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StandardTest Methods for Thickness of Solid Electrical Insulation (Metric)[1]

This standard is issued under the fixed designation 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.

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 SI units are 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]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 *absolute uncertainty (of a measurement), n*—the smallest division that may be read directly on the instrument used for measurement.

3.2.2 *micrometer, n*—an instrument for measuring any dimension with absolute uncertainty of 25 µm or smaller.

3.2.3 *1 micron, µm, n*—a dimension equivalent to 0.0000010 m.

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 Methods A through H) employ different micrometers that exert various pressures for varying times upon specimens of different geometries. Table 1 and Table 2 display basic differences of each test method and identify 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.

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

6.1.3 Use an instrument with the diameter of the anvil and spindle surfaces (which contact the specimen) of 6.25 ± 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 2 µm.

[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.

*A Summary of Changes section appears at the end of this standard

TABLE 1 Methods Suitable for Specific Materials

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

TABLE 2 Method Parameter Differences

Method	Apparatus	Diameter of Presser Foot or Spindle, mm	Pressure on Specimen, kPa approximate
A	Machinist micrometer with calibrated ratchet or thimble	6	not specified
B	Machinist micrometer without ratchet/thimble	6	unknown
C	Dead-weight dial type bench micrometer—manual	3 to 13	4 to 900
D	Dead-weight dial type bench micrometer—motor operated	3 to 13	4 to 900
E	Dead-weight dial type bench micrometer—motor operated	6	172
F	Dead-weight dial type bench micrometer—manual	6	172
G	Machinist micrometer with calibrated ratchet or thimble	6	172
H	Dead-weight dial type bench micrometer—manual	6	27

6.2.3 Use an instrument with the diameter of the anvil and spindle surfaces (which contact the specimen) of 6.25 ± 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 Gage:*[5]

6.3.1 Use a dead-weight dial-type gage 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 2 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 ±1.2 µm at zero setting, or on a steel gage block,

6.3.1.5 A frame, housing the indicator, of such rigidity that a load of 13 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 50 mm and graduated continuously to read directly to the nearest 2 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 Gage:*

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 of the pointer from a higher to a lower reading must 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. Failure to repeat the zero setting often represents evidence of dirt 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 6-mm nominal diameter plug gages be not greater than 2 µm. Spring-wire

[5] Hereinafter referred to as a dial gage.

stock or music-wire of known diameter are suitable substitutes. The wire (or the plug gage) has a diameter dimension that is known to be within ±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 gage) 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 gage 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 gage 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 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 fraction of a micron.

NOTE 2—Exercise care with this procedure. Calculations using the equations in X1.3.2 show that the use of a 0.68-kg mass and a ball between the hardened surfaces of presser foot and anvil can 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 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 gage by use of an optical flat which has clean surfaces. Surfaces shall be flat within 2 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 0.2 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 will potentially require 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 0.0018 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-gage blades with known thicknesses to within ±0.5 µm to check micrometers calibrated in metric units at approximately 50, 130, and 250-µm points. Use standard gage blocks at points greater than 25 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 gage block (or feeler-gage blade) thickness is not more than 2.5 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 23°C or some other standard condition as mutually agreed upon between the seller and the purchaser. Use standard gage 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 2 µm, the standard gage block thickness shall be known to within ±0.2 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 gage block or other calibrating device. Reverse the rotation so as to open the micrometer 100 to 125 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 is easy to count the scale divisions as they move past the reference mark. This rate approximates about 50 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 gage 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 gage block or other calibrating device. Reverse the rotation so as to open the micrometer 100 to 125 µm.

7.6.3.2 Close the micrometer again so slowly on the calibrating device that it is easy to count the scale divisions as they move past the reference mark. This rate approximates about 50 µm/s.

7.6.3.3 Continue the closing motion until the spindle face contacts the surface of the gage 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 gage 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 gage 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 gage 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 6 mm from any specimen edge. In some instances, particularly when measuring very narrow strip specimens used for tensile tests, and so forth, this requirement cannot be satisfied. In such cases, it is permissible to ignore this requirement.

9. Procedures

NOTE 3—In the remainder of this section the word *method* denotes a combination of both a specific apparatus and a procedure describing its use.

9.1 The selection of a 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 is not necessarily 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 method to differ significantly from measurements made using another method. The procedures that follow are categorized according to the materials to which each applies. See also Appendix X1.

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

9.2.1 Except as otherwise specified in other applicable documents, use either Method A or Method B for plastic sheet or film specimens having nominal thickness greater than 250 µm.

9.2.2 Except as otherwise specified in other applicable documents, use either Method C or Method D for plastic sheet or film specimens having nominal thickness at least 25 µm but not greater than 250 µm.

9.2.3 Annex A3 of Test Method E252 contains an alternative method applicable to all films of nominal thickness equal to or less than 50 µm.

9.2.4 When testing specimens by 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 Method C or Method D that has:

9.2.4.1 Presser foot diameter not less than 3 mm nor greater than 13 mm,

9.2.4.2 Diameter of the anvil surface upon which the specimen rests of at least 50 mm, and

9.2.4.3 A force applied by the presser foot to the specimen not less than 0.45 N nor greater than 7 N.

9.2.4.4 Calculations using the dimensions of 9.2.4.1 and the forces of 9.2.4.3 show that the pressure upon a specimen can range between 4 and 900 kPa.

9.2.4.5 It is acceptable to substitute an electronic gage for the dial gage in Method C if the presser foot and anvil meet the requirements of that method.

9.2.4.6 Cleaning the presser foot and anvil surfaces as described in 7.1 can cause damage to digital electronic gages. This can then lead to the need for very expensive repairs by the instrument manufacturer. To avoid these costs, obtain procedures for cleaning such electronic gages from the instrument manufacturer.

9.2.5 When testing specimens using Method D, use an instrument that has a drop rate from 0.75 to 1.5 mm/s between 650 and 25 µm on the dial and a capacity of at least 800 µm.

9.2.6 The presence of contaminating substances on the surfaces of the test specimens, presser foot, anvil, or spindle can 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.

9.2.7 *Method A (applicable to plastic sheet and film having nominal thickness greater than 250 µm):*

9.2.7.1 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 100 µm beyond the initial reading and move the specimen to the first measurement position. Avoid using measurement positions that are closer than 8 mm from any specimen edge.

9.2.7.2 Using the ratchet, or the friction thimble, close the micrometer at such a rate that it is easy to count the scale divisions as they pass the reference mark. This rate is approximately 50 µm/s.

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

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

9.2.7.5 Move the specimen to another measurement position and repeat 9.2.7.1 – 9.2.7.4.

9.2.7.6 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.

9.2.8 *Method B (applicable to plastic sheet and film having nominal thickness greater than 250 µm):*

9.2.8.1 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 100 µm beyond the initial reading and move the specimen to the first measurement position. Avoid using measurement positions that are closer than 6 mm from any specimen edge.

9.2.8.2 Slowly close the micrometer at such a rate that it is easy to count the scale divisions as they pass the reference mark. This rate is approximately 50 µm/s.

9.2.8.3 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.

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

9.2.8.5 Move the specimen to another measurement position and repeat 9.2.8.1 – 9.2.8.4.

9.2.8.6 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.

9.2.9 *Method C (applicable to plastic sheet and film having nominal thickness equal to or greater than 25 µm but not greater than 250 µm):*

9.2.9.1 Using Apparatus C and specimens in conformance with Section 8, place the dial gage 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.

9.2.9.2 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 100 µm beyond the initial reading and move the specimen to the first measurement position. Avoid using measurement positions that are closer than 6 mm from any specimen edge.

9.2.9.3 Raise the presser foot slightly.

9.2.9.4 Move the specimen to the first measurement location and lower the presser foot to a dial reading approximately 8 to 10 µm higher than the initial reading of 9.2.9.2.

9.2.9.5 Drop the foot onto the specimen. (See also Note 5.)

9.2.9.6 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.

9.2.9.7 Move the specimen to another measurement position and repeat 9.2.9.1 – 9.2.9.6.

9.2.9.8 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.

9.2.9.9 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 9.2.4.4).

9.2.10 *Method D (applicable to plastic sheet and film having nominal thickness equal to or greater than 25 µm but not greater than 250 µm):*

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

9.2.10.2 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.

9.2.10.3 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 6 mm from any specimen edge.

9.2.10.4 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.

9.2.10.5 While the presser foot is near its maximum lift, move the specimen to another measurement position and repeat 9.2.10.1 – 9.2.10.4.

9.2.10.6 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.

9.2.10.7 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 9.2.4.4).

9.3 *Test Methods Applicable to Papers:*

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

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

9.3.1.2 Is capable of applying a pressure of 172 ± 14 kPa on the paper specimen, and

9.3.1.3 Has a presser foot diameter 6.25 ± 0.05 mm.

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

9.3.3 Use any of the methods of 9.3 for any paper or pressboard having nominal thickness of at least 50 µm.

9.3.4 *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 760 to 1500 µm/s from 600 to 25 µm above zero; has a capacity of at least 800 µm; has a dwell time between 2 and 4 s from 600 to 25 µm above zero; and uses a presser foot assembly having a mass of 0.57 ± 0.057 kg, which exerts the force to meet the pressure requirement of 9.3.1.2.

9.3.4.1 Using Apparatus D as described in 9.3.4 and specimens in conformance with Section 8, place the motor operated dial gage on a solid, level, clean table or bench that is free of excessive vibration. Confirm that anvil and presser foot surfaces are clean.

9.3.4.2 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.

9.3.4.3 Historically, some but not all specifications for electrical insulating papers having nominal thickness under 50 µm require a thickness specimen that consists of a stack of at least eight (preferably ten) layers of paper (see Note 4). The micrometer reading of the stack, corrected from the calibration chart, is divided by the number of layers in the stack and reported as the thickness. Thickness of paper measured with a stack specimen deviates significantly from thickness of the same paper measured on a single layer specimen.

NOTE 4—Originally, the selection of stack versus single sheet specimens was based on data obtained using manually operated micrometers. Those micrometers were perceived to have greater measurement reliability at the wider micrometer openings. For very thin papers and values of n between 1 and 5, the ratio of total thickness of a stack of n sheets to n continuously decreases. The change in the ratio between $n = 6$ and $n = 10$ layers is approximately zero. Thickness variation within a single layer is largely hidden in a stacked specimen which results in reduced ranges of high and low thickness observations on stack specimens versus single sheet specimens.

9.3.4.4 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 which are closer than 6 mm from any specimen edge.

9.3.4.5 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.

9.3.4.6 While the presser foot is near its maximum lift, move the specimen to another measurement position and repeat 9.3.4.4 and 9.3.4.5. Select these subsequent measurement positions so that they are approximately on a line parallel to the cross machine direction of the paper. If practicable, make ten readings.

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

9.3.5 *Method F,* applicable to all electrical insulating paper and pressboard, uses a manually operated, dead-weight, dial-type, micrometer described as Apparatus C and conforming to 6.3, 7.3, 7.4, 7.6.1, 7.6.4, 9.3.1, which also has a capacity of at least 800 µm and uses a presser foot assembly having a mass of 0.57 ± 0.057 kg, which exerts the force to meet the pressure requirement of 9.3.1.2.

9.3.5.1 Using the apparatus as described in 9.3.5 and specimens in conformance with Section 8, place the manually operated dial gage on a solid, level, clean table or bench that is