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Standard Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation[1]

This standard is issued under the fixed designation E309; 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 specification has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice[2] covers a procedure for applying the eddy-current method to detect discontinuities in ferromagnetic pipe and tubing (Note 1) where the article being examined is rendered substantially non-magnetic by the application of a concentrated, strong magnetic field in the region adjacent to the examining coil.

NOTE 1—For convenience, the term tube or tubular product will hereafter be used to refer to both pipe and tubing.

1.2 The procedure is specifically applicable to eddy-current ~~examination~~testing methods using an encircling-coil assembly. However, eddy-current techniques that employ either fixed or rotating probe-coil assemblies may be used to either enhance discontinuity sensitivity on the large diameter tubular products or to maximize the response received from a particular type of discontinuity.

1.3 This practice is intended for use on tubular products having outside diameters from approximately ¼ to 10 in. (6.35 to 254.0 mm). These techniques have been used for smaller and larger sizes however, and may be specified upon contractual agreement between the purchaser and the supplier.

1.4 This practice does not establish acceptance criteria; they must be specified by the using party or parties.

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *Other Documents:*

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing[4]

ANSI/ASNT CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel[4]

2.3 *Military Standard:*

MIL-STD-410E Nondestructive Testing Personnel Qualification and Certification[5]

3. Terminology

~~3.1*General*—Standard terminology relating to electromagnetic examination may be found in Terminology~~

3.1 *General*—For definitions of terms used in this practice, refer to Terminology E1316~~, Section C, "Electromagnetic Testing."~~

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[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 Recommended Practice SE 309 in Section V of that Code.

[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 Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA ~~19111-5094, Attn: NPODS.~~19111-5098, http://dodssp.daps.dla.mil.

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

4. Summary of Practice

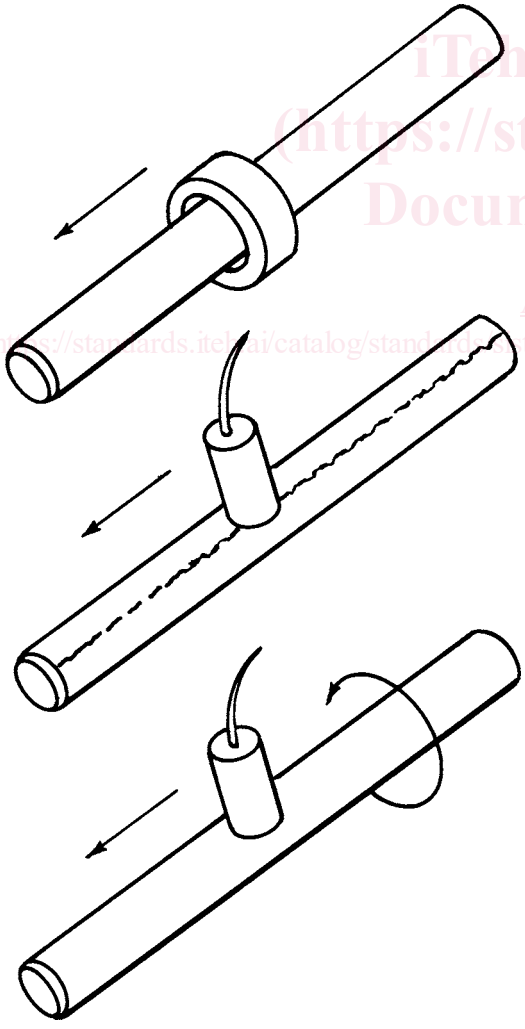
4.1 The examination is conducted using one of two general techniques shown in Fig. 1.

4.1.1 One technique employs one or more exciter and sensor coils that encircle the tube and through which the tubular product to be examined is passed. Some circuit configurations employ one or more coils that concurrently function as both exciters and sensors. Alternating current passes through the exciting coil which, by reason of its proximity, induces corresponding currents (eddy currents) to flow in the tubular product. The sensor coil detects the resultant electromagnetic flux related to these currents. The presence of discontinuities in the tubular product will alter the normal flow of currents and this change is detected by the sensor. The encircling-coil technique is capable of examining the entire circumference of a tubular product.

4.1.2 Another technique employs a probe coil with one or more sensors that are in close proximity to the surface of the tubular product to be examined. Since the probe is generally small and does not encircle the article being examined, it examines only a limited area in the vicinity of the probe. This technique is frequently used for examination of welded tubular products in which only the weld is examined by scanning along the weld zone.

4.1.3 The magnetic permeability of ferromagnetic materials severely limits the depth of penetration of induced eddy currents. Furthermore, the permeability variations inherent in ferromagnetic tubular products often cause anomalous test results. A useful solution to this problem involves the application of a strong external magnetic field in the region of the examining coil or probe. This technique, known as magnetic saturation, is applied to a magnetic material, such as a steel tube, to suppress the magnetic characteristics of permeability, hysteresis, etc., so that the material under examination is effectively rendered nonmagnetic. When achieved, this condition allows an eddy-current system to measure and detect electrical resistivity and geometrical variations (including defects) independent of concurrent variations in magnetic properties.

4.1.4 Changes in electromagnetic response caused by the presence of discontinuities are detected by the sensor, amplified, and modified in order to actuate audio or visual indicating devices, or both, a mechanical marker, or a signal-recording device, or a combination of these. Signals can be caused by outer surface, inner surface, or subsurface discontinuities if the eddy-current



(*a*) Encircling Coil.

(*b*) Probe Coil—longitudinal scanning of weld seam only.

(*c*) Probe Coil—scanning along a spiral path.

FIG. 1 Encircling-Coil and Probe-Coil Techniques for Electromagnetic Testing of Tubular Products

frequency provides sufficient depth of penetration (see ~~11.1~~5.4). The eddy-current method is sensitive to metallurgical variations that occur as a result of processing, thus all received indications are not necessarily indicative of defective tubing.

5. Significance and Use

5.1 The purpose of this practice is to outline a procedure for the detection and location of discontinuities such as pits, voids, inclusions, cracks, or abrupt dimensional variations in ferromagnetic tubing using the electromagnetic (eddy-current) method. Furthermore, the relative severity of a discontinuity may be indicated, and a rejection level may be set with respect to the magnitude of the indication.

5.2 The response from natural discontinuities can be significantly different than that from artificial discontinuities such as drilled holes or notches. For this reason, sufficient work should be done to establish the sensitivity level and set-up required to detect natural discontinuities of consequence to the end use of the product.

5.3 Eddy-current ~~examination~~testing systems are generally not sensitive to discontinuities adjacent to the ends of the tube. The extent of the end effect region can be determined in accordance with 8.6.

5.4 Since the density of eddy currents decreases nearly exponentially as the distance from the external surface increases, the response to deep-seated discontinuities decreases and some deep-seated discontinuities may give no detectable repsonse.

5.5 Discontinuity orientation also affects the system response and should be taken into consideration when establishing the examination sensitivity.

5.6 In preparing a reference standard for welded tubing, artificial discontinuities should be placed in both the weld metal and the parent metal when the responses are expected to be different and if both are to be examined. The apparatus is then adjusted to obtain an optimum signal-to-noise ratio.

5.6.1 When examining only the weld area, the discontinuities shall be placed only in the weld area.

5.7 The examination frequency and the type of apparatus being used should be considered when choosing the examining speed. Certain types of equipment are effective only over a given speed range; therefore, the examining speed should fall within this range.

5.8 Discontinuities such as scratches or seams that are continuous and uniform over the full length of the tube may not always be detected with differential encircling coils or probes scanned along the tube length.

6. Basis of Application

6.1 The following acceptance criteria may be specified in the purchase specification, contractual agreement, or elsewhere, and may require agreement between the purchaser and the supplier:

6.1.1 Time of examination or point(s) in the manufacturing process at which the material will be examined,

6.1.2 Maximum time interval between equipment calibration checks,

6.1.3 Methods for determining the extent of end effect,

6.1.4 Size and type of product,

6.1.5 Type, method of manufacture, dimensions, location, and number of artificial discontinuities to be placed on the reference standard,

6.1.6 Methods of verifying dimensions and allowable tolerances of artificial discontinuities,

6.1.7 Extent of examination, and

6.1.8 Disposition of material with indications.

6.1.9 *Operator Qualification and Certification*—If required, 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, or a similar document. The practice or standard used and its applicable revision shall be documented in the 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.

6.1.10 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated in accordance with Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

7. Apparatus

7.1 *Electronic Apparatus*—The electronic apparatus shall be capable of energizing the coils or probes with alternating currents of a selected frequency and shall be capable of sensing the changes in the electromagnetic response of the sensors. Equipment may include appropriate signal processing circuits such as a phase discriminator, filter circuits, etc., as required for the particular application.

7.2 *Encircling-Coil Assembly*—The encircling-coil assembly shall consist of one or more electrical coils that encircle the article being examined.

7.3 *Probe-Coil Assembly*—The probe-coil assembly normally contains an exciting coil and a sensor, although in some cases the exciter and sensor are one and the same.

7.4 *Magnetic Saturation System*—The magnetic saturation system shall consist of a suitable method of applying a strong magnetic field to the region of the tube adjacent to the coil or probe-coil assembly so as to render that region of the tube effectively nonmagnetic. Typical systems employ either permanent magnets or electromagnets.