



Designation: E243 – 13

Standard Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes¹

This standard is issued under the fixed designation E243; 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 practice² covers the procedures that shall be followed in eddy current examination of copper and copper-alloy tubes for detecting discontinuities of a severity likely to cause failure of the tube. These procedures are applicable for tubes with outside diameters to 3 $\frac{1}{8}$ in. (79.4 mm), inclusive, and wall thicknesses from 0.017 in. (0.432 mm) to 0.120 in. (3.04 mm), inclusive, or as otherwise stated in ASTM product specifications; or by other users of this practice. These procedures may be used for tubes beyond the size range recommended, upon contractual agreement between the purchaser and the manufacturer.

1.2 The procedures described in this practice are based on methods making use of encircling annular examination coil systems.

1.3 *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.

NOTE 1—This practice may be used as a guideline for the examination, by means of internal probe examination coil systems, of installations using tubular products where the outer surface of the tube is not accessible. For such applications, the technical differences associated with the use of internal probe coils should be recognized and accommodated. The effect of foreign materials on the tube surface and signals due to tube supports are typical of the factors that must be considered. See E690 for additional details regarding the in-situ examinations using internal probes.

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.*

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 ASME Boiler and Pressure Vessel Code applications see related Practice SE-243 in the Code.

2. Referenced Documents

2.1 ASTM Standards:³

B111/B111M Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock

B395/B395M Specification for U-Bend Seamless Copper and Copper Alloy Heat Exchanger and Condenser Tubes

B543 Specification for Welded Copper and Copper-Alloy Heat Exchanger Tube

E543 Specification for Agencies Performing Nondestructive Testing

E690 Practice for In Situ Electromagnetic (Eddy-Current) Examination of Nonmagnetic Heat Exchanger Tubes

E1316 Terminology for Nondestructive Examinations

2.2 Other Documents:

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing⁴

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel⁴

NAS-410 NAS Certification and Qualification of Nondestructive Personnel (Quality Assurance Committee)⁵

3. Terminology

3.1 Definitions of Terms Specific to this Standard

3.1.1 The following terms are defined in relation to this standard.

3.1.1.1 *artificial discontinuity reference standard*—a standard consisting of a selected tube with defined artificial discontinuities, used when adjusting the system controls to obtain some predetermined system output signal level. This standard may be used for periodic checking of the instrument during an examination.

³ 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.

⁴ Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

⁵ 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

3.1.1.2 *percent maximum unbalance standardization standard*—a method of standardization that can be used with speed-insensitive instruments (see 3.1.1.4). The acceptance level of the examination is established at the operating examination frequency as an accurate fraction of the maximum unbalance signal resulting from the end effect of a tube. Any low-noise tube from the production run having a squared end may be used as this standard. This standard may be used for periodic checking of the instrument during an examination.

3.1.1.3 *electrical center*—the center established by the electromagnetic field distribution within the examination coil. A constant-intensity signal, irrespective of the circumferential position of a discontinuity, is indicative of electrical centering. The electrical center may be different from the physical center of the examination coil.

3.1.1.4 *speed-sensitive equipment*—examination equipment that produces a variation in signal response with variations in the examination speed. Speed-insensitive equipment provides a constant signal response with changing examination speeds.

3.1.1.5 *off-line examining*—eddy current examinations conducted on equipment that includes the examination coil and means to propel individual tubes under examination through the coil at appropriate speeds and conditions.

3.1.1.6 *on-line examining*—eddy current examinations conducted on equipment that includes the examination coil and means to propel tubes under examination through the coil at appropriate speeds and conditions as an integral part of a continuous tube manufacturing sequence.

3.2 *Definitions of Terms*—Refer to Terminology E1316 for definitions of terms that are applicable to nondestructive examinations in general.

4. Summary of Practice

4.1 Examining is usually performed by passing the tube lengthwise through a coil energized with alternating current at one or more frequencies. The electrical impedance of the coil is modified by the proximity of the tube, the tube dimensions, electrical conductivity and magnetic permeability of the tube material, and metallurgical or mechanical discontinuities in the tube. During passage of the tube, the changes in electromagnetic response caused by these variables in the tube produce electrical signals which are processed so as to actuate an audio or visual signaling device or mechanical marker which produces a record.

5. Significance and Use

5.1 Eddy current testing is a nondestructive method of locating discontinuities in a product. Signals can be produced by discontinuities located either on the external or internal surface of the tube or by discontinuities totally contained within the walls. Since the density of eddy currents decreases nearly exponentially as the distance from the external surface increases, the response to deep-seated defects decreases.

5.2 Some indications obtained by this method may not be relevant to product quality; for example, a reject signal may be caused by minute dents or tool chatter marks that are not detrimental to the end use of the product. Irrelevant indications can mask unacceptable discontinuities. Relevant indications

are those which result from nonacceptable discontinuities. Any indication above the reject level that is believed to be irrelevant shall be regarded as unacceptable until it is demonstrated by re-examination or other means to be irrelevant (see 10.3.2).

5.3 Eddy current testing systems are generally not sensitive to discontinuities adjacent to the ends of the tube (end effect). On-line eddy current examining would not be subject to end effect.

5.4 Discontinuities such as scratches or seams that are continuous and uniform for the full length of the tube may not always be detected.

6. Basis of Application

6.1 *Personnel Qualification*—Nondestructive testing (NDT) personnel shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, MIL-STD-410, NAS-410, or a similar document. The practice or standard used and its applicable revision shall be specified in the purchase specification or contractual agreement between the using parties.

NOTE 2—MIL-STD-410 is canceled and has been replaced with NAS-410, however, it may be used with agreement between contracting parties.

6.2 *Qualification of Nondestructive Testing Agencies*—If specified in the purchase specification or contractual agreement, NDT agencies shall be evaluated and qualified as described in Practice E543. The applicable edition of Practice E543 shall be identified in the purchase specification or contractual agreement between the using parties.

7. Apparatus

7.1 *Electronic Apparatus*—The electronic apparatus shall be capable of energizing the examination coil with alternating currents of suitable frequencies (for example, 1 kHz to 125 kHz), and shall be capable of sensing the changes in the electromagnetic response of the coils. Electrical signals produced in this manner are processed so as to actuate an audio or visual signaling device or mechanical marker which produces a record.

7.2 *Examination Coils*—Examination coils shall be capable of inducing current in the tube and sensing changes in the electrical characteristics of the tube. The examination coil diameter should be selected to yield the largest practical fill-factor.

7.3 *Driving Mechanism*—A mechanical means of passing the tube through the examination coil with minimum vibration of the examination coil or the tube. The device shall maintain the tube substantially concentric with the electrical center of the examination coil. A uniform speed (± 5.0 % speed variation maximum) shall be maintained.

7.4 *End Effect Suppression Device*—A means capable of suppressing the signals produced at the ends of the tube. Individual ASTM product specifications shall specify when an end effect suppression device is mandatory.

NOTE 3—Signals close to the ends of the tube may carry on beyond the limits of end suppression. Refer to 9.5.

8. Reference Standards

8.1 Artificial Discontinuity Reference Standard:

8.1.1 The tube 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. The tubes shall be passed through the examination coil with the instrument sensitivity high enough to determine the nominal background noise inherent in the tubes. The reference standard shall be selected from tubes exhibiting low background noise. For on-line eddy current examining, the reference standard is created in a tube portion existent in the continuous manufacturing sequence or in other forms as allowed by the product specification.

8.1.2 The artificial discontinuities shall be spaced to provide signal resolution adequate for interpretation. The artificial discontinuities shall be prepared in accordance with one of the following options:

(a) A round bottom transverse notch on the outside of the tube in each of three successive transverse planes at 0, 120, and 240° (Fig. 1).

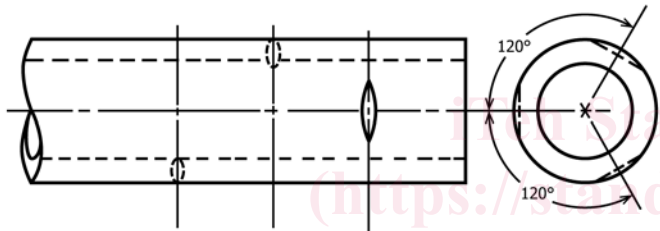


FIG. 1 Reference Standard with Three Notches

(b) A hole drilled radially through the tube wall in each of three successive transverse planes at 0, 120, and 240° (Fig. 2).

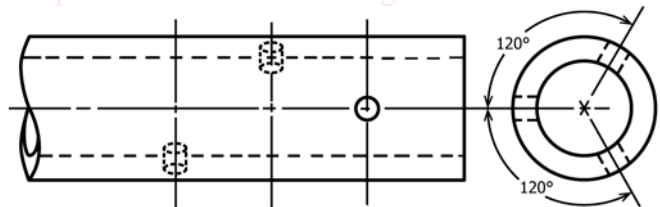


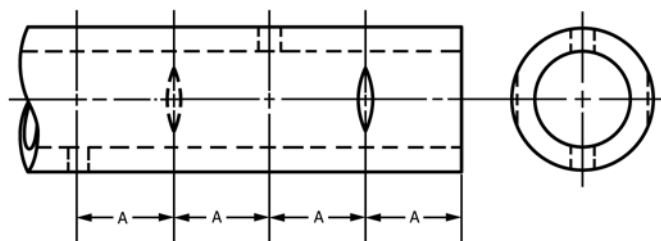
FIG. 2 Reference Standard with Three Holes

(c) One round bottom transverse notch on the outside of the tube at 0° and another at 180°, and one hole drilled radially through the wall at 90° and another at 270°. Only one notch or hole shall be made in each transverse plane (Fig. 3).

(d) Four round bottom transverse notches on the outside of the tube, all on the same element of the tube (Fig. 4).

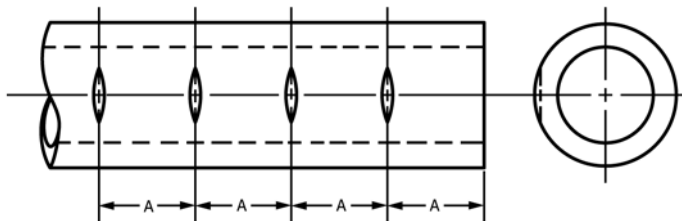
(e) Four holes drilled radially through the tube wall, all the same element of the tube (Fig. 5).

8.1.2.1 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 outside surface of the tube shall be stroked in a substantially straight line perpendicular to the axis of the tube. The notch depth shall be in accordance with the ASTM product specification or Appen-



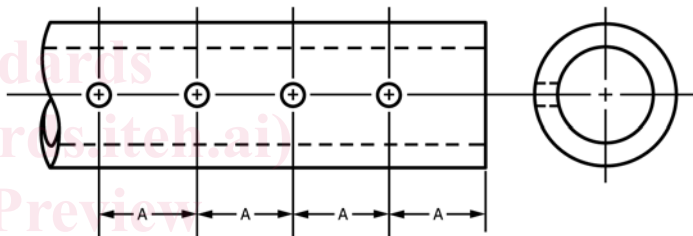
NOTE 1—A = Space to provide signal resolution adequate for interpretation.

FIG. 3 Reference Standard with Two Notches and Two Holes



NOTE 1—A = Space to provide signal resolution adequate for interpretation.

FIG. 4 Reference Standard with Four Notches in Line



NOTE 1—A = Space to provide signal resolution adequate for interpretation.

FIG. 5 Reference Standard with Four Holes in Line

dix X1 if the product specification does not specify and shall not vary from the notch depth by more than ±0.0005 in. (±0.013 mm) when measured at the center of the notch (see Table X1.1).⁶

NOTE 4—Tables X1.1 and X1.2 should not be used for acceptance or rejection of materials.

8.1.2.2 Drilled Holes—The hole shall be drilled radially through the wall using a suitable drill jig that has a bushing to guide the drill, care being taken to avoid distortion of the tube while drilling. The drilled hole diameter shall be in accordance with the ASTM product specification or Appendix X1 if the product specification does not specify and shall not vary by more than +0.001, -0.000 in. (+0.026 mm) of the hole diameter specified (see Table X1.2) (Note 4).⁶

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

⁶ Tables X1.1 and X1.2 are extracted from Specifications B111/B111M, B395/B395M, and B543.