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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Methods for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive Means[1]

This standard is issued under the fixed designation D 4138; 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 measurement of dry film thickness of coating films by microscopical observation of precision angular cuts in the coating film. Use of these methods usually requires repair of the coating film.

1.2 Three test methods are provided for measuring dry film thickness of protective coating system:

1.2.1 *Test Method A*—Using groove cutting instruments.

1.2.2 *Test Method B*—Using grinding instruments.

1.2.3 *Test Method C*—Using drill bit instruments.

1.3 The substrate should be sufficiently rigid to prevent deformation of the coating during the cutting process. The surface may be flat or moderately curved (pipes as small as 1 in. (25 mm) in diameter may be measured in the axial direction).

1.4 The range of thickness measurement is 0 to 50 mils (0 to 1.3 mm).

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *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:*

D 823 Practices for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[2]

D 1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometres[2]

D 1186 Test Methods for Nondestructive Measurements of Dry-Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[2]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[2]

3. Summary of Test Methods

3.1 The three methods are based on measurement of dry film thickness by observation of angular cuts in the coating through a microscope having a built-in reticle with a scale. Each method employs different instruments to make the cut in the coating.

3.2 *Test Method A*—Uses a carbide tipped wedge to cut a groove in the coating. The groove is cut at a precise angle to the surface. Three wedge angles are available.

3.3 *Test Method B*—Uses a high speed rotary grinding disk or drum type bit to cut partial cylindrical cavities in the coating. Axes of the cavities can be oriented at three angles of inclination to the surface.

3.4 *Test Method C*—Uses a specific angle tip drill bit to cut a conical cavity in the coating.

4. Significance and Use

4.1 The use of these test methods is not necessarily limited by the type of substrate material as are nondestructive magnetic-type means.

4.2 Individual coats or the overall thickness of a coating system can be measured by these methods.

5. Test Method A—Groove Cutting Instruments

5.1 **Apparatus**

5.1.1 *Scribe Cutter and an Illuminated Microscope, with Measuring Reticle*. The scribe cutter and illuminated microscope may be combined as a single instrument (see Fig. 1).[3] The instrument calibration shall be performed by taking measurements on applied films of known thickness (see Test Method D 1005).

5.1.2 *Tungsten Carbide Cutting Tips* shall be designed to provide a very smooth incision in the paint film at a precise angle to the surface (see Fig. 2). Separate tip designs (angles) shall provide cuts of known slopes such as 1 to 1, 1 to 2, and 1 to 10. These tips shall be nominally designated 1×, 2×, and 10× to indicate the ratio of the lateral measurement to vertical depth. The lateral measurement is represented by the reticle markings and this vertical depth is represented by the coating

[1] These test methods are under the jurisdiction of ASTM Committee D-33 on Protective Coating and Lining work for Power Generating Facilities and is the direct responsibility of Subcommittee D33.04 on Inspection.

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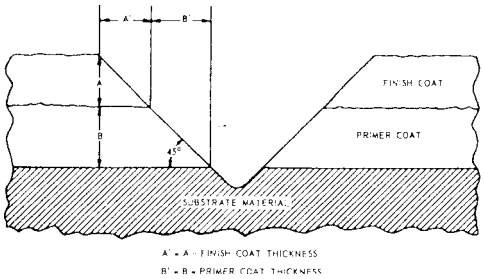
[2] *Annual Book of ASTM Standards*, Vol 06.01.

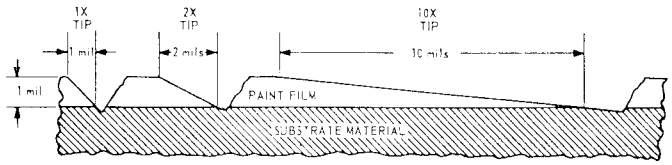
[3] The sole source of supply of the Tooke gage known to the committee at this time is MicroMetrics, P.O. Box 13804, Atlanta, GA 30324. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your commments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

FIG. 1 Tooke Inspection Gage[3]



(A)

FIG. 2 Geometry of Thickness Measurement



(B)

FIG. 2 Grooves Made by 1×, 2×, and 10× Cutting Tips *(continued)*

film thickness. Metal guide studs on the gage body shall, together with the cutting tip, form a firm base to ensure that the tip aligns vertically with the painted surface for a precisely aligned incision.

5.1.3 *Illuminated, 50-Power Microscope* shall contain a reticle scaled from 0 to 100 divisions (see Fig. 3). The total viewing field of the microscope shall be approximately 125 mils (3.18 mm).

NOTE 1—A photomicrographic adapter is available with some microscopic instruments that allows photographs to be taken through the view finder.

5.2 **Test Specimens**

5.2.1 If multiple coats of paint are to be measured, successive contiguous coats should be of contrasting colors to aid sharp discrimination of interfaces.

5.2.2 Generally, test specimens shall be prepared (as test panels) or chosen (as sites on a structure) to be representative of localized coating thickness and variability.

5.2.3 For test panels, if measurement repeatability is desired for a particular paint system, care shall be taken in panel preparation. Coating shall be uniformly applied in accordance with Test Method D 823. Panels shall be placed in a horizontal position during drying. Uniform application thickness shall be verified by another measurement method such as Test Methods D 1005, D 1186, or D 1400.

5.3 **Procedure**

5.3.1 Select a test panel or choose a site for the thickness measurement.

5.3.2 Using an appropriate surface marker of contrasting color, mark a line on the surface approximately 2-in. long (51-mm) where the thickness measurement will be made.

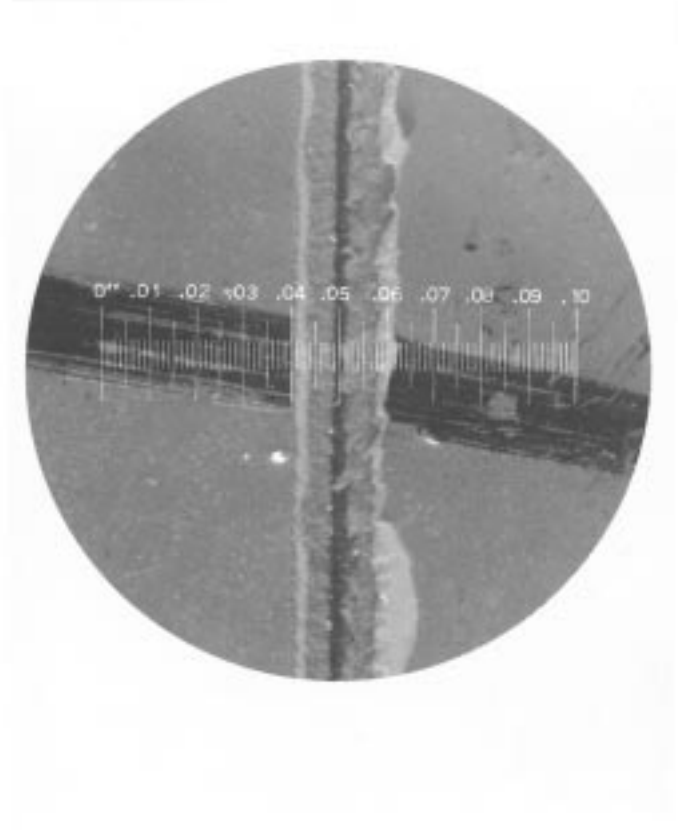


FIG. 3 Typical View Through Microscope of Tooke Inspector Gage Showing Reticle

5.3.3 Select a cutting tip based on estimated film thickness as follows:

Tip	Thickness Range, mils (μm)	Conversion Factor
1×	20 to 50 (500 to 1250)	1.0
2×	2 to 20 (50 to 500)	0.5
10×	0 to 3 (0 to 75)	0.1

If thickness is unknown, make a trial determination with the 2× tip.

5.3.4 To cut a groove, grasp the gage with the studs and cutting tip firmly forming a tripod on the painted surface. Place the gage at right angles to and about 2 in. (51 mm) perpendicularly from a marked line.

5.3.5 Draw the gage across the paint film toward the body, with guide studs leading the cutting tip, and increase pressure on the cutting tip until it barely cuts into the substrate before it crosses the marked line.

5.3.6 Take readings at the intersection of the marked line and incision. Read by measuring on the reticle the distance from the substrate/coating demarcation up the longer machined slope of the incision to the upper cut edge of each respective coating layer of the coating system. Make sure that the smooth cut face of the groove is measured. (The machined upper edge of the cutting tip usually leaves a less jagged cut). If multiple coats are observed, individual thicknesses of each coat may be read. The actual coating thickness is derived by multiplying the reticle reading by the conversion factor for the respective cutting tip.

6. Test Method B—Grinding Instruments

6.1 **Apparatus**

6.1.1 *Rotary Tool*[4]—A cordless high speed (5000 to 10 000 r/m) rotary grinder.

6.1.2 *Grinding Bit*—Tungsten carbide cylindrical-shaped grinding bit placed in a chuck of a microgroover for grinding through the coating system.

6.1.3 *Positioning Block*—The positioning block provides two specific angles with the coated surface for microgroover grinding through the coating system. The third angle is accomplished without using the positioning block.

6.1.4 *Measuring Microscope*—A 50-power illuminated microscope used in Test Method A is also used in Test Method B (see 5.1.3).

6.2 **Test Specimens**

6.2.1 See requirements outlined in 5.2.

6.3 **Procedure**

6.3.1 Select a test panel or choose a site for thickness measurement.

6.3.2 Using an appropriate surface marker of contrasting color, mark a line on the surface approximately ¼-in. (6.2-mm) wide by approximately 1-in. (25.4-mm) long where the thickness measurement will be made.

6.3.3 Select a grinding position based on estimated coating system thickness as follows:

Position	Coating System Thickness, mils (μm)	Conversion Factor
1×	20 to 50 (500 to 1250)	1.0
2×	2 to 20 (50 to 500)	0.5
4×	0 to 3 (0 to 75)	0.25

If thickness is unknown, make a trial determination in 2× position.

6.3.4 Install the tungsten carbide grinding tip so that it extends 1¼ in. (31.75 mm) from the chuck mouth.

6.3.5 The cut is made by grinding a groove through the coating system down to the substrate.

NOTE 2—Take care to hold the instrument at the predetermined angle with sufficient firmness to prevent sideways movement, as shown in Fig. 4.

6.3.6 Grinding slopes or positions of 1×, 2×, and 4× are accomplished by using the "position block" or supports as follows (see Fig. 5):

1×: 0.97 in. (24.6 mm) high (block resting on narrow face)
2×: 0.41 in. (10.4 mm) high (block resting on wide face)
4×: 0.0 in. (0.0 mm) (block not used)

6.3.7 Ground area will appear as partial cylindrical cavity, with the cavity wall angling gradually upward from the substrate to the coating system's exterior surface.

6.3.8 Thickness of each coating system layer of any combination of layers may be determined using an illuminated microscope as indicated in paragraph 5.1.3 and shown in Fig.

FIG. 4 Holding Microgroover[4] for Grinding

[4] The sole source of supply of the Microgroover rotary tool known to the committee at this time is MicroMetrics, P.O. Box 13804, Atlanta, GA 30324. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your commments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

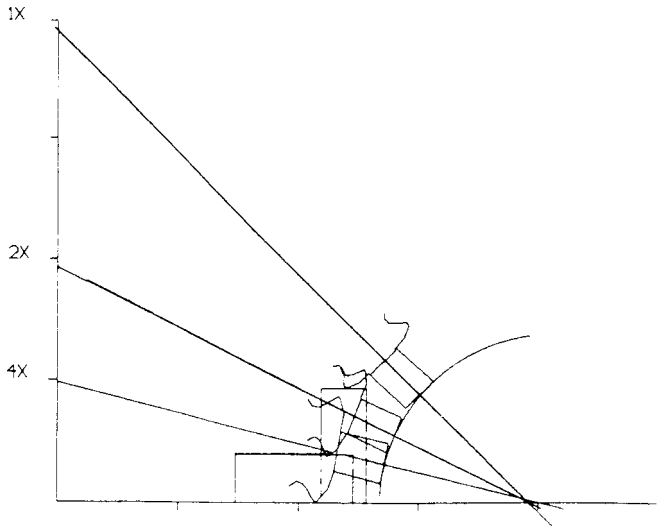
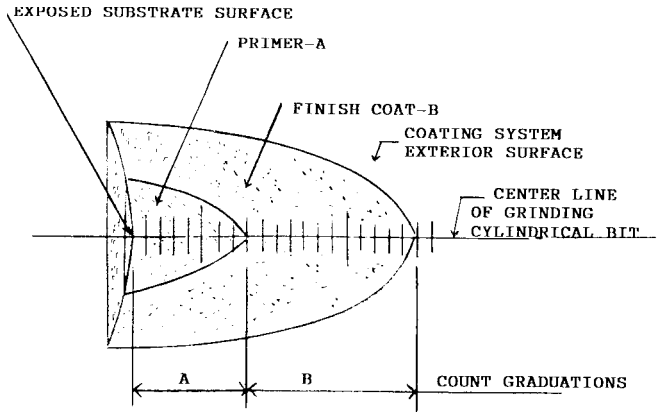


FIG. 5 Microgroover Block—Positions for Various Cutting Angles (Slopes)

FIG. 7 Saberg[5] Drill With Microscope



NOTE 1—The coating thickness is determined using the graduations along the long axis of the cut represented by the A and B dimensions in this drawing.

FIG. 6 Typical View Through Microscope of Tooke Inspector Gage for Microgroover

6. The sum of the reticle graduations shall be multiplied by the appropriate conversion factor for the instrument angle position used.

7. Test Method C—Drilling Instruments

7.1 **Apparatus**

7.1.1 *Cutter/Drill Body*—An implement to hold the drill bit in place over the coating system surface (see Fig. 7).[5]

7.1.2 *Handwheels*—Light and heavy hand wheels for holding the cutter/drill in place and turning.

7.1.3 *Cutter/Drill*—Cutter/drill bit to penetrate through the coating system down to the substrate.

7.1.4 *Microscope*—A 50-power microscope with sealed divisions showing through reticle.

7.2 **Test Specimens**

7.2.1 See requirements outlined in 5.2.

7.3 **Procedure**

7.3.1 Select a test panel or choose a site for thickness measurement.

7.3.2 Using an appropriate surface marker of contrasting color, mark a surface area ¼ by ¼ in. (6.2 mm) where the thickness measurement will be made.

7.3.3 Select the appropriate handwheel. Use the heavy wheel on hard or thick coatings above 10 mils (250 µm) and light wheel for soft or thin coatings below 10 mils.

7.3.4 Insert the cutter in the handwheel selected. Tighten the recess socket-head screw.

7.3.5 Place the drill body on the surface to be measured with the hole directly above the measurement area. Fit the cutter into the drill hole.

7.3.6 Rotate the handwheel in a clockwise direction, using pressure as necessary (for soft coatings rotate with finger in recess) until the cutter has penetrated the coating and marked the substrate.

7.3.7 Remove the cutter assembly and the drill body. View the cut hole with the microscope, focusing on the side of the hole.

7.3.8 Note the number of reticle divisions between the coating surface and the substrate or the individual layers of paint as shown in Fig. 8.

7.3.9 To calculate the coating thickness: for mils—multiply gradations by 0.79, and for microns—multiply gradations by 20.0.

8. Report

8.1 Report the following information:

8.1.1 Results of a thickness determination, and

8.1.2 If more than one measurement is made and specific results for each location are not needed, report the minimum, the maximum, and the average thickness.

[5] The sole source of supply of the Salberg thickness drill known to the committee at this time is Elcometer Inc., 1893 Rochester Industrial Drive, Rochester Hill, MI 48309. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your commments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

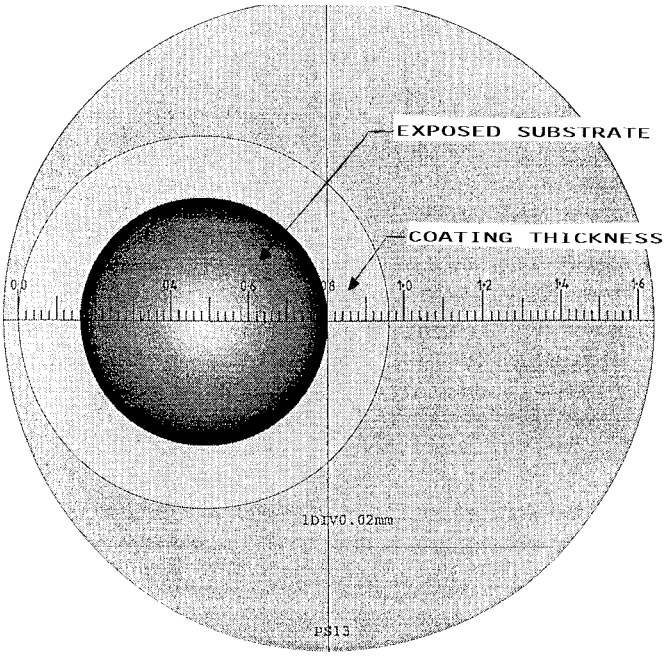


FIG. 8 Typical View Through Microscope Used with Saberg Drill

9. Precision

9.1 Individual observations of a uniform coating on a smooth substrate have been determined to be within ±10 % (the percentage error increases as film thickness decreases).

9.2 Field-applied coatings are characteristically subject to short-range thickness variability resulting from rough substrates and normal variations in application. The magnitude of this variability will be reflected by the range or standard deviation of thickness determinations.