Designation: D 1186 – ~~93~~01

Standard Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[1]

This standard is issued under the fixed designation D 1186; 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 Department of Defense.

1. Scope

1.1 These test methods cover the nondestructive measurement of the dry film thickness of nonmagnetic coatings applied over a ferrous base material using commercially available test instruments. The test methods are intended to supplement manufacturers' instructions for the manual operation of the gages and are not intended to replace them. They cover the use of instruments based on magnetic measuring principles only. Test Method A provides for the measurement of films using mechanical magnetic pull-off gages and Test Method B provides for the measurement of films using magnetic ~~flux~~ electronic gages.

1.2 These test methods are not applicable to coatings that will be readily deformable under the load of the measuring instruments, as the instrument probe must be placed directly on the coating surface to take a reading.

1.3 The values given in SI units of measurement are to be regarded as the standard. The values in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety ~~problems~~, 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:*

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[1] These test methods are under the jurisdiction of ASTM Committee ~~D-1~~ D1 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

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D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[2]

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 Micrometers[2]~~

~~D 3980 Practice for Interlaboratory Testing of Paint and Related Materials[2]~~

2.2 *Steel Structures Painting Council Standard:*

SSPC-PA2 Measurement of Dry Paint Thickness with Magnetic Gages[3]

TEST METHOD A—MAGNETIC PULL-OFF GAGES

3. Summary of Test Method

3.1 Instruments complying with this test method measure thickness by using a spring calibrated to determine the force required to pull a ~~permanent~~ magnet from a ferrous base coated with a nonmagnetic film. The instrument must be placed directly on the coating surface to take a reading.

3.2 The attractive force of the magnet to the substrate varies inversely with the thickness of the applied film. The spring tension required to overcome the attraction of the magnet to the substrate is shown on the instrument scale as the distance (in mils or ~~micrometres)~~ microns) between the magnet and the substrate.

~~3.3 It should be recognized that the accuracy of the measurements can be influenced when measurements are made closer than 1 in. (25 mm) to an edge.~~

4. Significance and Use

~~4.1 After calibrating the instrument using shims of known thickness and either a bare part of the metal object or metal of the same kind, the instrument magnet (or metal foot) is placed in contact with the coated metal in the manner described in 12.1. The results of many test methods applicable to coatings~~

4.1 Many coating properties are markedly affected by the ~~film~~ thickness of the dry ~~film, some examples being~~ film such as adhesion, corrosion protection, flexibility, and ~~hardness to name a few.~~ hardness. To be able to compare results obtained by different operators, it is essential to ~~measure~~ know film ~~thickness closely.~~ thickness.

4.2 Most protective and high performance coatings are applied to meet a requirement or a specification for the dry-film thickness of each coat, or for the complete system, or both. Coatings must be applied within certain minimum and maximum ~~thickness tolerances in order that they can fulfill~~ thicknesses to fill their ~~intended~~ expected function. In addition to potential performance deficiencies, it is uneconomical to apply more material than necessary when coating large ~~areas such as metal structures and coils.~~ areas. This test method is used to measure film thickness of coatings on ferrous metals.

5. Apparatus

5.1 *Permanent Magnet*, small, either attached directly to a coil spring (“pencil” gage) or to a horizontal lever arm ~~which~~ that is attached to a helical spring ~~(“banana”~~ (“dial-type” gage). Increasing force is applied to the magnet by extending the coil spring in the first case or turning a graduated dial that coils the helical spring in the second. The readings obtained are shown directly on the instrument ~~scale or converted by reference to a calibration curve.~~ scale.

5.2 ~~*Nonmagnetic*~~*Coating Thickness ~~Shims or Polished Metal Certification Calibration~~ Standards*~~—Shims~~, with assigned values traceable to ~~N~~ national ~~S~~ standards are ~~available, but when shims are used that are not traceable to National Standards, the~~ available from several sources, including most manufacturers of coating thickness ~~must be measured to the nearest 0.1 mil (2.5 µm) using a micrometer as described in Procedure D in Test Method D 1005.~~ gages.

6. Test Specimens

6.1 When this test method is used in the field, the specimen is the coated structure or article on which the thickness is to be evaluated.

6.2 For laboratory use, apply the materials to be tested to panels of similar roughness, shape, thickness, composition and ~~surface conditions~~ magnetic properties on which it is desired to determine the thickness.

NOTE 1—Applicable test panel description and surface preparation methods are given in Practice D 609.

NOTE 2—Coatings should be applied in accordance with Practices D 823 or as agreed upon between the ~~purchaser and the seller.~~ contracting parties.

7. Verification of Calibration of Apparatus

~~7.1 Calibrate the instrument in an area free~~

7.1 Different gage manufacturers follow different methods of ~~stray magnetic fields, such as power lines, generators, or welding equipment. There shall be no vibration apparent on the test piece when the instrument is being calibrated.~~

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

[3] Available from ~~Steel Structures Painting Council, 4516 Henry~~ SSPC: The Society for Protective Coatings, 40 24th St., Sixth Floor, Pittsburgh, PA 152122–4643 (see www.sspc.org).

~~7.2 Use a bare~~ calibration adjustment. Verify calibration according to manufacturer's instructions.

7.2 The section of the ~~substrate after the specified surface preparation has been accomplished. If an uncoated section~~ type of ~~the substrate is not available, uncoated test panels similar~~ standards used to ~~the type on which the specified surface preparation has been performed may be used.~~

~~7.3 Select~~ verify calibration ~~shims in the expected thickness range to~~ should be ~~measured. For example, if a coating is approximately 3 mils (75 µm) in thickness, calibrate~~ predicated upon which type provides the ~~instrument at 3 mils. Then check the calibration, using shims~~ best and most appropriate calibration considering: type of ~~both a lesser~~ gage, sample surface geometry, and ~~greater thickness,~~ contract requirements. Appendix X1 provides information helpful to ~~determine the thickness range over which the instrument is calibrated. The limits~~ making an informed selection of ~~this range are set at~~ standards.

7.3 Following the ~~points where~~ manufacturer's operating instructions, measure the ~~gage no longer registers the shim~~ thickness ~~within the manufacturer's stated accuracy (for example, ±15 %).~~

~~7.4 Lay~~ of a series of calibration ~~shim on~~ standards covering the ~~bare, uncoated substrate and bring the instrument magnet in direct contact~~ expected range of coating thickness. To guard against measuring with an inaccurate gage, recheck the ~~shim. Remove the magnet from the shim by slowly rotating the dial scale ring clockwise (for helical spring-type instruments) or lifting the entire instrument housing (for coil spring-type instruments). Hold the shim so that it will not flex during calibration, causing the magnet to lift prematurely. Observe the thickness shown on the instrument scale~~ gage at ~~the moment when the magnet breaks contact with the surface.~~

~~7.5 If the instrument scale reading does not agree with the shim thickness, calibration is required. This can~~ regular intervals. That interval should be ~~accomplished~~ set by ~~physical calibration or by drafting a calibration curve. A calibration curve involves plotting a graph with the actual gage reading on one axis~~ agreement between contracting parties and maintained throughout the ~~shim reading on the other. For physical calibration, consult the manufacturer's instructions.~~ control process.

NOTE ~~3—Instruments based on the scale dial ring/helical spring~~ 3—Generally "Dial-type" instruments can be ~~calibrated and~~ used in any position, while ~~those based on the coil spring must~~ "pencil-type" instruments may be ~~calibrated and~~ used in the vertical position only unless they have separate indicators for the horizontal and vertical positions. Follow the manufacturer's recommendations.

8. ~~Calibration of Apparatus—Polished Metal Calibration Standards~~

~~8.1 Follow 7.1, 7.2, and 7.3.~~

~~8.2 Place the gage directly on the calibration standard. If the instrument scale reading does not agree with the shim thickness, calibration is required as in 7.5.~~

~~8.3 After the gage is calibrated, take ten readings on the bare, prepared substrate. Record the mean of these readings. This is a correction for variations of magnetic attraction due to the roughness of the substrate.~~

~~8.4 Subtract the value obtained in 8.3 when measuring the coating thickness to obtain the corrected thickness of the paint.~~

NOTE ~~4—More information on this calibration test method is described in SSPC-PA 2.~~

9. Procedure

9~~8~~.1 Use the instrument only after calibration has been ~~calibrated~~ verified in accordance with Section ~~7 or 8.~~

~~9.2 Assure~~ 7.

8.2 Ensure that the coating is dry prior to use of the instrument.

9~~8~~.3 Inspect the ~~magnet~~ probe tip and surface to be measured to ~~assure~~ ensure that they are clean. Adherent magnetic filings or other surface contaminants will affect gage readings.

9~~8~~.4 Take readings in locations free of ~~vibration, electrical,~~ electrical or magnetic ~~fields.~~

~~9.5 If thickness readings are found to~~ fields. The location should also be ~~outside~~ free of vibration when using mechanical magnetic pull-off instruments.

8.5 The accuracy of the ~~calibration range established in 7.3, repeat~~ measurement can be influenced when made within 25 mm (1 in.) of the ~~calibration procedure~~ edge or right angle in the ~~appropriate range. Check~~ sample.

8.6 Measure the coating, following the manufacturer's instructions.

8.7 Verify calibration ~~before, during, and after each use~~ periodically to ensure that the instrument continues to read properly. If the instrument is found to be out of adjustment, remeasure the thicknesses taken since the last satisfactory calibration check was made.

9~~8~~.6~~8~~ Take a sufficient number of readings to characterize the surface.

9~~8~~.6~~8~~.1 For laboratory measurements, a recommended minimum is three for a ~~3~~ 75 by ~~6-in. (75~~ 150-mm (3 by ~~150-mm)~~ 6-in.) panel and more in proportion to size.

9~~8~~.6~~8~~.2 For field measurements, a recommended minimum is five determinations at random for every 10 m^2 (100 ft^2 (10 m^2) of surface area. Each of the five determinations should be the mean of three separate gage readings within the area of a ~~½-in. (12-mm)~~ 4-cm (1.5-in.) diameter circle.

9~~8~~.~~7~~9 Make measurements at least ~~1 in. (25 mm)~~ 13 mm (½ in.) away from any edge or corner of the specimen. If it is necessary to measure closer than ~~1 in., recheck~~ 13 mm (½ in.), verify the ~~calibration in the specific area to determine the extent of the~~ effect (if any), the edge has on the mesurement.

NOTE 4—For additional information describing the number of measurements to be taken on large structures, and on non-smooth surfaces, refer to SSPC PA-2.

109. Report

109.1 Report the following information: the i

9.1.1 Instrument used, serial number, r

9.1.2 Range, and mean of the thickness readings fou, and

9.1.3 Depending upon the application, it may be useful to record the individual readings as well.

110. Precision and Bias

11.1 On the basis of an interlaboratory

10.1 A new round-robin study of this test method, conducted to determine was performed recently. Data are being analyzed statistically. When completed, the precision of several types of instrument in measuring a wide range of coating thicknesses, the intralaboratory required "Repeatability and interlaboratory coefficients Repoducibility" sections of variation, calculated using procedures described in Practice D 3980 were found to this test method will be those shown in Table 1 for written and the instrument evaluated. Based upon these coefficients, the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

11.1.1 *Repeatability*—Two results, each the mean of four measurements, obtained by the same operator using the same instrument should be considered suspect if they differ by more than the maximum allowable difference values given round-robin study documented in Table 1 for the appropriate film thickness.

11.1.2 *Reproducibility*—Two results, each the mean of four measurements, obtained by operators in different laboratories, each obtained using instruments from the same category, should be suspect if they differ by more than the maximum allowable difference values shown in Table 1.

11.2 an ASTM research report.

10.2 *Bias*—The bias for Test Method A of this standard for measuring dry film thickness cannot be determined because each instrument has its own bias.

TEST METHOD B—MAGNETIC FLUX B—ELECTRONIC GAGES

121. Summary of Test Method

12.1 After calibrating the instrument using shims of known thickness and either

11.1 Instruments complying with this test method measure thicknesses by placing a bare part of the metal object or metal of the same kind, the instrument probe is placed in contact with on the coated m surface and use electronic circuitry to convert a reference signal into coating thickness.

11.2 Instruments of this type determine, within the probe of or the instrument itself, changes in the magneitic flux caused by variations in the distance between the magnet probe and the substrate.

12.2 It should be recognized that the accuracy of the measurements may be influenced when made closer than 1 in. (25 mm) to an edge or 3 in. (75 mm) to another mass of metal. The edge or mass of the steel may cause flux leakage from the instrument, thus distorting the readings.

13.

12. Apparatus

132.1 The testing apparatus shall be mechanically or an electrically operated. Mechanically operated instruments house an internal horseshoe magnet, the contacts of which are placed directly on the coated substrate.[4] Electrically operated instruments utilize a separate instrument utilizing a probe that houses the a permanent magnet or coil energized by alternating current and that is placed directly on the surface. In both types, the The coating thickness is shown on the instrument's display.

12.2 Coating thickness standards with assigned value os tr macetable to national standards are available.

143. Test Specimens

14.1 The test specimens described in

13.1 See Section 6 are also applicable to Test Method B. Refer to the manufacturer's instructions when measuring paint thicknesses on substrates less than ⅛ in. thickness.

15. 6.

14. Calibration of Apparatus

15.1 Follow the steps outlined in 7.1-7.3.

15.2 Hold the instrument contact or probe handle firmly on the surface and perpendicular to the measuring plane during calibration and use. Follow the manufacturer's instructions for the specific adjustment of the instrument.

NOTE 5—The probe-type instruments can be calibrated and used in any position, but the integral-magnet type must be recalibrated or calibration verified for each position of use.

16.

14.1 See Section 7.

15. Procedure

16.1 Follow the

15.1 See Section 8. Exclude steps outlined in 9.1-9.3.

16.2 Take measurements no closer than 1 in. (25 mm) to an edge or 3 in. (75 mm) to another mass of steel. If such measurements are necessary, recheck the calibration in the specific area to determine the effect the edge or mass of steel has on the instrument reading.

17. 8.5 and 8.7.

16. Report

17.1 Report the following information: the instrument used, serial number, range, and mean of the thickness readings found. Depending upon the application, it may be useful to record the individual readings as well.

18.

16.1 See Section 9.

17. Precision and Bias

187.1 *Precision*—On the basis of an interlaboratory study of this test method in which several types of instruments were used in various laboratories to measure a wide range of dry-film thickness on the same set of panels, the intra- and interlaboratory coefficients of variation, calculated using procedures described in Practice D 3980, were found to be as shown in Table 1. Based upon these coefficients the following criteria should be used for judging, at the 95 % confidence level, the acceptability of results:

18.1.1 *Repeatability*—Two results, each the mean of four measurements, obtained by the same operator using instruments from the same category should be considered suspect if they differ by more than the maximum allowable difference values given in Table 1 for the appropriate film thickness.

18.1.2 *Reproducibility*—Two results, each the mean of four measurements, obtained by operators in different laboratories using instruments from the same category should be considered suspect if they differ by more than the maximum allowable difference values given in Table 1 for the appropriate film thickness.

18.2 —See Section 10.

17.2 *Bias*—The bias for Test Method A B of this standard for measuring dry film thickness cannot be determined because each instrument has its own bias.

198. Keywords

198.1 coating thickness; dry film thickness; magnetic gages; nondestructive thickness; paint thickness

APPENDIX

X1. CHARACTERISTICS AFFECTING GAGE READINGS

X1.1 It is always good practice to ensure the reliability of gage readings by performing a verification test periodically, either before or after critical determinations. This practice ensures that, not only is the gage reading correctly, but also that it is correctly calibrated to provide maximum accuracy of readings on the sample. Not all applications require this level of certainty so, while suggested, the inclusion of this practice is up to the contacting individuals to decide on implementation.

X1.2 Certain characteristics of samples may affect the accuracy of the calibrations. These include, but may not be limited to:

X1.2.1 Surface profile of the substrate (roughness),

X1.2.2 Surface profile of the coating,

X1.2.3 Thickness of the substrate,

X1.2.4 Geography of the sample surface (curves with small radii, small diameters, complex curves, etc.), and

X1.2.5 Any characteristic that affects the magnetic or eddy current permeability of the substrate or coating, such as residual magnetism, or lack of homogeneity of magnetic characteristics.

X1.3 Calibration done on smooth, polished standards ensure that a gage can be properly calibrated, and that calibration is appropriate for any measurements on samples *of the same* characteristics, but it may not be the best for measurements of samples

that differ from the calibration materials. When possible, verification should be done on samples of known thickness of coating applied to substrates as similar as possible to the sample to be tested.

X1.4 It is not practical to provide known thickness standards for all possible sample configurations. An alternative method is to verify calibration on a bare substrate as similar as possible to the sample, using a nonmagnetic metal foil, plastic shim or film of known thickness to simulate a coating.

X1.5 In using this verification of calibration method, it is necessary to be aware of additional characteristics that can affect the measured values. Plastic or brass shim stock typically has an inherent curve. This curve can act as a leaf spring and cause a magnetic pull-off gage to be "pushed" off the surface prematurely, resulting in an incorrect reading.

X1.6 With some materials and thickness, it is possible that the shim will not lie flat, which will also cause an erroneous reading. Various techniques exist to minimize this effect, such as mounting the shim in a holder that maintains tension on the shim to eliminate the tendency of the shim to curve.

X1.7 Other factors experienced with plastic shims, which are not usually present with painted or plated calibration standards include (but are not limited to):

X1.7.1 Permanent creases in the shim due to folding,

X1.7.2 Air entrapment between the shim and substrate,

X1.7.3 Distortion due to environmental conditions, such as temperature, and

X1.7.4 Shim thickness inconsistency due to the pressure of the probe tip. This may be a permanent "dimple" in the shim.

X1.8 Even with these factors affecting potential accuracy of plastic shims, in many applications, verification of calibration using plastic shims on the sample to be measured, can be a more appropriate (accurate) calibration than using plated or painted standards.

X1.9 No matter what standards are used, they should be periodically verified to ensure the assigned value is correct. Even metal coated on metal can wear or be damaged to an extent that readings are affected.