Guard Electrodeâ€—Use coaxial cable, with the core lead to one electrode and the shield terminated about 1 cm from the end of the core lead (see also Fig. 10).
7.3 Direct Measurementsâ€—The current through a specimen at a fixed voltage is measured using any equipment that has the required sensitivity and accuracy (Â±10 % is usually adequate). Current-measuring devices available include electrometers, d-c amplifiers with indicating meters, and galvanometers. Typical methods and circuits are given in Appendix X3. When the measuring device scale is calibrated to read ohms directly no calculations are required for resistance measurements.
7.4 Comparison Methodsâ€—A Wheatstone-bridge circuit may be used to compare the resistance of the specimen with that of a standard resistor (see Appendix X3).
7.5 Precision and Bias Considerations:
7.5.1 Generalâ€—As a guide in the choice of apparatus, the pertinent considerations are summarized in Table 2, but it is not implied that the examples enumerated are the only ones applicable. This table is not intended to indicate the limits of sensitivity and error of the various methods per se, but rather is intended to indicate limits that are distinctly possible with modern apparatus. In any case, such limits can be achieved or exceeded only through careful selection and combination of the apparatus employed. It must be emphasized, however, that the errors considered are those of instrumentation only. Errors such as those discussed in Appendix X1 are an entirely different matter. In this latter connection, the last column of Table 2 lists the resistance that is shunted by the insulation resistance

between the guarded electrode and the guard system for the various methods. In general, the lower such resistance, the less probability of error from undue shunting.

TABLE 1 Calculation of Resistivity or Conductivity[A]

Type of Electrodes or Specimen	Volume Resistivity, Ω-cm	Volume Conductivity, S/cm	Effective Area of Measuring Electrode
	$\rho_v = \frac{A}{t}R_v$	$\gamma_v = \frac{t}{A}G_v$	
Circular (Fig. 4)	$\rho_v = \frac{A}{t}R_v$	$\gamma_v = \frac{t}{A}G_v$	$A = \frac{\pi(D_1 + g)^2}{4}$
Rectangular	$\rho_v = \frac{A}{t}R_v$	$\gamma_v = \frac{t}{A}G_v$	$A = (a + g)(b + g)$
Square	$\rho_v = \frac{A}{t}R_v$	$\gamma_v = \frac{t}{A}G_v$	$A = (a + g)^2$
Tubes (Fig. 5)	$\rho_v = \frac{A}{t}R_v$	$\gamma_v = \frac{t}{A}G_v$	$A = \pi D_0(L + g)$
Cables	$\rho_v = \frac{2\pi L R_v}{\ln \frac{D_2}{D_1}}$	$\gamma_v = \frac{\ln \frac{D_2}{D_1}}{2\pi L R_v}$	
	Surface Resistivity, Ω (per square)	Surface Conductivity, S (per square)	Effective Perimeter of Guarded Electrode
	$\rho_s = \frac{P}{g}R_s$	$\gamma_s = \frac{g}{P}G_s$	
Circular (Fig. 4)	$\rho_s = \frac{P}{g}R_s$	$\gamma_s = \frac{g}{P}G_s$	$P = \pi D_0$
Rectangular	$\rho_s = \frac{P}{g}R_s$	$\gamma_s = \frac{g}{P}G_s$	$P = 2(a + b + 2g)$
Square	$\rho_s = \frac{P}{g}R_s$	$\gamma_s = \frac{g}{P}G_s$	$P = 4(a + g)$
Tubes (Figs. 5 and 6)	$\rho_s = \frac{P}{g}R_s$	$\gamma_s = \frac{g}{P}G_s$	$P = 2\pi D_2$

Nomenclature:
A = the effective area of the measuring electrode for the particular arrangement employed,
P = the effective perimeter of the guarded electrode for the particular arrangement employed,
R_v = measured volume resistance in ohms,
G_v = measured volume conductance in siemens,
R_s = measured surface resistance in ohms,
G_s = measured surface conductance in siemens,
t = average thickness of the specimen,
D_0, D_1, D_2, g, L = dimensions indicated in Fig. 4 and Fig. 6 (see Appendix X2 for correction to g),
a, b, = lengths of the sides of rectangular electrodes, and
ln = natural logarithm.

[A] All dimensions are in centimetres.

NOTE 2â€”No matter what measurement method is employed, the highest precisions are achieved only with careful evaluation of all sources of error. It is possible either to set up any of these methods from the component parts, or to acquire a completely integrated apparatus. In general, the methods using high-sensitivity galvanometers require a more permanent installation than those using indicating meters or recorders. The methods using indicating devices such as voltmeters, galvanometers, d-c amplifiers, and electrometers require the minimum of manual adjustment and are easy to read but the operator is required to make the reading at a particular time. The Wheatstone bridge (Fig. X1.4) and the potentiometer method (Fig. X1.2 (b)) require the undivided attention of the operator in keeping a balance, but allow the setting at a particular time to be read at leisure.

7.5.2 Direct Measurements:
7.5.2.1 Galvanometer-Voltmeterâ€”The maximum percentage error in the measurement of resistance by the galvanometer-voltmeter method is the sum of the percentage errors of galvanometer indication, galvanometer readability, and voltmeter indication. As an example: a galvanometer having a sensitivity of 500 pA/scale division will be deflected 25 divisions with 500 V applied to a resistance of 40 GV (conductance of 25 pS). If the deflection can be read to the nearest 0.5 division, and the calibration

error (including Ayrton Shunt error) is Â±2 % of the observed value, the resultant galvanometer error will not exceed Â±4 %. If the voltmeter has an error of Â±2 % of full scale, this resistance can be measured with a maximum error of Â±6 % when the voltmeter reads full scale, and Â±10 % when it reads one-third full scale. The desirability of readings near full scale are readily apparent.
7.5.2.2 Voltmeter-Ammeterâ€"The maximum percentage error in the computed value is the sum of the percentage errors in the voltages, Vx and Vs, and the resistance, Rs. The errors in Vs and Rs are generally dependent more on the characteristics of the apparatus used than on the particular method. The most significant factors that determine the errors in Vs are indicator errors, amplifier zero drift, and amplifier gain stability. With modern, well-designed amplifiers or electrometers, gain stability is usually not a matter of concern. With existing techniques, the zero drift of direct voltage amplifiers or electrometers cannot be eliminated but it can be made slow enough to be relatively insignificant for these measurements. The zero drift is virtually nonexistent for carefully designed converter-type amplifiers. Consequently, the null method of Fig. X1.2 (b) is theoretically less subject to error than those methods employing an indicating instrument, provided, however, that the potentiometer voltage is accurately known. The error in Rs is to some extent dependent on the amplifier sensitivity. For measurement of a given current, the higher the amplifier sensitivity, the greater likelihood that lower valued, highly precise wirewound standard resistors can be used. Such amplifiers can be obtained. Standard resistances of 100 GV known to Â±2 %, are available. If 10-mV input to the amplifier or electrometer gives full-scale deflection with an error not greater than 2 % of full scale, with 500 V applied, a resistance of 5000 TV can be measured with a maximum error of 6 % when the voltmeter reads full scale, and 10 % when it reads 1â•„3 scale.

7.5.2.3 Comparison-Galvanometerâ€"The maximum percentage error in the computed resistance or conductance is given by the sum of the percentage errors in Rs, the galvanometer deflections or amplifier readings, and the assumption that the current sensitivities are independent of the deflections. The latter assumption is correct to well within Â±2 % over the useful range (above 1â•„10 full-scale deflection) of a good, modern galvanometer (probably 1â•„3 scale deflection for a dc current amplifier). The error in Rs depends on the type of resistor used, but resistances of 1 MV with a limit of error as low as 0.1 % are available. With a galvanometer or d-c current amplifier having a sensitivity of 10 nA for full-scale deflection, 500 V applied to a resistance of 5 TV will produce a 1 % deflection. At this voltage, with the preceding noted standard resistor, and with Fs = 10^5, ds would be about half of full-scale deflection, with a readability error not more than Â±1 %. If dx is approximately 1â•„4 of full-scale deflection, the readability error would not exceed Â±4 %, and a resistance of the order of 200 GV could be measured with a maximum error of 5 1â•„2 %.
7.5.2.4 Voltage Rate-of-Changeâ€"The accuracy of the measurement is directly proportional to the accuracy of the measurement of applied voltage and time rate of change of the electrometer reading. The length of time that the electrometer switch is open and the scale used should be such that the time can be measured accurately and a full-scale reading obtained. Under these conditions, the accuracy will be comparable with that of the other methods of measuring current.
7.5.2.5 Comparison Bridgeâ€"When the detector has adequate sensitivity, the maximum percentage error in the computer resistance is the sum of the percentage errors in the arms, A, B, and N. With a detector sensitivity of 1 mV/scale division, 500 V applied to the bridge, and RN = 1 GV, a resistance of 1000 TV will produce a detector deflection of one scale division. Assuming negligible errors in RA and RB, with RN = 1 GV known to within Â±2 % and with the bridge balanced to one detector-scale division, a resistance of 100 TV can be measured with a maximum error of Â±6 %.

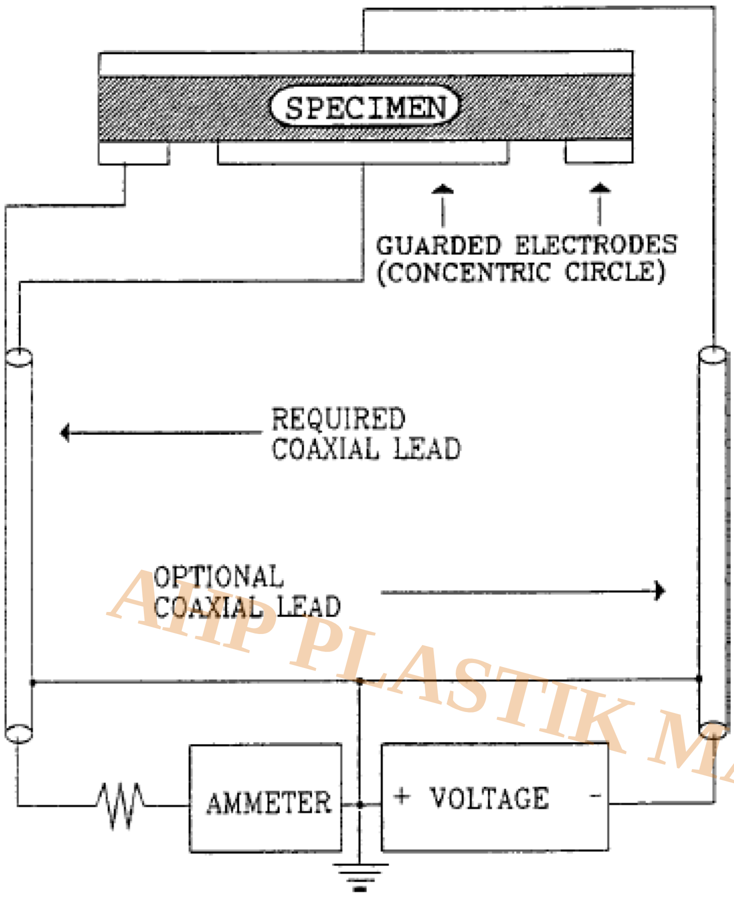


FIG. 9 Connections to Guarded Electrode for Volume and Surface Resistivity Measurements (Volume Resistance hook-up shown)

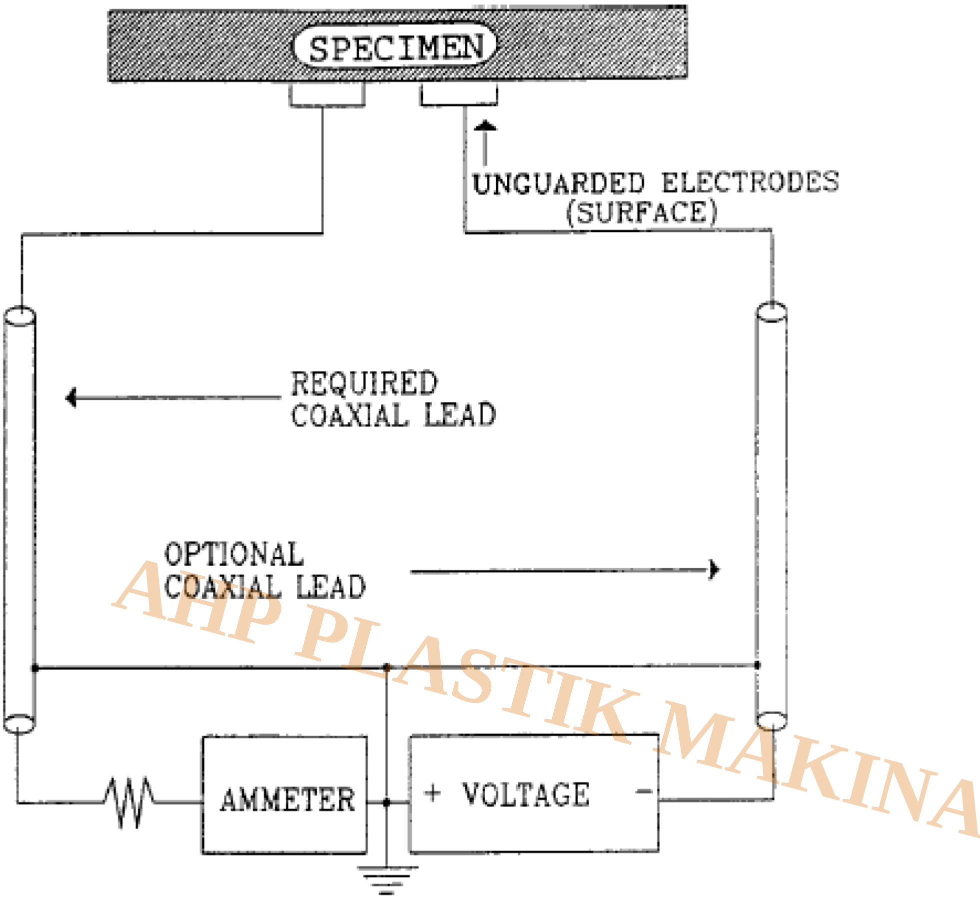


FIG. 10 Connections to Unguarded Electrodes for Volume and Surface Resistivity Measurements (Surface Resistance Hook-Up Shown)

TABLE 2 Apparatus and Conditions for Use

Method	Reference		Maximum Ohms Detectable at 500 V	Maximum Ohms Measurable to ±6 % at 500 V	Type of Measurement	Ohms Shunted by Insulation Resistance from Guard to Guarded Electrode
	Section	Figure				
Voltmeter-ammeter (galvanometer)	X3.1	Fig. X1.1	10^{12}	10^{11}	deflection	10 to 10^5
Comparison (galvanometer)	X3.4	Fig. X1.3	10^{12}	10^{11}	deflection	10 to 10^5
Voltmeter-ammeter (dc amplification, electrometer)	X3.2	Fig. X1.2(*a*)			deflection	10^2 to 10^9
		(Position *1*)	10^{15}	10^{13}		
		Fig. X1.2(*a*)			deflection	10^2 to 10^3
		(Position *2*)	10^{15}	10^{13}	deflection	10^3 to 10^{11}
		Fig. X1.2(*b*)	10^{17}	10^{15}	null	0 (effective)
		Fig. X1.2(*b*)	10^{17}	10^{15}		
Comparison (Wheatstone bridge)	X3.5	Fig. X1.4	10^{15}	10^{14}	null	10^5 to 10^6
Voltage rate-of-change	X3.3	Fig. X3.1	~100 MΩ-F		deflection	unguarded
Megohmmeter (typical)	commercial instruments		10^{15}	10^{14}	direct-reading	10^4 to 10^{10}

7.6 Several manufacturers are available that can supply the necessary components or dedicated systems that will meet the requirements of this methodology. Reference the equipment database for a listing of companies who have provided information regarding their instrument offerings.

Sampling

8.1 Refer to applicable materials specifications for sampling instructions.

Test Specimens

9.1 Insulation Resistance or Conductance Determination:

9.1.1 The measurement is of greatest value when the specimen has the form, electrodes, and mounting required in actual use. Bushings, cables, and capacitors are typical examples for which the test electrodes are a part of the specimen and its normal mounting means.

9.1.2 For solid materials, the test specimen may be of any practical form. The specimen forms most commonly used are flat plates, tapes, rods, and tubes. The electrode arrangements of Fig. 2 may be used for flat plates, rods, or rigid tubes whose inner diameter is about 20 mm or more. The electrode arrangement of Fig. 3 may be used for strips of sheet material or for flexible tape. For rigid strip specimens the metal support may not be required. The electrode arrangements of Fig. 6 may be used for flat plates, rods, or tubes. Comparison of materials when using different electrode arrangements is frequently inconclusive and should be avoided.

9.2 Volume Resistance or Conductance Determination:

9.2.1 The test specimen may have any practical form that allows the use of a third electrode, when necessary, to guard against error from surface effects. Test specimens may be in the form of flat plates, tapes, or tubes. Fig. 4, Fig. 7, and Fig. 8 illustrate the application and arrangement of electrodes for plate or sheet specimens. Fig. 5 is a diametral cross section of three electrodes applied to a tubular specimen, in which electrode No. 1 is the guarded electrode; electrode No. 2 is a guard electrode consisting of a ring at each end of electrode No. 1, the two rings being electrically connected; and electrode No. 3 is the unguarded electrode (7, 8). For those materials that have negligible surface leakage and are being examined for volume resistance only, omit the use of guard rings. Convenient and generally suitable dimensions applicable to Fig. 4 in the case of test specimens that are 3 mm in thickness are as follows: D3 = 100 mm, D2 = 88 mm, and D1 = 76 mm, or alternatively, D3 = 50 mm, D2 = 38 mm, and D1 = 25 mm. For a given sensitivity, the larger specimen allows more accurate measurements on materials of higher resistivity.

9.2.2 Measure the average thickness of the specimens in accordance with one of the methods in Test Methods D374 pertaining to the material being tested. The actual points of measurement shall be uniformly distributed over the area to be covered by the measuring electrodes.

9.2.3 It is not necessary that the electrodes have the circular symmetry shown in Fig. 4 although this is generally convenient. The guarded electrode (No. 1) may be circular, square, or rectangular, allowing ready computation of the guarded electrode effective area for volume resistivity or conductivity determination when such is desired. The diameter of a circular electrode, the side of a square, or the shortest side of a rectangular electrode, should be at least four times the specimen thickness. The gap width should be great enough so that the surface leakage between electrodes No. 1 and No. 2 does not cause an error in the measurement (this is particularly important for high-input-impedance instruments, such as electrometers). If the gap is made equal to twice the specimen thickness, as suggested in 9.3.3, so that the specimen can be used also for surface resistance or conductance determinations, the effective area of electrode No. 1 can be taken, usually with sufficient accuracy, as extending to the center of the gap. If, under special conditions, it becomes desirable to determine a more accurate value for the effective area of electrode No. 1, the correction for the gap width can be obtained from Appendix X2. Electrode No. 3 may have any shape provided that it extends at all points beyond the inner edge of electrode No. 2 by at least twice the specimen thickness.

9.2.4 For tubular specimens, electrode No. 1 should encircle the outside of the specimen and its axial length should be at least four times the specimen wall thickness. Considerations regarding the gap width are the same as those given in 9.2.3. Electrode No. 2 consists of an encircling electrode at each

end of the tube, the two parts being electrically connected by external means. The axial length of each of these parts should be at least twice the wall thickness of the specimen. Electrode No. 3 must cover the inside surface of the specimen for an axial length extending beyond the outside gap edges by at least twice the wall thickness. The tubular specimen (Fig. 5) may take the form of an insulated wire or cable. If the length of electrode is more than 100 times the thickness of the insulation, the effects of the ends of the guarded electrode become negligible, and careful spacing of the guard electrodes is not required. Thus, the gap between electrodes No. 1 and No. 2 may be several centimetres to permit sufficient surface resistance between these electrodes when water is used as electrode No. 1. In this case, no correction is made for the gap width.
9.3 Surface Resistance or Conductance Determination:
9.3.1 The test specimen may be of any practical form consistent with the particular objective, such as flat plates, tapes, or tubes.

9.3.2 The arrangements of Fig. 2 and Fig. 3 were devised for those cases where the volume resistance is known to be high relative to that of the surface (2). However, the combination of molded and machined surfaces makes the result obtained generally inconclusive for rigid strip specimens. The arrangement of Fig. 3 is somewhat more satisfactory when applied to specimens for which the width is much greater than the thickness, the cut edge effect thus tending to become relatively small. Hence, this arrangement is more suitable for testing thin specimens such as tape, than for testing relatively thicker specimens. The arrangements of Fig. 2 and Fig. 3 should never be used for surface resistance or conductance determinations without due considerations of the limitations noted previously.
9.3.3 The three electrode arrangements of Fig. 4, Fig. 6, and Fig. 7 may be used for purposes of material comparison. The resistance or conductance of the surface gap between electrodes No. 1 and No. 2 is determined directly by using electrode No. 1 as the guarded electrode, electrode No. 3 as the guard electrode, and electrode No. 2 as the unguarded electrode (7, 8). The resistance or conductance so determined is actually the resultant of the surface resistance or conductance between electrodes No. 1 and No. 2 in parallel with some volume resistance or conductance between the same two electrodes. For this arrangement the surface gap width, g, should be approximately twice the specimen thickness, t, except for thin specimens, where g may be much greater than twice the material thickness.
9.3.4 Special techniques and electrode dimensions may be required for very thin specimens having such a low volume resistivity that the resultant low resistance between the guarded electrode and the guard system would cause excessive error.
9.4 Liquid Insulation Resistanceâ€”The sampling of liquid insulating materials, the test cells employed, and the methods of cleaning the cells shall be in accordance with Test Method D1169.

Specimen Mounting
10.1 In mounting the specimens for measurements, it is important that no conductive paths exist between the electrodes or between the measuring electrodes and ground, significantly affecting the reading of the measuring instrument (9). Avoid handling insulating surfaces with bare fingers by wearing acetate rayon gloves. For referee tests of volume resistance or conductance, clean the surfaces with a suitable solvent before conditioning. When surface resistance is to be measured, mutually agree whether or not the surfaces should be cleaned. If cleaning is required, record details of any surface cleaning.

Conditioning
11.1 Condition the specimens in accordance with Practice D6054.

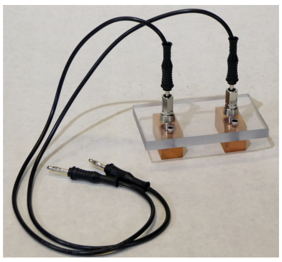
11.2 Circulating-air environmental chambers or the methods described in Practices E104 or D5032 are useful for controlling the relative humidity.

Procedure

12.1 Insulation Resistance or Conductanceâ€"Properly mount the specimen in the test chamber. If the test chamber and the conditioning chamber are the same (recommended procedure), the specimens should be mounted before the conditioning is started. Make the measurement with a suitable device having the required sensitivity and accuracy (see Appendix X3). Unless otherwise specified, use 60 s as the time of electrification and 500 Â± 5 V as the applied voltage.
12.2 Volume Resistivity or Conductivityâ€"Measure and record the dimensions of the electrodes and width of guard gap, g. Calculate the effective area of the electrode. Make the resistance measurement with a suitable device having the required sensitivity and accuracy. Unless otherwise specified, use 60 s as the time of electrification, and 500 Â± 5 V as the applied direct voltage.
12.3 Surface Resistance or Conductance:
12.3.1 Measure the electrode dimensions and the distance between the electrodes, g. Measure the surface resistance or conductance between electrodes No. 1 and 2 with a suitable device having the required sensitivity and accuracy. Unless otherwise specified, use 60 s for the time of electrification , and apply a direct voltage of 500 Â± 5 V.
12.3.2 When the electrode arrangement of Fig. 3 is used, P is taken as the perimeter of the cross section of the specimen. For thin specimens, such as tapes, this perimeter effectively reduces to twice the specimen width.
12.3.3 When the electrode arrangements of Fig. 6 are used, and if the volume resistance is known to be very high compared to the surface resistance (such as moisture contaminating the surface of a good insulation material), P is taken to be two times the length of the electrode or two times the circumference of the cylinder.

Calculation

13.1 Calculate the volume resistivity, [rho]v, and the volume conductivity, [gama]v, using the equations in Table 1.
13.2 Calculate the surface resistivity, [rho]s, and the surface conductivity, [gama]s, using the equations in Table 1.



Volume and Surface Resistivity Tester for Flat Samples

- Voltage up to 500V or 1000 V as per customer request
- Sample electrode for flat samples according to ASTM D257
- Other electrode systems will be quoted as per customer request
- Picture is as reference only, suitable device will be selected according to test criteria
- Training video included

Category

1. Equipment for Standards
2. Standards