Designation: E376 – 17

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

This standard is issued under the fixed designation E376; 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 U.S. Department of Defense.

1. Scope*

1.1 This practice covers the use of magnetic- and eddy current-type thickness instruments (gauges) for nondestructive thickness measurement of a coating on a metal (i.e. electrically conducting) substrate. The substrate may be ferrous or nonferrous. The coating or plating being measured may be electrically conducting or insulating as well as ferrous or non-ferrous.

1.2 More specific uses of these instruments are covered by Practice D7091 and the following test methods issued by ASTM: Test Methods B244, B499, and B530.

1.3 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.4 Measurements made in accordance with this practice will be in compliance with the requirements of ISO 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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]

B244 Test Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments

B499 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

B530 Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates

D7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Standards:*[3]

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT-CP-189 Standard for Qualification and Certification of NDT Personnel

2.3 *AIA Standard:*

NAS-410 Certification and Qualification of Nondestructive Testing Personnel[4]

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

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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 Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org. (Replacement standard for MIL-STD-410.)

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

2.4 *International Standards:*[5]

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

ISO 9712 Non-destructive Testing—Qualification and Certification of NDT Personnel

NOTE 1—See Appendix X1.

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this practice, refer to Terminology E1316.

4. Significance and Use

4.1 *General*—Most thickness gages are not applicable to all combinations of coating-substrate thicknesses and materials. The limitations of a particular instrument are generally delineated by its manufacturer. The substrate material and coating combination to be measured as well as the inherent variations in the substrate and coating shall be reviewed prior to selecting the instrument to be used and the measurement accuracy required.

4.2 *Magnetic*—Magnetic-type gauges 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 gauges 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.[6]

4.3 *Eddy Current*—Eddy current-type thickness gauges 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.

4.4 *Accuracy*—The accuracy of a measurement depends on the instrument, the foils, its calibration and standardization, and its operating conditions. The accuracy is also affected by the interferences listed in Section 5, such as part geometry (curvature), magnetic permeability, electrical conductivity, and surface roughness.

NOTE 2—This practice under ideal conditions may allow the coating thickness to be determined within ±10 % of its true thickness or to within ±2.5 µm (or ±0.0001-in.), whichever is the greater. (See exceptions in Appendix X2.)

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 gauges are affected by variations of the magnetic properties of the basis metal. For practical purposes, magnetic variations in low-carbon AISI 1005-1020 steels may be considered to be insignificant. To avoid the influences of severe or localized heat treatments and cold working, the instrument should be standardized using a reference 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 examined 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 of 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 examination 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 standardized 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 Examination 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 Base 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 Base Metal*—Instruments with two pole pieces may be sensitive to direction of rolling of the base metal; that is, gauge readings may change depending on alignment of pole pieces with surface of specimen or part under examination.

5.9 *Residual Magnetism in Base Metal*—Residual magnetism in base 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 gauges.

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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[6] 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.