



Designation: E 1606 – 99

Standard Practice for Electromagnetic (Eddy-Current) Examination of Copper Redraw Rod for Electrical Purposes¹

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1. Scope

1.1 This practice covers the procedures that shall be followed in electromagnetic (eddy-current) examination of copper redraw rods for detecting discontinuities or imperfections of a severity likely to cause failure or markedly impair surface quality of the rod. These procedures are applicable for continuous lengths of redraw rod in diameters from $\frac{1}{4}$ to $1\frac{3}{8}$ in. (6.4 to 35 mm) suitable for further fabrication into electrical conductors.

1.2 This practice covers redraw rod made from tough-pitch or oxygen-free coppers.

1.3 The procedures described in this practice are based on methods for making use of stationary encircling annular test coil systems.

1.4 The values stated in inch-pound units are to be regarded as the standard. The SI equivalents of inch-pound units may be approximate.

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:

E 543 Practice for Agencies Performing Nondestructive Testing²

E 1316 Terminology for Nondestructive Examination²

2.2 ASNT Standards:

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing³

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel³

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 03.03.

³ Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

2.3 AIA Standard:

NAS 410 Certification and Qualification of Nondestructive Testing Personnel⁴

3. Terminology

3.1 *Definitions*—Standard terminology relating to electromagnetic (eddy-current) examination may be found in Terminology E 1316, Section C, Electromagnetic Testing.

4. Summary of Practice

4.1 Examination is performed by passing the rod lengthwise through a coil energized with alternating current at a fixed frequency. The electrical impedance of the coil is affected by rod vibrations, rod dimensions, electrical conductivity of the rod material, and metallurgical or mechanical discontinuities in the rod surface. During passage of the rod, the changes in impedance caused by these variables in the rod produce electrical signals that are processed so as to actuate an audio, visual, or electrical signaling device or mechanical marker that produces a record.

5. Significance and Use

5.1 Eddy-current examination is a nondestructive method of locating surface discontinuities in a product. Signals can be produced by discontinuities located on the surface of the rod. Since the density of eddy-currents decreases nearly exponentially as the distance from the surface increases, deep-seated defects may be undetected.

5.2 Some indications obtained by this practice may not be relevant to product quality. For example, a signal may be caused by minute flaws or irregularities, by anomalies in the material, or by other factors such as operator error, or a combination thereof, that are not detrimental to the end use of the product. Nonrelevant indications can mask unacceptable discontinuities. On the other hand, relevant indications are those that may result from nonacceptable discontinuities and should be determined by agreement between the user and the supplier. Any indication that is believed to be irrelevant shall

⁴ Available from the Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, DC 20005.

be regarded as unacceptable until it is demonstrated by reexamination or other means to be nonrelevant.

6. Basis of Application

6.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally recognized nondestructive testing (NDT) personnel qualification practice or standard, such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

6.2 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

7. Apparatus

7.1 *Electronic Apparatus*, capable of energizing the test coil with alternating currents of suitable frequencies (for example, in the range from 1 kHz to 1 MHz), and capable of sensing the changes in the electrical impedance of the coils. Electrical signals produced in this manner are processed so as to actuate an audio, electrical, or visual signaling device or mechanical marker that produces a record.

7.2 *Test Coils*, capable of inducing currents in the rod and sensing changes in the electrical characteristics of the rod. The test coil diameter should be selected to yield the largest practical fill factor.

7.3 *Driving Mechanism*—A mechanical means shall be used for passing the standardization rod through the test coil with minimum vibration of the test coil or rod. The device shall maintain the rod substantially concentric with the electrical center of the test coil. A constant speed ($\pm 5.0\%$ of the actual rod speed) shall be maintained.

8. Standards

8.1 *Artificial Discontinuity Standard:*

8.1.1 The standardization rod used when adjusting the sensitivity setting of the apparatus shall be selected from a typical production run and shall be representative of the purchaser's order. Furthermore, it shall be processed subsequently into a mechanically shaved or machined condition. The rods shall be passed through the test coil with the instrument sensitivity set high enough to determine the nominal background noise inherent in the rods. Any standard used shall be selected from rods exhibiting low background noise.

8.1.2 The artificial discontinuities shall be spaced to provide signal resolution adequate for interpretation. These artificial discontinuities shall be prepared with a hole drilled radially into the rod in each of three successive transverse planes at 0, 120, and 240°, and one round bottom transverse notch on the rod surface at 120° (Fig. 1).

8.1.2.1 *Drilled Holes*—The holes shall be drilled radially with No. 72 drill into the rod using a suitable drill jig that has a bushing to guide the drill, with care being taken to avoid

distortion or mechanical damage of the rod while drilling. The diameter of the drilled hole shall be 0.025 in. (0.635 mm) and shall not vary by more than ± 0.001 in. (± 0.025 mm). The depth shall be 0.075 in. (1.90 mm) and shall not vary more than ± 0.003 in. (± 0.076 mm).

8.1.2.2 *Round Bottom Transverse Notch*—The notch shall be made using a suitable jig with a 0.250-in. (6.35-mm) diameter No. 4 cut, straight, round file. The rod surface shall be stroked in a substantially straight line perpendicular to its longitudinal axis. The notch depth shall be 0.010 in. (0.25 mm) and shall not vary from the prescribed depth by more than ± 0.001 in. (± 0.025 mm) when measured at the center of the notch.

8.1.2.3 The straightness of the sample should not vary more than ± 0.015 in. (± 0.38 mm) over a 12-in. (305-mm) length.

8.1.2.4 Diameter variations between the test sample and any other replacements should not vary more than ± 0.015 in. (± 0.381 mm) of the diameter of the test sample being replaced, that is, between 1.1 and 6 % variation.

8.1.2.5 *Other Artificial Discontinuities*—Discontinuities of other contours may be used in the calibration standard by mutual agreement between the supplier and the purchaser.

8.1.2.6 Electrical discharge machinery (EDM) can be used as an alternative to drilling holes or filing the notch, but the same dimension tolerances must be adapted.

8.2 *Other Standards*—Other standards may be used by mutual agreement between the supplier and the purchaser.⁵

8.2.1 Artificial discontinuities are not intended to be representative of natural discontinuities or produce a direct relationship between instrument response and discontinuity severity; they are intended only for establishing sensitivity levels as outlined in Section 9. The relationship between instrument response and discontinuity size, shape, and location is important and should be established separately, particularly as related to test frequency.

9. Adjustment and Standardization of Apparatus Sensitivity

9.1 The rod manufacturer shall select equipment, standards, and test parameters consistent for the product, unless otherwise agreed upon between the manufacturer and the purchaser.

9.2 When using the artificial discontinuity standard, adjust the apparatus to the lowest sensitivity required to detect all four discontinuities. The rod speed maintained during standardization by the driving mechanism should be any value up to approximately 500 ft/min (152 m/min), $\pm 5\%$ of the selected speed.⁶ A constant rod speed shall be maintained during the adjustment process.

⁵ Any copper-zinc-lead alloy (leaded brasses) may also be used as a calibration standard. These materials have significantly lower electrical conductivity values compared with tough-pitch or oxygen-free copper and therefore, have a conductivity value at room temperature that is comparable to that of copper rod at elevated temperature.

⁶ In actual production, throughput speed of the rod oftentimes exceeds this value. However, most eddy-current instruments are speed sensitive and require a filter adjustment based on rod speed. This type of equipment produces variations in signal response with variations in test speed. Speed-insensitive equipment provides a constant signal response with changing test speeds.