Designation: D 4138 – 07

Standard Practices for Measurement of Dry Film Thickness of Protective Coating Systems by Destructive, Cross-Sectioning 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 This practice describes the measurement of dry film thickness of coating films by microscopic observation of precision angular cuts in the coating film. Use of these procedures may require repair of the coating film. This practice is intended to supplement the manufacturers' instructions for the manual operation of the gages and is not intended to replace them. It includes definitions of key terms, reference documents, the significance and use of the practice, and the advantages and limitations of the instruments.

1.2 Three procedures are provided for measuring dry film thickness of protective coating systems:

1.2.1 *Procedure A*—Using groove cutting instruments.

1.2.2 *Procedure B*—Using grinding instruments.

1.2.3 *Procedure C*—Using drill bit instruments.

1.3 These procedures are not applicable for soft or ductile substrates that may deform under the test gage cutting tip. 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 25 mm (1 in.) in diameter may be measured in the axial direction.

1.4 Individual coats in a multicoat system where there is a discernible visual difference between coats or the overall thickness of a coating system can be measured by these procedures.

1.5 The range of thickness measurement is typically 2 to 2000 microns (0.1 to 80 mils) and depends upon the cutting angle of the blade.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.7 *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]

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

D 1005 Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

D 7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *accuracy*, *n*—the measure of the magnitude of error between the result of a measurement and the true thickness of the item being measured.

3.1.2 *dry film thickness*, *n*—the thickness of a coating (or coating layers) as measured from the surface of the substrate.

3.1.2.1 *Discussion*—If the surface is roughened, the dry film thickness is considered the thickness of the coating or coating layers above the peaks of a surface profile.

3.1.3 *micrometre (micron)*, *n*—one one-thousandths of a millimetre (0.001 mm); 25.4 microns = 1 mil.

3.1.4 *mil*, *n*—an imperial unit of measure; one one-thousandths of an inch (0.001 in.); 1 mil = 25.4 microns.

4. Summary of Practice

4.1 The three procedures 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 procedure employs different instruments to make the cut in the coating.

[1] This practice is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

Current edition approved Feb. 1, 2007. Published March 2007. Originally approved in 1982. Last previous edition approved in 2001 as D 4138 – 94 (2001) $^{\epsilon 1}$.

[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.

4.2 *Procedure A*—Uses a carbide tipped wedge to cut a groove in the coating. The groove is cut at a precise angle to the surface. Various wedge angles are available.

4.3 *Procedure 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 various angles of inclination to the surface.

4.4 *Procedure C*—Uses a specific angle tip drill bit to cut a conical cavity in the coating.

5. Significance and Use

5.1 All procedures involve cutting through the coating. The cutting operation works better on some coatings than on others. For example elastomeric coatings may close up after cutting. Some plastic coatings may stretch. Other coatings may tear. The cutting process must result in a clearly visible cross-section of the coating or coating system and the substrate. Soft or elastic materials can sometimes be cooled or frozen to obtain good cutting characteristics. With some coatings, improved cuts can be achieved by wetting the surface, or by speeding or slowing the cutting rate.

5.2 *Procedure A* requires the manual cutting of the coating by dragging a cutting wedge through both the coating and the surface of the substrate. In this operation, the cutter trails midway between the two guide studs, and continuous 3-point surface contact should be maintained to assure precise vertical alignment of the groove. Excessive pressure on the guide studs should be avoided. On wood or other directional material, incisions should be made in the grain or "machine" direction to avoid ragged cuts.

5.3 *Procedure B* is similar to *Procedure A* except the cut is made with a rotary disk. This technique eliminates the deformations of coating and substrate which may occur when conventional cutting wedges are used. Hard, brittle, tough, fibrous, tender, or elastomeric materials exhibit clean, non-tearing, controlled disintegration under the rotary cutter. The high-speed cutter "erodes" away surface material in a precise pattern, leaving adjacent and underlying areas undisturbed.

5.4 *Procedure C* is commonly used for hard, brittle or very thin coatings. Less damage often results from the small hole used to measure thickness.

6. Test Specimen

6.1 The test specimen can be the coated structure or component/part on which the thickness is to be evaluated, or can be test panels of similar material and surface roughness on which it is desired to measure the coating thickness.

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

6.3 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 Practice D 823 or as agreed upon between the contracting parties. Panels shall be placed in a horizontal position during drying. Uniform application thickness shall be verified by another measurement method such as Test Method D 1005 or Practice D 7091.

PROCEDURE A — GROOVE CUTTING INSTRUMENTS

7. Apparatus

7.1 *Scribe Cutter and an Illuminated Microscope with Measuring Reticle*. The scribe cutter and illuminated microscope may be combined as a single instrument. Verification of instrument accuracy shall be performed by taking measurements on applied films of known thickness (see Test Method D 1005).

7.2 *Cutting Tips* shall be designed to provide a very smooth incision in the paint film at a precise angle to the surface (see Fig. 1). 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 (see Fig. 2). The lateral measurement is represented by the reticle markings and the vertical depth is represented by the coating film thickness. Ensure that the tip aligns vertically with the painted surface for a precisely aligned incision.

7.3 *Illuminated Microscope* typically of 50+ magnification, shall contain a scaled reticle (see Fig. 3).

8. Procedure

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

8.2 Using an appropriate surface marker of contrasting color, mark a line on the surface approximately 50 mm (2 in.) long where the thickness measurement will be made.

8.3 Select a cutting tip based on estimated film thickness. If thickness is unknown, make a trial determination with a 2× tip.

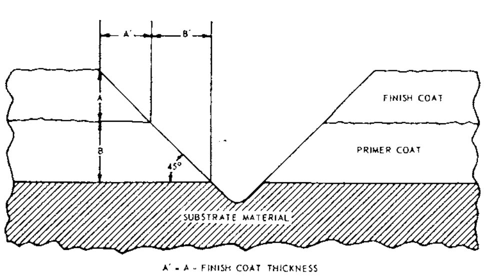

FIG. 1 Geometry of Thickness Measurement

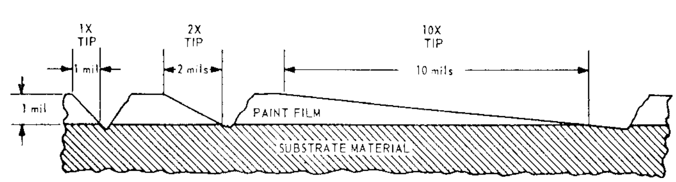

FIG. 2 Grooves Made by 1×, 2×, and 10× Cutting Tips

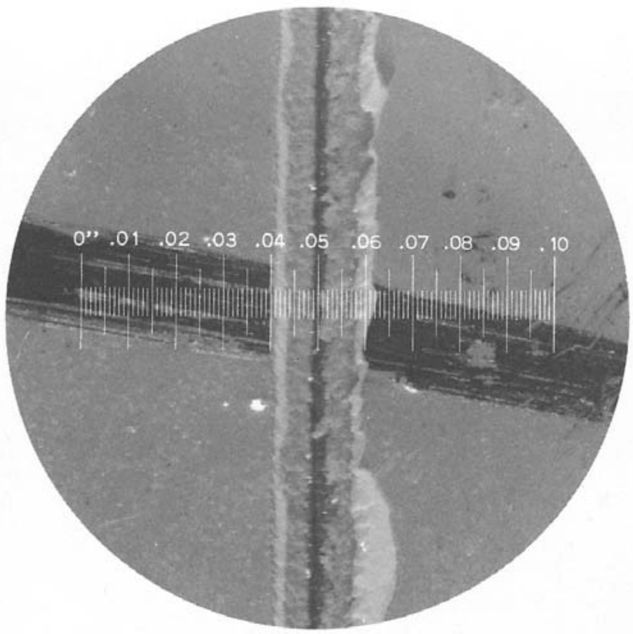

FIG. 3 Typical View Through Microscope Showing Reticle

8.4 Draw the cutting tool across the paint film toward the body and increase pressure on the cutting tip until it barely cuts into the substrate before it crosses the marked line.

8.5 Take readings at the intersection of the marked line and incision. Align the scale at right angles to the cut so that the scale divisions are parallel to the cut. 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

PROCEDURE B — GRINDING INSTRUMENTS

9. Apparatus

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

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

9.3 *Positioning Block*—The positioning block provides specific angles with the coated surface for the rotary tool to grind through the coating system.

9.4 *Illuminated Microscope*—See 7.3.

10. Procedure

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

10.2 Using an appropriate surface marker of contrasting color, mark a line on the surface approximately 6 mm (¼ in.) wide by approximately 25 mm (1 in.) long where the thickness measurement will be made.

10.3 Select a grinding position based on estimated coating system. If thickness is unknown, make a trial determination in 2× position.

10.4 Install the grinding bit so that it extends from the chuck mouth.

10.5 The cut is made by grinding a groove through the coating system down to the substrate. Take care to hold the instrument at the predetermined angle with sufficient firmness to prevent sideways movement, as shown in Fig. 4.

10.6 Grinding slopes or positions are accomplished by using the position block or supports (see Fig. 5).

10.7 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.

10.8 Thickness of each coating system layer of any combination of layers may be determined using the illuminated microscope. Fig. 6 depicts the groove that results from grinding through a coating system. 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. Note that the sketch depicts successive coats and the reticle graduations associated with each. The sum of the reticle graduations shall be multiplied by the appropriate conversion factor for the instrument angle position used.