INTERNATIONAL

Designation: ~~E1606 – 09~~ E1606 – 15

Standard Practice for Electromagnetic ~~(Eddy-Current)~~ (Eddy Current) Examination of Copper and Aluminum Redraw Rod for Electrical Purposes[1]

This standard is issued under the fixed designation E1606; 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.

1. ~~Scope~~ Scope*

1.1 This practice covers the procedures that shall be followed in electromagnetic ~~(eddy-current)~~ (eddy current) examination of copper and aluminum 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 ¼ to 1⅜ 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. It can also be used for other types of copper such as fire-refined high conductivity rod. It is also appropriate for aluminum and other nonferrous alloys used for electrical purposes.

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

1.4 This practice does not establish acceptance criteria. Acceptance criteria must be established by the using parties.

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

1.6 *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:*[2]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

E1033 Practice for Electromagnetic (Eddy Current) Examination of Type F-Continuously Welded (CW) Ferromagnetic Pipe and Tubing Above the Curie Temperature

E2884 Guide for Eddy Current Testing of Electrically Conducting Materials Using Conformable Sensor Arrays

2.2 *ASNT ~~Standards:~~ Documents:*[3]

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

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

2.3 *AIA Standard:*[4]

NAS 410 Certification and Qualification of Nondestructive Testing Personnel

[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.

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

2.4 *ISO Standard:*[5]
ISO 9712 Non-Destructive Testing—Qualification and Certification of NDT Personnel

3. Terminology

3.1 Standard terminology relating to electromagnetic ~~examination~~testing may be found in Terminology E1316, Section C: Electromagnetic Testing.

4. Summary of Practice

4.1 ~~Examination~~ The examination is performed by passing the rod lengthwise through a ~~coil~~ differential or absolute coil, or both, energized with alternating current at a fixed frequency. The electrical impedance of the test 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.~~device. These electrical signals can also be displayed and stored digitally or used to actuate mechanical markers to produce a record of indications.

4.2 The relative severity and type of imperfections may be indicated by eddy current signal amplitude, phase, or both with automatic display and recording. Alarm levels can be set to provide data for counting and recording of event totals in various categories, as well as for providing outputs for actuating other devices. Because the responses from natural discontinuities may vary significantly from those of artificial discontinuities, care must be exercised in establishing sensitivity and acceptance criteria for the examination.

5. Significance and Use

5.1 ~~Eddy-current examination is~~ Eddy current instrumentation provides timely and useful information regarding the acceptability of copper and aluminum rod for quality control purposes as well as providing for early warning that unacceptable rod is being produced. Eddy current testing 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~~ eddy currents decreases nearly exponentially as the distance from the surface increases, deep-seated defects may be undetected.

5.1.1 An exception is the detection of subsurface ferromagnetic inclusions with an additional, or shared, winding enveloped in a DC magnetic field and the addition of appropriate instrumentation. The coil winding, acting as a transducer, generates a voltage as the magnetized inclusion passes through, providing an electrical signal separate from the eddy current response to surface imperfections. The rod is transparent to the DC effect allowing high sensitivity to ferromagnetic inclusions, in the absence of eddy current noise. The method is inherently speed sensitive but is enhanced by high throughput speeds enabling the detection of small subsurface ferromagnetic inclusions which are particularly detrimental to rod quality.

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~~ indications, referred to as "noise," can mask unacceptable discontinuities. On the other hand, relevant indications are those that may result from ~~nonacceptable~~unacceptable discontinuities and should be determined by agreement between the user and the supplier. Any indication that is believed to be irrelevant shall 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, ISO 9712, 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 Testing Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

7. Apparatus

7.1 *Electronic Apparatus,* differential or absolute systems (or both) 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

[5] ~~Any copper-zinc-lead alloy (leaded brasses) may also be used as a reference 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.~~Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

impedance of the coils. Electrical signals ~~produced in this manner~~ that are processed so as to actuate an audio, ~~electrical,~~visual, or ~~visual signaling device or mechanical marker that produces a record.~~electrical signaling device. These electrical signals can also be displayed and stored digitally or used to actuate mechanical markers to produce a record of indications.

7.1.1 The electronic apparatus should also be able to provide an electrical signal, either internally or externally, that can be used to test the apparatus without having a test coil connected. This electrical signal is used to verify sensitivity levels and alarm threshold for the apparatus.

7.1.2 The electronic apparatus should have an adjustable filter that includes in its bandwidth the anticipated flaw signal frequencies.

7.1.3 The electronic apparatus may have a "filter out" configuration that allows the adjustable filter to be bypassed during system standardization.

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. The coil assembly, whether differential or absolute coils, consists of one or more electrical coils, cooling apparatus that is adequate to maintain the proper coil-operating temperature and prevent thermal damage, if needed, and positioning mechanisms for adjusting and maintaining a constant spacing between the coil and the rod surface. Some assemblies may include mechanical guides to prevent physical damage to the coils by contact with the product.

7.3 *Driving Mechanism*—~~A~~ An optional mechanical means ~~shall~~may be used for passing the ~~standardization rod~~reference standard through the test coil with minimum vibration of the test coil or rod. ~~The~~ If used, the mechanical device shall maintain the rod substantially concentric with the electrical center of the test coil. ~~A constant speed (±5.0 %~~ When using an apparatus that is sensitive to speed variations a constant speed (up to ±5.0 % of the actual rod speed) shall be maintained. When using an apparatus that can be configured to be insensitive to speed variations for the purposes of calibration or standardization, the reference standard can be moved through the test coil manually with the mechanical centering maintained by removable, closely fitted bushings. This technique should be utilized by the apparatus supplier as well as the user.

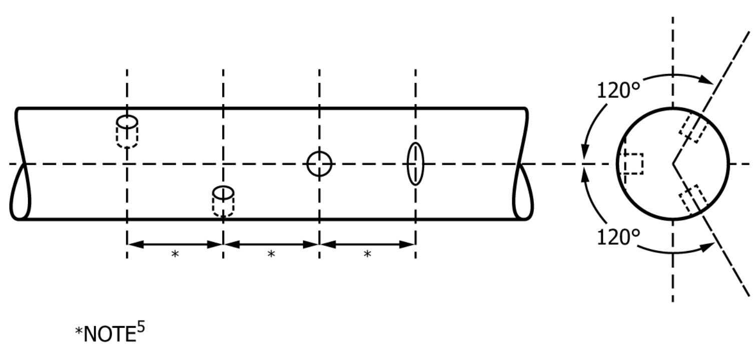
8. Reference Standards

8.1 Reference standards containing one or more artificial discontinuity may be used to establish sensitivity and alarm threshold settings to be used during eddy current examination. Sensitivity and alarm thresholds can be established using a reference standard with a single artificial discontinuity if the instrument is configured to respond only to signal amplitude, without regard to phase differences. If phase differences are detected and processed, additional artificial notches can be included in the reference standard to create and display phase responses.

8.2 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 consistent 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 the excitation frequency.

8.3 A suggested material reference standard is shown in Fig. 1. Artificial discontinuities of any other dimension or contour may be used in a reference standard by mutual agreement between the supplier and purchaser.

8.4 ~~*Artificial Discontinuity Standard:*~~ When using a reference standard with multiple artificial discontinuities, they shall be spaced to provide signal resolution adequate for interpretation. A sample of this type might 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).



NOTE 1—A suggested length between discontinuities is 2 in. (51 mm). However, this space should be sufficient to provide signal resolution adequate for interpretation. The speed of the ~~standardization rod~~reference standard through the test coil is not critical, but a range from 5 to 150 ft/min (1.5 to 45.72 m/min) is recommended.

FIG. 1 Reference Standards With Three Holes and One Notch