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Standard Test Methods for Thickness of Solid Electrical Insulation[1]

This standard is issued under the fixed designation D374/D374M; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 These test methods cover the determination of the thickness of several types of solid electrical insulating materials employing recommended techniques. Use these test methods except as otherwise required by a material specification.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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]

D1711 Terminology Relating to Electrical Insulation

D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]

E252 Test Method for Thickness of Foil, Thin Sheet, and Film by Mass Measurement

3. Terminology

3.1 Refer to Terminology D1711 for definitions pertinent to this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *1 micron, µm, n*—a dimension equivalent to 0.03937 mils.

3.2.2 *1 mil, n*—a dimension equivalent to 0.0010 in.

3.2.3 *absolute uncertainty (of a measurement), n*—the smallest division able to be read directly on the instrument used for measurement.

3.2.4 *micrometer, n*—an instrument for measuring any dimension with absolute uncertainty of 1 mil [25 µm] or smaller.

4. Summary of Test Methods

4.1 This standard provides eight different test methods for the measurement of thickness of solid electrical insulation materials. The test methods (identified as Test Methods A through H) employ different micrometers that exert various pressures for varying times upon specimens of different geometries. Tables 1 and 2 display basic differences of each test method and identify test methods applicable for use on various categories of materials.

5. Significance and Use

5.1 Some electrical properties, such as dielectric strength, vary with the thickness of the material. Determination of certain properties, such as relative permittivity (dielectric constant) and volume resistivity, usually require a knowledge of the thickness. Design and construction of electrical machinery require that the thickness of insulation be known.

6. Apparatus

6.1 *Apparatus A—Machinist's Micrometer Caliper*[4] with Calibrated Ratchet or Friction Thimble:

6.1.1 Apparatus A is a micrometer caliper without a locking device but is equipped with either a calibrated ratchet or a friction thimble. By use of a proper manipulative procedure and a calibrated spring (see Annex A1), the pressure exerted on the specimen is controllable.

[1] These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are 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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Hereinafter referred to as a machinist's micrometer.

TABLE 1 Test Methods Suitable for Specific Materials

Material	Test Method
Plastic sheet and film	A B C or D
Paper (all thicknesses)	E
Paper (over 2 mils [50 µm] thickness)	F or G
Rubber and other elastomers	H

TABLE 2 Test Method Parameter Differences

Test Method	Apparatus	Diameter of Presser Foot or Spindle, mils [mm]	Pressure on Specimen, approximate, PSI [kPa approximate]
A	Machinist micrometer with calibrated ratchet or thimble	250 [6]	not specified
B	Machinist micrometer without ratchet/thimble	250 [6]	unknown
C	Dead-weight dial type bench micrometer—Manual	125 to 500 [3 to 13]	0.5 to 130 [4 to 900]
D	Dead-weight dial type bench micrometer—Motor operated	125 to 500 [3 to 13]	0.5 to 130 [4 to 900]
E	Dead-weight dial type bench micrometer—Motor operated	250 [6]	25 [172]
F	Dead-weight dial type bench micrometer—Manual	250 [6]	25 [172]
G	Machinist micrometer with calibrated ratchet or thimble	250 [6]	25 [172]
H	Dead-weight dial type bench micrometer—Manual	250 [6]	4 [27]

6.1.2 Use an instrument constructed with a vernier capable of measurement to the nearest 0.1 mil [2 µm].

6.1.3 Use an instrument with the diameter of the anvil and spindle surfaces (which contact the specimen) of 250 ± 1 mil [6.35 ± 0.05 mm].

6.1.4 Use an instrument conforming to the requirements of 7.1, 7.2, 7.5, 7.6.1, and 7.6.2.

6.1.5 Periodically, test the micrometer for conformance to the requirements of 6.1.4.

6.2 *Apparatus B—Machinist's Micrometer Without a Ratchet:*

6.2.1 Apparatus B is a micrometer caliper without a locking device.

6.2.2 Use an instrument constructed with a vernier capable of measurement to the nearest 0.1 mil [2 µm].

6.2.3 Use an instrument with the diameter of the anvil and spindle surfaces (which contact the specimen) 250 ± 1 mil [6.35 ± 0.05 mm].

6.2.4 Use an instrument conforming to the requirements of 7.1, 7.2, 7.5.1, 7.5.2, 7.5.3, 7.6.1, and 7.6.3.

6.2.5 Periodically, examine and test the micrometer for conformance to the requirements of 6.2.4.

6.3 *Apparatus C—Manually-Operated, Dead-Weight, Dial Type Thickness Gauge:*[5]

6.3.1 Use a dead-weight dial-type gauge in accordance with the requirements of 7.1, 7.3, 7.4, 7.6.1, 7.6.4, that has:

6.3.1.1 A presser foot that moves in an axis perpendicular to the anvil face,

6.3.1.2 The surfaces of the presser foot and the anvil (which contact the specimen) parallel to within 0.079 mil [2 µm] or 0.1 mil [2.54 µm] (see 7.3),

6.3.1.3 A vertical dial spindle,

6.3.1.4 A dial indicator essentially friction-free and capable of repeatable readings within ±0.05 mil [±1.2 µm] at zero setting, or on a steel gauge block,

6.3.1.5 A frame, housing the indicator, of such rigidity that a load of 2.92 lbf [13 N] or 3 lbf [13.34 N] applied to the dial housing, out of contact with the presser foot spindle (or any weight attached thereto) will produce a deflection of the frame not greater than the smallest scale division on the indicator dial, and,

6.3.1.6 A dial diameter at least 2 in. [50 mm] and graduated continuously to read directly to the nearest 0.079 mil [2 µm] or 0.1 mil [2.54 µm]. If necessary, equip the dial with a revolution counter that displays the number of complete revolutions of the large hand.

6.3.1.7 An electronic instrument having a digital readout in place of the dial indicator is permitted if that instrument meets the other requirements of 6.3.

6.3.2 The preferred design and construction of manually operated dead-weight dial-type micrometers calls for a limit on the force applied to the presser foot. The limit is related to the compressive characteristics of the material being measured.

6.3.2.1 The force applied to the presser foot spindle and the weight necessary to move the pointer upward from the zero position shall be less than the force that will cause permanent deformation of the specimen. The force applied to the presser foot spindle and the weight necessary to just prevent movement of the pointer from a higher to a lower reading shall be more than the minimum permissible force specified for a specimen.

6.4 *Apparatus D—Motor-Operated Dead-Weight Dial Gauge:*

6.4.1 Except as additionally defined in this section, use an instrument that conforms to the requirements of 6.3. An electronic instrument having a digital readout in place of the dial indicator is permitted if that instrument meets the other requirements of 6.3 and 6.4.

6.4.2 Use a motor operated instrument having a presser foot spindle that is lifted and lowered by a constant speed motor through a mechanical linkage such that the rate of descent (for a specified range of distances between the presser foot surface and the anvil) and the dwell time on the specimen are within the limits specified for the material being measured. Design the mechanical linkage so that the only downward force upon the presser foot spindle is that of gravity upon the weighted spindle assembly without any additional force exerted by the lifting/lowering mechanism.

6.4.2.1 The preferred design and construction of motor operated dead-weight dial-type micrometers calls for a limit on the force applied to the presser foot. The limit is related to the compressive characteristics of the material being measured.

6.4.2.2 The force applied to the presser foot spindle and the weight necessary to move the pointer upward from the zero position shall be less than the force that will cause permanent deformation of the specimen. The force applied to the presser foot spindle and the weight necessary to just prevent movement

[5] Herein referred to as a dial gauge.

of the pointer from a higher to a lower reading needs to be more than the minimum permissible force specified for a specimen.

7. Calibration (General Considerations for Care and Use of Each of the Various Pieces of Apparatus for Thickness Measurements)

7.1 Good testing practices require clean anvil and presser foot surfaces for any micrometer instrument. Prior to calibration or thickness measurements, clean such surfaces by inserting a piece of smooth, clean bond paper between the anvil and the presser foot and slowly moving the bond paper between the surfaces. During measurements, check the zero setting frequently. It is possible that failure to repeat the zero setting will be evidence of dirt or contamination on the surfaces.

NOTE 1—Avoid pulling any edge of the bond paper between the surfaces to reduce the probability of depositing any lint particles on the surfaces.

7.2 The parallelism requirements for machinist's micrometers demand that observed differences of readings on a pair of screw-thread-pitch wires or a pair of standard 250 mil [6.35 mm] or 236 mil [6 mm] nominal diameter plug gauges be not greater than 0.079 mil [2 µm] or 0.1 mil [2.5 µm]. Spring-wire stock or music-wire of known diameter are suitable substitutes. The wire (or the plug gauge) has a diameter dimension that is known to be within ±0.05 mil [±1.3 µm]. It is possible that diameter dimensions will vary by an amount approximately equal to the axial movement of the spindle when the wire (or the plug gauge) is rotated through 180°.

7.2.1 Lacking a detailed procedure supplied by the instrument manufacturer, confirm the parallelism requirements of machinist's micrometers using the following procedure:

7.2.1.1 Close the micrometer on the screw-thread-pitch wire or the plug gauge in accordance with the calibration procedure of 7.6.2 or 7.6.3 as appropriate.

7.2.1.2 Observe and record the thickness indicated.

7.2.1.3 Move the screw-thread-pitch wire or the plug gauge to a different position between the presser foot and the anvil and repeat 7.2.1.1 and 7.2.1.2.

7.2.1.4 If the difference between any pair of readings is greater than 0.1 mil [2.5 µm], the surfaces are NOT parallel.

7.3 Lacking a detailed procedure supplied by the instrument manufacturer, confirm the requirements for parallelism of dial-type micrometers given in 6.3.1.2 by placing a hardened steel ball (such as is used in a ball bearing) of suitable diameter between the presser foot and the anvil. Mount the ball in a fork-shaped holder to allow the ball to be conveniently moved from one location to another between the presser foot and the anvil. The balls used commercially in ball bearings are almost perfect spheres having diameters constant within a few microinches [micrometres].

NOTE 2—Exercise care with this procedure. Calculations using the equations in X1.3.2 show that it is possible that the use of a 24-oz [0.68 kg] weight on a ball between the hardened surfaces of presser foot and anvil will result in dimples in the anvil or presser foot surfaces caused by exceeding the yield stress of the surfaces.

7.3.1 Observe and record the diameter as measured by the micrometer at one location.

7.3.2 Move the ball to another location and repeat the measurement.

7.3.3 If the difference between any pair of readings is greater than 0.1 mil [2.5 µm], the surfaces are NOT parallel.

7.4 Lacking a detailed procedure supplied by the instrument manufacturer, confirm the flatness of the anvil and the spindle surface of a micrometer or dial gauge by use of an optical flat which has clean surfaces. Surfaces shall be flat within 0.05 mil [1.3 µm].

7.4.1 After cleaning the micrometer surfaces (see 7.1), place the optical flat on the anvil and close the presser foot as described in 7.6.2 or 7.6.3 or 7.6.4 or 7.6.5 as appropriate.

7.4.2 When illuminated by diffused daylight, interference bands are formed between the surfaces of the flat and the surfaces of the micrometer. The shape, location, and number of these bands indicate the deviation from flatness in increments of half the average wavelengths of white light, which is taken as 0.079 mil [2 µm] or 0.1 mil [2.5 µm].

7.4.2.1 A flat surface forms straight parallel fringes at equal intervals.

7.4.2.2 A grooved surface forms straight parallel fringes at unequal intervals.

7.4.2.3 A symmetrical concave or convex surface forms concentric circular fringes. Their number is a measure of deviation from flatness.

7.4.2.4 An unsymmetrical concave or convex surface forms a series of curved fringes that cut the periphery of the micrometer surface. The number of fringes cut by a straight line connecting the terminals of any fringes is a measure of the deviation from flatness.

7.5 *Machinist's Micrometer Requirements :*

7.5.1 The requirements for zero reading of machinist's micrometers are met when ten closings of the spindle onto the anvil, in accordance with 7.6.2.3 or 7.6.3.3 as appropriate, result in ten zero readings. The condition of zero reading is satisfied when examinations with a low-power magnifying glass show that at least 66 % of the width of the zero graduation mark on the barrel coincides with at least 66 % of the width of the reference mark.

7.5.2 Proper maintenance of a machinist's micrometer requires adjusting the instrument for wear of the micrometer screw so that the spindle has no perceptible lateral or longitudinal looseness yet rotates with a torque load of less than 0.25 ozf–in. [0.0018 Nm]. If this is not achievable after disassembly, cleaning, and lubrication, replace the instrument.

7.5.3 After the zero reading has been checked, use the calibration procedure of 7.6.2 or 7.6.3 (as appropriate for the machinist's micrometer under examination) to check for maximum acceptable error in the machinist's micrometer screw.

7.5.3.1 Use selected feeler-gauge blades with known thicknesses to within ±0.02 mil [±0.5 µm] to check micrometers calibrated in English units at approximately 2, 5, and 10-mil [50.8, 127, and 254 µm]. Use standard gauge blocks at points greater than 10 mil [254 µm].

7.5.3.2 At each point checked, take ten readings. Calculate the arithmetic mean of these ten readings.

7.5.3.3 The machinist's micrometer screw error is within requirements if the difference between the mean value of

7.5.3.2 and the gauge block (or feeler-gauge blade) thickness is not more than 0.1 mil [2.54 µm].

7.5.4 *Calibration of Spindle Pressure in Machinist's Micrometer with Ratchet or Friction Thimble:*

7.5.4.1 See Annex A1, which details the apparatus and procedure required for this calibration.

7.6 *Calibration of Micrometers :*

7.6.1 Calibrate all micrometers in a standard laboratory atmosphere maintained at 50 % relative humidity and 73.4°F [23°C] or some other standard condition as mutually agreed upon between the seller and the purchaser. Use standard gauge blocks or other metallic objects of known thickness. The known thickness accuracy of such blocks shall be within ±10 % of the smallest scale division of the micrometer dial or scale. Thus, if an instrument's smallest scale division is 0.1 mil [2.54 µm], the standard gauge block thickness shall be known to within ±0.01 mil [0.254 µm]. Perform calibration procedures only after the instrument has been checked and found to meet the requirements of the pertinent preceding paragraphs of this standard. Perform calibration procedures at least once every 30 days.

7.6.2 *Calibration Procedure for Apparatus A, Machinist's Micrometer with Ratchet or Friction Thimble:*

7.6.2.1 Calibrate the ratchet spring or friction thimble in accordance with Annex A1.

7.6.2.2 Rotate the spindle so as to close the micrometer on the gauge block or other calibrating device. Reverse the rotation so as to open the micrometer 4 to 5 mils [103 to 127 µm].

7.6.2.3 Using the ratchet knob or the friction thimble, again close the micrometer so slowly on the calibrating device that it becomes easy to count the scale divisions as they move past the reference mark. This rate approximates about 2 mils/s [50.8 µm/s].

7.6.2.4 Continue the closing motion until the ratchet clicks three times or the friction thimble slips.

7.6.2.5 Observe and record the thickness reading.

7.6.2.6 Repeat the procedures in 7.6.2.2 – 7.6.2.5 using several gauge blocks (or other calibration devices) of different thicknesses covering the range of thickness of electrical insulation for measurement with this micrometer.

7.6.2.7 Construct a calibration curve that will provide the corrections for application to the observed thickness of specimens tested for thickness using this calibrated micrometer.

7.6.3 *Calibration Procedure for Apparatus B, Machinist's Micrometer without Ratchet or Friction Thimble:*

7.6.3.1 Rotate the spindle so as to close the micrometer on the gauge block or other calibrating device. Reverse the rotation so as to open the micrometer 4 to 5 mils [103 to 127 µm].

7.6.3.2 Close the micrometer again so slowly on the calibrating device that it becomes easy to count the scale divisions as they move past the reference mark. This rate approximates about 2 mils/s [50.8 µm/s].

7.6.3.3 Continue the closing motion until the spindle face contacts the surface of the gauge block (or other calibrating device). Contact is made when frictional resistance initially develops to the movement of the calibrating device between the anvil and the spindle face.

7.6.3.4 Observe and record the thickness reading.

7.6.3.5 Repeat the procedures in 7.6.3.1 – 7.6.3.4 using several gauge blocks (or other calibration devices) of different thicknesses covering the range of thickness of electrical insulation for measurement with this micrometer.

7.6.3.6 Construct a calibration curve that will provide the corrections for application to the observed thickness of specimens tested for thickness using this calibrated micrometer.

7.6.4 *Calibration Procedure for Apparatus C, Manually-Operated Dial-Type Micrometers:*

7.6.4.1 Using the procedures detailed in Section 9 pertinent to the material to be measured, collect calibration data from observations using several gauge blocks (or other calibration devices) of different thicknesses covering the range of thickness of electrical insulation for measurement with this micrometer.

7.6.4.2 Construct a calibration curve that will provide the corrections for application to the observed thickness of specimens tested for thickness using this calibrated micrometer.

7.6.5 *Calibration Procedure for Apparatus D, Motor-Operated Dial-Type Micrometers:*

7.6.5.1 Using the procedures detailed in Section 9 pertinent to the material to be measured, collect calibration data from observations using several gauge blocks (or other calibration devices) of different thicknesses covering the range of thickness of electrical insulation for measurement with this micrometer.

7.6.5.2 Construct a calibration curve that will provide the corrections for application to the observed thickness of specimens tested for thickness using this calibrated micrometer.

8. Test Specimens

8.1 Prepare and condition each specimen in equilibrium with the appropriate standard laboratory test conditions in accordance with the test method applicable to the specific material for test.

8.2 For each specimen, take precautions to prevent damage or contamination that might adversely affect the thickness measurements.

8.3 Unless otherwise specified, make all thickness measurements at the standard laboratory atmosphere in accordance with Practice D6054.

8.4 In the procedure sections a requirement is made to avoid making measurements at locations that are less than 250 mils [6 mm] from any specimen edge. There are instances, particularly when measuring very narrow strip specimens used for tensile tests, and so forth, when this requirement cannot be satisfied. In such cases, it is permissible to ignore this requirement.

9. Procedures

9.1 In the section on procedures, the word *test method* denotes a combination of both a specific apparatus and a procedure describing its use.

9.2 The selection of a test method for measurement of thickness is influenced by the characteristics of the solid electrical insulation for measurement. Each material will differ in its response to test method parameters, which include, but are not be limited to: compressibility, rate of loading, ultimate load, dwell time, and the dimensions of the presser foot and anvil. For a specific electrical insulating material, it is possible that these responses will cause measurements made using one test method to differ significantly from measurements made using another test method. The procedures that follow are categorized according to the materials to which each applies. See also Appendix X1.

9.3 *Test Methods Applicable to Plastic Sheet and Film:*

9.3.1 Except as otherwise specified in other applicable documents, use either Test Method A or B for plastic sheet or film specimens having nominal thickness greater than 10 mils [254 µm].

9.3.2 Except as otherwise specified in other applicable documents, use either Test Method C or D for plastic sheet or film specimens having nominal thickness at least 1 mil [25.4 µm] but not greater than 10 mils [254 µm].

9.3.3 Annex A3 of Test Method E252 contains an alternative test method applicable to all films of nominal thickness equal to or less than 2 mils [50.8 µm].

9.3.4 When testing specimens by Test Methods A, B, C, or D, use apparatus that conforms to the requirements of appropriate parts of Sections 6 and 7 including the requirement for accuracy of zero setting. In addition, use an instrument for either Test Method C or D that has:

9.3.4.1 Presser foot diameter not less than 118 mils [3 mm] nor greater than 513 mils [13 mm],

9.3.4.2 Diameter of the anvil surface upon which the specimen rests of at least 2 mils [50.8 µm], and

9.3.4.3 A force applied by the presser foot to the specimen not less than 0.1 lbf [0.45 N] nor greater than 1.6 lbf [7 N].

9.3.4.4 Calculations using the dimensions of 9.3.4.1 and the forces of 9.3.4.3 show that the pressure upon a specimen is likely to range between 0.58 and 130 psig [3 and 900 kPa]. (**Warning**—It is possible that cleaning the presser foot and anvil surfaces as described in 7.1 will cause damage to digital electronic gauges. If that happens, it is possible that it will then require very expensive repairs by the instrument manufacturer. To avoid these costs, obtain procedures for cleaning such electronic gauges from the instrument manufacturer.)

9.3.4.5 An electronic gauge is an acceptable substitute for the dial gauge in Test Method C if the presser foot and anvil meet the requirements of that test method.

9.3.5 When testing specimens using Test Method D, use an instrument that has a drop rate from 45 ± 15 mils/s [0.75 to 1.5 mm/s] between 25 and 1 mil [650 and 25 µm] on the dial and a capacity of at least 31 mils [800 µm].

9.3.6 It is possible that the presence of contaminating substances on the surfaces of the test specimens, presser foot, anvil, or spindle will interfere with thickness measurements and result in erroneous readings. To help prevent this interference, select only clean specimens for testing and keep them and the thickness measuring instrument covered until ready to make measurements.

9.3.7 *Test Method A (applicable to plastic sheet and film having nominal thickness greater than 10 mils [254 µm]):*

9.3.7.1 Using Apparatus A and specimens in conformance with Section 8, close the micrometer on an area of the specimen outside of the area for measurement. Observe this initial reading and then open the micrometer approximately 4 mils [100 µm] beyond the initial reading and move the specimen to the first measurement position. Avoid using measurement positions that are closer than 250 mils [6.35 mm] or 315 mils [8 mm] from any specimen edge.

9.3.7.2 Using the ratchet, or the friction thimble, close the micrometer at such a rate that it becomes easy to count the scale divisions as they pass the reference mark. This rate is approximately 2 mils/s [50.8 µm/s].

9.3.7.3 Continue the closing motion until the ratchet clicks three times, or the friction thimble slips. Observe the indicated thickness.

9.3.7.4 Correct the observed indicated thickness using the calibration chart obtained in accordance with 7.6 and record the corrected thickness value.

9.3.7.5 Move the specimen to another measurement position and repeat 9.3.7.1 – 9.3.7.4.

9.3.7.6 Unless otherwise specified make and record at least three thickness measurements on each specimen. The arithmetic mean of all thickness values is the thickness of the specimen.

9.3.8 *Test Method B (applicable to plastic sheet and film having nominal thickness greater than 10 mils [254 µm]):*

9.3.8.1 Using Apparatus B and specimens in conformance with Section 8, close the micrometer on an area of the specimen outside of the area for measurement. Observe this initial reading and then open the micrometer approximately 4 mils [103 µm] beyond the initial reading and move the specimen to the first measurement position. Avoid using measurement positions that are closer than 250 mils [6.35 mm] from any specimen edge.

9.3.8.2 Slowly close the micrometer at such a rate that it becomes easy to count the scale divisions as they pass the reference mark. This rate is approximately 2 mils/s [50.8 µm/s].

9.3.8.3 Continue the closing motion until contact with the specimen surface is just made as evidenced by the initial development of frictional resistance to movement of the micrometer screw. Observe the indicated thickness.

9.3.8.4 Correct the observed indicted thickness using the calibration chart obtained in accordance with 7.6 and record the corrected thickness value.

9.3.8.5 Move the specimen to another measurement position and repeat 9.3.8.1 – 9.3.8.4.

9.3.8.6 Unless otherwise specified, make and record at least three thickness measurements on each specimen. The arithmetic mean of all thickness values is the thickness of the specimen.

9.3.9 *Test Method C (applicable to plastic sheet and film having nominal thickness greater than 1 mil but not greater than 10 mils [25.4 µm but not greater than 254 µm]):*

9.3.9.1 Using Apparatus C and specimens in conformance with Section 8, place the dial gauge on a solid, level, clean table or bench that is free of excessive vibration. Confirm that the anvil and presser foot surfaces are clean. Adjust the zero point.

9.3.9.2 Using Apparatus C and specimens in conformance with Section 8, close the micrometer on an area of the specimen outside of the area for measurement. Observe this initial reading and then open the micrometer approximately 4 mils [100 µm] beyond the initial reading and move the specimen to the first measurement position. Avoid using measurement positions that are closer than 250 mils [6.35 µm] from any specimen edge.

9.3.9.3 Raise the presser foot slightly.

9.3.9.4 Move the specimen to the first measurement location and lower the presser foot to a dial reading approximately 0.3 to 0.4 mils [7.6 to 10.2 µm] higher than the initial reading of 9.3.9.2.

9.3.9.5 Drop the foot onto the specimen. See also Note 4.

9.3.9.6 Observe the dial reading. After correcting the observed indicated thickness using the calibration chart obtained in accordance with 7.6, record the corrected thickness value.

9.3.9.7 Move the specimen to another measurement position and repeat 9.3.9.1 – 9.3.9.6.

9.3.9.8 Unless otherwise specified, make and record at least three thickness measurements on each specimen. The arithmetic mean of all thickness values is the thickness of the specimen.

9.3.9.9 Recheck the instrument zero setting after measuring each specimen. A change in the setting is usually the result of contaminating particles carried from the specimen to the contacting surfaces of the presser foot and anvil. This condition necessitates the cleaning of these surfaces (see 7.1 and 9.3.4.4).

9.3.10 *Test Method D (applicable to plastic sheet and film having nominal thickness or greater than 1 mil but not greater than 10 mils [25.4 µm but not greater than 254 µm]):*

9.3.10.1 Using Apparatus D and specimens in conformance with Section 8, place the motor operated dial gauge on a solid, level, clean table or bench that is free of excessive vibration. Confirm that the anvil and presser foot surfaces are clean.

9.3.10.2 Apply power to the motor and allow the instrument to reach a thermal equilibrium with the ambient. Equilibrium is attained when the zero point adjustment becomes negligible. Do not stop the motor until all of the measurements are made. This will minimize any tendency to disturb the thermal equilibrium between the instrument and the ambient during the thickness measurements.

9.3.10.3 When the opening between the presser foot and the anvil is near its maximum, insert and position a specimen for the first measurement. Avoid using measurement positions that are less than 250 mils [6.35 mm] from any specimen edge.

9.3.10.4 While the presser foot is at rest on the specimen surface, observe the dial reading. After correcting the observed indicated thickness using the calibration chart obtained in accordance with 7.6, record the corrected thickness value.

9.3.10.5 While the presser foot is near its maximum lift, move the specimen to another measurement position and repeat 9.3.10.1 – 9.3.10.4.

9.3.10.6 Unless otherwise specified, make and record at least three thickness measurements on each specimen. The arithmetic mean of all thickness values is the thickness of the specimen.

9.3.10.7 Recheck the instrument zero setting after measuring each specimen. A change in the setting is usually the result of contaminating particles carried from the specimen to the contacting surfaces of the presser foot and anvil. This condition necessitates the cleaning of these surfaces (see 7.1 and 9.3.4.4).

9.4 *Test Methods Applicable to Papers:*

9.4.1 Each of the test methods for measurement of thickness of paper requires apparatus that:

9.4.1.1 Meets the requirements of the appropriate parts of Sections 6 and 7,

9.4.1.2 Is capable of applying a pressure of 25 ± 2 psig [172 ± 14 kPa] on the paper specimen, and

9.4.1.3 Has a presser foot diameter 0.25 in ± 2 mil [6.25 ± 0.05 mm].

9.4.2 Except as otherwise specified in other applicable documents, for electrical insulating paper having nominal thickness less than 2 mils [50 µm], use Test Method E with a specimen comprised of at least eight, and preferably ten, layers of paper. Test Method E is also the preferred test method for use with any paper of nominal thickness from 2 to 26 mils [50 to 660 µm] using a specimen consisting of a single sheet. Test Method E does not prohibit the testing of single sheet specimens of paper having nominal thickness under 2 mils [50.8 µm].

9.4.3 Use any of the test methods of 9.4 for any paper or pressboard having nominal thickness of at least 2 mils [50.8 µm].

9.4.4 *Test Method E,* applicable to all electrical insulating paper and pressboard, uses a motor operated, dead-weight, dial-type micrometer described as Apparatus D and conforming to 6.4, 7.1, and 7.6 and that also uses a drop rate of 45 ± 15 mils/s [760 to 1500 µm/s] from 25 to 1 mil [600 to 25 µm] above zero; has a capacity of at least 31 mils [800 µm]; has a dwell time between 2 and 4 s from 25 to 1 mil [600 to 25 µm] above zero; and uses a presser foot assembly having a weight of 20 ± 2 oz [0.57 ± 0.057 kg], which exerts the force to meet the pressure requirement of 9.4.1.2.

9.4.4.1 Using Apparatus D as described in 9.4.4 and specimens in conformance with Section 8, place the motor operated dial gauge on a solid, level, clean table or bench that is free of excessive vibration. Confirm that anvil and presser foot surfaces are clean.

9.4.4.2 Apply power to the motor and allow the instrument to reach a thermal equilibrium with the ambient. Equilibrium is attained when the zero point adjustment becomes negligible. Do not stop the motor until all of the measurements are made. This will minimize any tendency to disturb the thermal equilibrium between the instrument and the ambient during the thickness measurements.

9.4.4.3 Historically, some but not all specifications for electrical insulating papers having nominal thickness under 2 mils [50 µm] require a thickness specimen that consists of a stack of at least eight (preferably ten) layers of paper (see Note 3). The micrometer reading of the stack, corrected from the