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Standard Guide for Determination of Thickness of Plastic Film Test Specimens[1]

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1. ~~Scope*~~Scope

1.1 This guide covers the determination of the thickness of plastic films where the thickness is used directly in determining the results of tests for various properties. Use this practice except as otherwise required in material specifications or in applicable test standards.

NOTE 1—Film is defined in Terminology D883 as an optional term for sheeting having a nominal thickness no greater than 0.25 mm (0.010 ~~in).~~in.).

NOTE 2—Alternative methods are acceptable if they meet the requirements of measurement precision as noted in this guide.

NOTE 3—This guide is not intended to address the sampling techniques or the measurement of film thickness for the commercial classification of commercial products or for quality control purposes.

1.2 The values stated in SI units are to be regarded as 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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory ~~requirements~~limitations prior to use.*

NOTE 4—This standard and ISO 4593 address the same subject matter but differ in technical content.

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]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens
D6287 Practice for Cutting Film and Sheeting Test Specimens

2.2 *ISO Standard:*

ISO 472 Plastics—Vocabulary[3]

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[1] This guide is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.19 on Film, Sheeting, and Molded Products.

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

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

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

3. Terminology

3.1 *Definitions*—See Terminologies D883 and ISO 472 for definitions pertinent to this guide.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absolute uncertainty (of a measurement), n*—the smallest division that can be read directly on the instrument used for measurement.

3.2.2 *calibration, n*—the set of operations that establishes, under specified conditions, the relationship between values measured or indicated by an instrument or system, and the corresponding reference standard or known values derived from the appropriate reference standards.

3.2.3 *dead-weight micrometer, n*—an instrument capable of measuring the thickness of thin films utilizing a weight to apply uniform pressure to the specimen.

3.2.4 *verification, n*—proof, with the use of calibrated standards or standard reference materials that the calibrated instrument is operating within specified requirements.

4. Summary of Methods

4.1 This guide describes four different methods for the thickness measurement of plastic film specimens. The methods (identified as Methods A, B, C, and D) use different micrometers that actuate the weights in different manners or utilize different means of reading the thickness.

4.2 It is permissible to use other instruments, including non-contact instruments and instruments using alternative readout systems in place of dials provided they meet or exceed the precision requirements noted in this practice.

5. Significance and Use

5.1 This guide is intended to provide recommendations and suggested good practices to determine precise dimensions when necessary for the calculation of properties expressed in physical units. It is not intended to replace practical thickness measurements based on commercial portable tools, nor is it implied that thickness measurements made by the procedures will agree exactly.

6. Apparatus

6.1 The instruments described in this guide share many common features:

6.1.1 A dead-weight gauge calibrated in accordance with the guidelines described in Appendix X2 and consisting of the following:

NOTE 5—Additional guidance for calibration and verification of gauges can be found in Test Method D5947.

NOTE 6—Since there is such a wide variety of instruments in use, there can be significant differences in the accuracy of different instrument types. The values stated for each type of apparatus are intended to be typical of that type of instrument.

6.1.1.1 A presser foot that moves in an axis perpendicular to the anvil face;

6.1.1.2 The surfaces of the presser foot and anvil (which contact the specimen) parallel to within 2.5 µm;

6.1.1.3 A spindle, vertically oriented if a dead-weight apparatus;

6.1.1.4 An indicator essentially capable of repeatable readings within ± 0.001 mm at zero setting or within ±0.001 mm when using a steel gauge block;

6.1.1.5 A frame, housing the indicator, of such rigidity that a load of 15 N applied to the 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 or digital count on the indicator;

6.1.1.6 If employed, a dial diameter of at least 50 mm and graduated continuously to read directly to the nearest 2.5 µm. The dial can be equipped with a revolution counter that displays the number of complete revolutions of the large hand, or

6.1.1.7 An electronic instrument having a digital readout in place of the dial indicator if that instrument meets all of the other requirements of this guide, and

6.1.1.8 The force applied to the presser foot spindle and the force necessary to register a change in the indicator reading shall be less than the force that will cause deformation of the specimen. The force applied to the presser foot spindle and the force necessary to just prevent a change in the indicator reading shall be more than the minimum permissible force specified for a specimen.

6.2 *Apparatus A—Manually Operated Thickness Gauge:*

6.2.1 An instrument having a presser foot and spindle that is manually lifted and lowered.

6.3 *Apparatus B—Automatically Operated Thickness Gauge:*

6.3.1 A pneumatic or motor-operated instrument having a presser foot spindle that is lifted and lowered either by a pneumatic cylinder or 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 anvil) and dwell time on the specimen are within the limits specified for the material being measured.

6.3.2 A preferred drop rate between 0.750 and 1.500 mm/s between 0.625 and 0.025 mm on the dial and a capacity of at least 0.775 mm.

6.4 *Apparatus C—Manually Operated Thickness Gauge with Linear Optical Encoder:*

6.4.1 Similar to Apparatus A except it employs a digital device with an electronic readout capable of repeatable readings to within ± 1 µm at zero setting or on a steel gauge block and a linear optical encoder using a scale of increments not less than 100 lines/mm and capable of reading within 0.5 µm with a 10 mm range.

6.5 *Apparatus D—Automatically Operated Thickness Gauge with Digital Display:*

6.5.1 Similar to Apparatus B except it employs an electronic device with a digital readout capable of a resolution not less than 0.5 µm and repeatable readings to within ± 1 µm at zero setting or on a steel gauge block.

6.5.2 A preferred drop rate between 0.750 and 1.500 mm/s between 0.625 and 0.025 mm on the dial and a capacity of at least 0.775 mm.

6.6 *Other Instruments:*

6.6.1 Other instruments are commercially available that utilize different methods of measuring thickness. These are generally non-contact devices employing ultrasonic response, electrical capacitance, or similar material properties that can be correlated to thickness. Some of these devices are also designed to provide a means of measuring discreet sections of film in a continuous scanning mode. Instruments of this nature are acceptable provided they meet or exceed the precision requirements noted in this practice and the requirements of the applicable material or product specifications or applicable test standards.

7. Test Specimens

7.1 The test specimens shall be prepared from plastic films that have been cut to the required dimensions according to Practice D6287.

7.2 Allow specimens to equilibrate at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity in accordance with Procedure A of Practice D618 unless otherwise specified by agreement or the relevant ASTM material specification.

7.3 Unless otherwise specified, make all dimension measurements at the same conditions used for equilibration.

7.4 For each specimen, take precautions to prevent damage or contamination that will adversely affect the measurements.

8. Procedure

8.1 *General Guidelines:*

NOTE 7—In this section, the word "method" denotes a combination of both a specific apparatus and a procedure describing its use.

8.1.1 The selection of a method for measurement of film thickness is influenced by the characteristics of the film for measurement. Each material and, in some cases, film construction in the case of multi-layer structures, will differ in its response to test method parameters, which include, but are not limited to, compressibility, rate of loading, ultimate load, dwell time, and dimensions of the presser foot and anvil. For a specific plastic material or structure, these responses can, in some cases, cause measurements made using one method to differ significantly from measurements made using another method. The effects due to differences in elasticity are addressed in Appendix X1.

TABLE 1 Instrument Guidelines

Method	Diameter of Presser Foot or Spindle, mm[A]	Pressure on Specimen, Approximate, kPa[B]
A	3.2 to 12.7	160 to 185
B	3.2 to 12.7	160 to 185
C	3.2 to 12.7	160 to 185
D	3.2 to 12.7	160 to 185

[A] It is known that the diameters of the pressure foot and spindle can influence the results. Data obtained from instruments with different geometries may not be comparable.
[B] The total force applied to the specimen shall be less than the force that will cause permanent deformation or distortion of the specimen. For very thin or deformable films, a practical pressure range of 5 to 70 kPa has been found to be suitable.

NOTE 8—The pressure exerted by the gauge on the specimen being measured shall not distort or deform the specimen. For thin films, ≤ 0.025 mm ~~[0.001 in.],~~(0.001 in.), or films which exhibit visual deformation during measurement, a maximum pressure of 70 kPa ~~[10 psi]~~(10 psi) is suggested. For thicker or stiffer films, a pressure range between 160 and 185 kPa ~~[23~~(23 and 27 ~~psi]~~psi) is suggested. See Table 1.

NOTE 9—An electronic gauge can be substituted for the dial gauge in Method A or B if the presser foot and anvil meet the requirements of that method.

8.1.2 The presence of contaminating substances on the surfaces of the test specimens, presser foot, anvil, or spindle can interfere with dimension measurements and result in erroneous readings. To help prevent this interference, select only clean specimens for testing, and keep them and the dimension measuring instrument covered until ready to make measurements. (**Warning—**Cleaning the presser foot and anvil surfaces as described in X2.1 can cause damage to digital electronic gauges resulting in very expensive repairs by the instrument manufacturer. Obtain procedures for cleaning such electronic gauges from the instrument manufacturer to prevent these costs.)

8.1.3 One thickness determination per specimen or the average thickness determined by a continuous scanning instrument is acceptable if it can be demonstrated that the overall thickness does not deviate > ± 10 % from the average. This is especially applicable if measurements are being made for reference, that is, to report nominal film thickness, and are not required for the determination of specific properties.

8.1.4 Some instruments do not require calibration. For these instruments, periodic verification procedures ~~should~~shall be conducted according to the recommendations of the instrument supplier.

8.2 *Method A:*

8.2.1 Using Apparatus A and specimens in conformance with Section 7, place the instrument 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.

8.2.2 Lower the presser foot on an area of the specimen for measurement. Observe this reading.

8.2.3 Raise the presser foot slightly.

8.2.4 Move the specimen to the first measurement location, and lower the presser foot to a reading approximately 0.007 to 0.010 mm higher than the initial reading of 8.2.2.

8.2.5 Drop the foot onto the specimen (see **Warning** in 8.1.2).

NOTE 10—This procedure minimizes small errors present when the pressure foot is lowered slowly onto the specimen and does not allow the presser foot to seat properly.

8.2.6 Observe the reading. After correcting the observed indicated dimension, record the corrected dimension value. A method for developing a calibration correction curve is described in X2.4.

8.2.7 Move the specimen to another measurement position, and repeat the steps given in 8.2.3 through 8.2.6.

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

8.2.9 Recheck the instrument zero setting after measuring each specimen. If a change is observed, this is usually indicative of contamination on the contact surfaces and will require cleaning. (See **Warning** in 8.1.2 and Note 9.)

8.3 *Method B:*

8.3.1 Using Apparatus B and specimens in conformance with Section 7, place the instrument on a solid, level, clean table or bench that is free of excessive vibration. Confirm that the anvil and presser foot surfaces are clean.

8.3.2 Apply power to the motor or air to the pneumatics, 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 or remove the air until all of the measurements are made. This will minimize any tendency to disturb the thermal equilibrium between the instrument and ambient during the dimension measurements.

8.3.3 Insert and position a specimen for the first measurement when the opening between the presser foot and anvil is near its maximum.

8.3.4 Observe the dial reading while the presser foot is at rest on the specimen surface. After correcting the observed indicated dimension, record the corrected dimension value. A method for developing a calibration correction curve is described in X2.4.

8.3.5 While the presser foot is near its maximum lift, move the specimen to another measurement position, and repeat the steps given in 8.3.3 and 8.3.4.

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

8.3.7 Recheck the instrument zero setting after measuring each specimen. If a change is observed, this is usually indicative of contamination on the contact surfaces and will require cleaning. (See **Warning** in 8.1.2 and Note 9.)

8.4 *Method C:*

8.4.1 Using Apparatus C and specimens in conformance with Section 7, place the instrument 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.

8.4.2 Drop the presser foot on an area of the specimen for measurement. Observe and record this reading.

8.4.3 Raise the presser foot as high as possible in the range of allowable motion and move the specimen to the next location. Observe and record this reading. (See **Warning** in 8.1.2.)

8.4.4 Move the specimen to another position and repeat step 8.4.3 as needed.

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

8.4.6 Recheck the instrument zero after measuring each specimen. If a change is observed, this is usually indicative of contamination on the contact surfaces and will require cleaning. (See **Warning** in 8.1.2 and Note 9.)

8.5 *Method D:*

8.5.1 Using Apparatus D and specimens in conformance with Section 7, place the motor-operated instrument on a solid, level, clean table or bench that is free of excessive vibration. Confirm that the anvil and presser foot surfaces are clean.

8.5.2 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 ambient during the dimension measurements.

8.5.3 Insert and position a specimen for the first measurement when the opening between the presser foot and anvil is near its maximum.

8.5.4 Observe the dial reading while the presser foot is at rest on the specimen surface. After correcting the observed indicated dimension using the calibration correction curve obtained in accordance with X2.4, record the corrected dimension value.

8.5.5 While the presser foot is near its maximum lift, move the specimen to another measurement position, and repeat the steps given in 8.5.3 and 8.5.4.

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

8.5.7 Recheck the instrument zero setting after measuring each specimen. If a change is observed, this is usually indicative of contamination on the contact surfaces and will require cleaning. (See **Warning** in 8.1.2 and Note 9.)

9. Report

9.1 Report the following information:

9.1.1 Complete identification of the material, including the type, grade, source, and lot number;

9.1.2 Date of testing, identity of the testing laboratory, and identity of the responsible personnel;

9.1.3 Method used and details of any deviation therefrom;

9.1.4 Number of specimens per sample and number of measurements per specimen; and

9.1.5 Arithmetic mean and range of all measurements made on a sample.

10. Precision and Bias

10.1 *Precision*—Since the methods described herein use different pieces of apparatus, call for one of several magnitudes of forces to be exerted on specimens of widely different geometries for varying periods of time, and are used for a wide variety of materials, it is the consensus that a precision statement is not practicable. There will be different precisions between methods and between materials. The reader is directed to seek precision statements in those other ASTM standards that deal with specific plastics or elastomeric material measured by any of these methods.

10.2 *Bias*—The bias of any one of these methods is unknown. A standard film specimen of known thickness is not available for measurement of thickness by each of these methods.

11. Keywords

11.1 dial gauge; dimensions; film; plastics; thickness

APPENDIXES

(Nonmandatory Information)

X1. ELASTICITY THEORY ADAPTED TO THICKNESS MEASUREMENT

X1.1 Introduction

X1.1.1 Theoretical dissertations pertinent to the problems involved when a rigid cylindrical die is pressed into a semi-infinite elastic solid can be found in treatises on elasticity.[4]

X1.1.2 The equations derived therein indicate that the distance of penetration of the die (analogous to the presser foot of a micrometer) into the elastic solid (analogous to a thickness specimen) is proportional to the ratio of the applied force to the diameter of the cylinder.

X1.1.3 Other mechanical properties of the materials involved also have some influence on the distance of penetration.

X1.1.4 If a plot of measured thickness versus the ratio of applied force to presser foot diameter is made for each of several materials (including rubbers and recorder tapes), a linear relationship is found.

X1.1.5 In the absence of any better theoretical model, the equations for a cylinder die and a spherical die indenting a semi-infinite solid are presented and adapted to thickness measurements in the hope that further work is stimulated based on adapting the semi-infinite model to finite size models.

X1.1.6 In thickness measurements, keeping the average pressure constant when changing the diameter of presser feet has never been satisfactory, and this old notion needs to be discarded.

X1.1.7 The theory developed in the treatises does not give any information on how to handle the effects due to time of loading. Until something better is established, the effects of time need evaluation for each material over the range of thicknesses, forces, and foot diameters expected.

X1.2 Cylindrical Pressure Foot

X1.2.1 For the cylindrical presser foot, the expression for penetration, d, is as follows:

$$d = (W/D) \times [(1 - \sigma^2)/E] \tag{X1.1}$$

[4] Timoshenko, S., *Theory of Elasticity*, McGraw-Hill Book Co., New York, NY, 1934, p. 338.