Designation: E 376 – 96

An American National Standard

Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods[1]

This standard is issued under the fixed designation E 376; 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 This practice covers the use of magnetic- and eddy-current-type thickness instruments (gages) for nondestructive thickness measurement of a coating on a metal substrate.

1.2 More specific uses of these instruments are covered by the following test methods issued by ASTM: Test Methods B 244, B 499, B 530, D 1186, D 1400, and G 12.

1.3 The values stated in SI units are to be regarded as standard. The inch-pound units in parentheses are for information only and may be approximate.

1.4 Measurements made in accordance with this test method will be in compliance with the requirements of ISO International Standard 2178 as printed in 1982.

1.5 *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:*

B 244 Test Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments[2]

B 499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals[2]

B 530 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates[2]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[3]

D 1400 Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base[3]

E 1316 Terminology for Nondestructive Examinations[4]

G 12 Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel[5]

2.2 *International Standard:*

ISO 2178 Nonmagnetic Coatings on Magnetic Substrate—Measurement of Coating Thickness—Magnetic Method[6]

NOTE 1—See Appendix X1.

3. Terminology

3.1 *Definitions*—Definitions of terms relating to electromagnetic testing are given in Terminology E 1316.

4. Significance and Use

4.1 *General*—No presently available thickness gage is applicable to all combinations of coating-substrate thicknesses and materials. The limitations of a particular instrument are generally delineated by its manufacturer.

4.2 *Magnetic*—Magnetic-type gages measure either magnetic attraction between a magnet and a coating or its substrate, or reluctance of a magnetic flux path passing through the coating and substrate. These gages are designed to measure thickness of a nonmagnetic coating on a magnetic substrate. Some of them will also measure thickness of nickel coatings on a magnetic or nonmagnetic substrate.[7]

4.3 *Eddy Current*—Eddy-current-type thickness gages are electronic instruments that measure variations in impedance of an eddy-current inducing coil caused by coating thickness variations. They can only be used if the electrical conductivity of the coating differs significantly from that of the substrate.

[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.07 on Electromagnetic Method.

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[2] *Annual Book of ASTM Standards*, Vol 02.05.

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

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] *Annual Book of ASTM Standards*, Vol 06.02.

[6] Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

[7] Autocatalytically deposited nickel-phosphorus alloys containing more than 8 % phosphorus are sufficiently nonmagnetic to be measured by this method, as long as the measurement is made prior to any heat treatment.

5. Interferences

5.1 *Thickness of Coating*—The precision of a measurement changes with coating thickness depending on method used and instrument design. Generally, the precision is a percentage of the coating thickness except at the lower end of the ranges where it is a fixed thickness.

5.2 *Magnetic Properties of Basis Metal*—Magnetic thickness gages are affected by variations of the magnetic properties of the basis metal. For practical purposes, magnetic variations in low-carbon 1005-1020 steel may be considered to be insignificant. To avoid the influences of severe or localized heat treatments and cold working, the instrument should be calibrated using a calibration standard having a base metal with the same magnetic properties as that of the test specimen or, preferably and if available, with a sample of the part to be tested before application of the coating.

5.3 *Thickness of Substrate*—For each method there is an effective depth of penetration of field created by the instrument probe. This is the critical depth or thickness beyond which the instrument will no longer be affected by increase or substrate thickness. Since it depends on the instrument probe and substrate, it should be determined experimentally.

5.4 *Structure and Composition of Coating and Substrate*—Eddy-current instruments are sensitive to variations of structure, composition, and other factors affecting electrical conductivity and magnetic permeability of the coating and substrate. For example, such instruments are sensitive to differences between: (*1*) aluminum alloys, (*2*) chromium coatings deposited at different temperatures, and (*3*) organic coatings containing variable amounts of metallic pigments.

5.5 *Edge Effect*—All test methods are sensitive to abrupt surface changes of test specimens; therefore, measurements made too near an edge or inside corner will not be valid unless the instrument is specifically calibrated for such a measurement. The effect usually extends 3 to 13 mm (⅛ to ½ in.) from the discontinuity, depending on method probe configuration, and instrument. Edge effect is usually a function of coil diameter.

5.6 *Curvature of Test Surface*—Thickness measurements are sensitive to curvature of the specimen. This sensitivity varies considerably between instruments and becomes more pronounced with increasing curvature.

5.7 *Smoothness of Surface, Including That of Basis Metal*—Since a rough surface may make single measurements inaccurate, a greater number of measurements will provide an average value that is more truly representative of the overall coating thickness. Roughness also may cause certain instruments to read high since their probes may rest on peaks.

5.8 *Direction of Rolling of Basis Metal*—Instruments with two pole pieces may be sensitive to direction of rolling of the basis metal; that is, gage readings may change depending on alignment of pole pieces with surface of specimen under test.

5.9 *Residual Magnetism in Basis Metal*—Residual magnetism in basis metal may affect readings of magnetic- and eddy-current-type instruments.

5.10 *Stray Magnetic Fields*—Strong magnetic fields, as from arc welding, can seriously interfere with operations of certain thickness gages.

5.11 *Cleanness of Probe and Test Surface*—Measurements are sensitive to foreign material that prevents intimate contact between probe and coating surface.

5.12 *Pressure of Probe*—Instrument readings can be sensitive to pressure with which probe is applied to test surface.

5.13 *Probe Position*—Some magnetic-type gages are sensitive to position of probe relative to the earth. For example, operation of gage in a horizontal or upside-down position may require a new calibration or may be impossible.

5.14 *Temperature*—Eddy-current instruments may be affected by temperature variations.

6. Calibration and Standardization

6.1 Each instrument should be calibrated in accordance with the manufacturer's instructions before use by employing suitable thickness standards. Calibration should be checked at frequent intervals during use. Attention should be given to Section 5 and Section 7.

6.2 Calibration standards of uniform thickness are available in either of two types, foil or coated substrate, as supplied or recommended by the manufacturer of the instrument. There are instances, however, where calibration standards are made by other than instrument manufacturers.

6.2.1 *Calibration Foils (Shims)*—Calibration foil is placed on the surface of uncoated basis metal when calibrating the instrument. Foils are advantageous for calibrating on curved surfaces and are often more readily available than a coated standard. To prevent measurement errors due to poor contact between foil and substrate, make sure of intimate contact between them. Calibration foils are subject to indentation and should, therefore, be replaced when damaged.

6.2.1.1 Nonmagnetic foils may be used to calibrate magnetic thickness gages for measurement of nonmagnetic coatings. Nonconductive plastic foils can be used to calibrate eddy-current instruments for measurement of nonconductive coatings.

6.2.1.2 Resilient foils should not be used if there is possibility that the instrument probe will cause a change in thickness reading. Use of two or more foils on top of each other should be avoided unless flexibility of thin foils is required for a curved surface.

6.2.2 *Coated Substrates Standards*—Calibration standards consist of coatings of known thickness permanently bonded to the substrate material.

6.3 Thicknesses of calibration standards should bracket and be as close as possible to the coating thickness being measured.

6.4 For magnetic instruments, calibration standards should have the same magnetic properties as the coated test specimen.

6.5 For eddy-current instruments, the calibration standard should have the same electrical and magnetic properties as those of coated test specimen being measured (see 5.4).

6.6 To determine calibration validity, a reading on a bare specimen identical in magnetic and electrical properties to that of the test specimen substrate is recommended.

6.7 If the coating process is changed, the calibration may no longer be valid, especially for magnetic coatings and eddy-current gages (see 5.4).