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AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals[1]

This standard is issued under the fixed designation B 499; 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 test method covers the use of magnetic instruments for the nondestructive measurement of the thickness of nonmagnetic coatings over ferrous or other magnetic base metals.

NOTE 1—Autocatalytically deposited nickel-phosphorus alloys containing more than 8 % phosphorus are sufficiently nonmagnetic to be measured by this test method, as long as the measurement is made prior to any heat treatment.

1.2 These instruments measure either the magnetic attraction between a magnet and the basis metal, as influenced by the presence of the coating, or the reluctance of a magnetic-flux path passing through the coating and the basis metal.

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

1.4 *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 *International Standard:*

ISO 2178 Non-Magnetic Coatings on Magnetic Substrate—Measurement of Coating Thickness—Magnetic Method[2]

3. Significance and Use

3.1 The thickness of a coating is often critical to its performance. For most nonferrous coatings on steel, the magnetic method is reliable for measuring coating thickness nondestructively and is suitable for specification acceptance testing and SPC/SQC applications. The test method requires that the magnetic properties of the substrate used during the calibration be the same as that of the test specimen.

4. Factors Affecting the Measuring Accuracy

4.1 The following factors affect the accuracy of a coating thickness measurement:

4.1.1 *Coating Thickness*—Inherent to the test method is a measurement uncertainty that, for thin coatings, is constant and independent of the coating thickness. The magnitude of this measurement uncertainty is primarily a function of test piece surface finish (see 4.1.6 on surface roughness). For thicknesses greater than about 25μ m, this uncertainty is proportional to the coating thickness.

4.1.2 *Magnetic Properties of the Basis Metal*—Magnetic thickness measurements are affected by variations in the magnetic properties of the basis metal. (For practical purposes, magnetic variations in low-carbon steel can often 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 basis 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.)

4.1.3 *Basis Metal Thickness*—For each instrument, there is a critical thickness of the basis metal above which the measurements will not be affected by an increase in the thickness of the basis metal. Since it depends on the instrument probe (Note 2) and the nature of the basis metal, its value should be determined experimentally if not supplied by the manufacturer.

NOTE 2—In this method "instrument probe" will also include the term "magnet."

4.1.4 *Edge Effects*—The method is sensitive to abrupt changes in the surface contour of the test specimen. 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 may extend to about 20 mm from the discontinuity, depending on the instrument.

4.1.5 *Curvature*—The measurements are affected by the curvature of the test specimen. The influence of curvature varies considerably with the make and type of instrument but always becomes more pronounced as the radius of curvature decreases. Instruments with two-pole probes may also produce different readings if the poles are aligned in planes parallel or

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[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

perpendicular to the axis of a cylindrical surface. A similar effect can occur with a single-pole probe if the tip is unevenly worn.

4.1.6 *Surface Roughness*—Measurements are influenced by the surface topography of the basis metal and coating. Surface roughness becomes significant when the degree of roughness is greater than 10 % of the coating thickness, causing increased scatter in measurements. Therefore, it is necessary, on a rough or scratched surface, to make a greater number of measurements at different positions to obtain an average value that is representative of the mean coating thickness. If the basis metal is rough, it may also be necessary to check the zero of the instrument at several positions on a portion of the uncoated, rough, basis metal.

4.1.7 *Direction of Mechanical Working of the Basis Metal*—Measurements made by an instrument having a two-pole probe or an unevenly worn single-pole probe may be influenced by the direction in which the magnetic basis metal has been subjected to mechanical working (such as rolling), the reading changing with the orientation of the probe on the surface.

4.1.8 *Residual Magnetism*—Residual magnetism in the basis metal affects the measurements made by instruments which employ a stationary magnetic field. Its influence on measurements made by reluctance instruments employing an alternating magnetic field is much smaller.

4.1.9 *Stray Magnetic Fields*—Strong stray magnetic fields, such as are produced by various types of electrical equipment, can seriously interfere with the operation of magnetic thickness instruments.

4.1.10 *Foreign Particles*—Magnetic instruments of all types must make physical contact with the test surface and are, therefore, sensitive to foreign material that prevents intimate contact between probe and coating surface. Both the test surface and instrument probe should be kept free of foreign material.

4.1.11 *Conductivity of Coating*—Some magnetic instruments work at frequencies between 200 and 2000 Hz. At these frequencies, eddy currents produced in thick, highly conductive coatings may interfere with the reading.

4.1.12 *Pressure*—Instrument readings are sensitive to the pressure with which the probe is applied to the test specimen. Application of the probe should not be allowed to deform the coating.

4.1.13 *Probe Orientation*—Instruments using the principle of magnetic attraction may be sensitive to the orientation of the magnet in relation to the field of gravity of the earth. Thus, the operation of an instrument in a horizontal or upside-down position may require a different calibration, or may be impossible.

5. Calibration of Instruments

5.1 Before use, each instrument shall be calibrated in accordance with the instructions of the manufacturer, employing suitable thickness standards.

5.2 During use, the calibration shall be checked at frequent intervals, at least once a day. Attention shall be given to the factors listed in Section 4 and to the procedures described in Section 5.

5.3 Calibration standards of known thickness are available either as shims or foils or as coated specimens.

5.3.1 *Calibration Foils*:

NOTE 3—In the following paragraphs, the use of the word "foil'' will imply a nonmagnetic metallic or nonmetallic foil or shim.

5.3.1.1 Because of the difficulty of ensuring adequate contact, foils are generally not recommended for the calibration of instruments based on the principle of magnetic attraction but they are suitable in some circumstances provided the necessary precautions are taken. They can normally be used for the calibration of other types of instruments.

5.3.1.2 Foils are advantageous for calibration on curved surfaces and are more readily available than coated standards. To prevent measurement errors it is necessary to ensure that intimate contact is established between foil and substrate. Resilient foils should be avoided to prevent indentation errors. Only nonferrous metal foils should be used for thicknesses less than 15 µm. Calibration foils are subject to wear and indentation and, therefore, should be replaced frequently. Worn foils shall not be used to calibrate the instrument.

5.3.2 *Coated Standards*—These calibration standards consist of coatings of known, uniform thickness permanently bonded to the substrate material.[3]

5.4 The basis metal of the calibration standards shall have magnetic properties similar to those of the basis metal of the coated test specimen. To confirm their suitability, a comparison of the readings obtained with the basis metal of the bare standard and that of the test specimen is recommended.

5.5 In some cases the calibration of the instrument should be checked by rotating the probe in increments of 90° (see 4.1.7 and 4.1.8).

5.6 The basis-metal thickness for the test and the calibration shall be the same if the critical thickness, defined in 4.1.3, is not exceeded. It is often possible to back up the basis metal of the standard or of the test specimen with a sufficient thickness of similar material to make the readings independent of the basis-metal thickness.

5.7 If the curvature of the coating to be measured is such as to preclude calibration on a flat surface, the curvature of the coated standard, or of the substrate on which the calibration foil is placed, shall be the same.

6. Measuring Procedure

6.1 Operate each instrument in accordance with the instructions of the manufacturer giving appropriate attention to the factors listed in Section 4.

6.2 Check the calibration of the instrument at the test site each time the instrument is put into service and at frequent intervals during use to assure proper performance.

6.3 Observe the following precautions:

6.3.1 *Basis-Metal Thickness*—Check whether the basis-metal thickness exceeds the critical thickness. If not, either use the back-up method mentioned in 5.6 or make sure that the calibration has been made on a standard having the same thickness and magnetic properties as the test specimen.

[3] Coated standards suitable for many applications of the test method may be purchased from the office of Standard Reference Materials, National Institute of Standards and Technology, Gaithersburg, MD 20899.