Designation: E 2096 – 00

Standard Practice for In Situ Examination of Ferromagnetic Heat-Exchanger Tubes Using Remote Field Testing[1]

This standard is issued under the fixed designation E 2096; 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

1.1 This practice describes procedures to be followed during remote field examination of installed ferromagnetic heat-exchanger tubing for baseline and service-induced discontinuities.

1.2 This practice is intended for use on ferromagnetic tubes with outside diameters from 0.500 to 2.000 in. (12.70 to 50.80 mm), with wall thicknesses in the range from 0.028 to 0.134 in. (0.71 to 3.40 mm).

1.3 This practice does not establish tube acceptance criteria; the tube acceptance criteria must be specified by the using parties.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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 practice 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 Testing[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *Other Documents:*

ASNT SNT-TC-1A Recommended Practice for Nondestructive Testing Personnel Qualification and Certification[3]

Can CGSB-48.9712-95 Qualification of Nondestructive Testing Personnel, Natural Resources Canada[4]

3. Terminology

3.1 *General*—Definitions of terms used in this practice can be found in Terminology E 1316, Section A, "Common NDT Terms," and Section C, "Electromagnetic Testing."

3.2 *Definitions:*

3.2.1 *detector*, *n*—one or more coils or elements used to sense or measure magnetic field; also known as a receiver.

3.2.2 *exciter*, *n*—a device that generates a time-varying electromagnetic field, usually a coil energized with alternating current (ac); also known as a transmitter.

3.2.3 *nominal tube*, *n*—a tube or tube section meeting the tubing manufacturer's specifications, with relevant properties typical of a tube being examined, used for reference in interpretation and evaluation.

3.2.4 *remote field*, *n*—*as applied to nondestructive testing*, the electromagnetic field which has been transmitted through the test object and is observable beyond the direct coupling field of the exciter.

3.2.5 *remote field testing*, *n*—a nondestructive test method that measures changes in the remote field to detect and characterize discontinuities.

3.2.6 *using parties*, *n*—the supplier and purchaser.

3.2.6.1 *Discussion*—The party carrying out the examination is referred to as the "supplier," and the party requesting the examination is referred to as the "purchaser," as required in *Form and Style for ASTM Standards*, October 1999. In common usage outside this practice, these parties are often referred to as the "operator" and "customer," respectively.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *flaw characterization standard*, *n*—a standard used in addition to the RFT system reference standard, with artificial or service-induced flaws, used for flaw characterization.

3.3.2 *nominal point*, *n*—a point on the phase-amplitude diagram representing data from nominal tube.

[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 Methods.

Current edition approved June 10, 2000. Published August 2000.

[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.

[4] Available from CGSB Sales Centre; Place du Portage, Phase 3, 6B1; 11 Laurier Street, Hull QC, Canada K1A 1G6.

3.3.3 *phase-amplitude diagram*, *n*—a two-dimensional representation of detector output voltage, with angle representing phase with respect to a reference signal, and radius representing amplitude (Fig. 1a and 1b).

3.3.3.1 *Discussion*—In this practice, care has been taken to use the term "phase angle" (and "phase") to refer to an angular equivalent of time displacement, as defined in Terminology E 1316. When an angle is not necessarily representative of time, the general term "angle of an indication on the phase-amplitude diagram" is used.

3.3.4 *RFT system*, *n*—the electronic instrumentation, probes, and all associated components and cables required for performing RFT.

3.3.5 *RFT system reference standard*, *n*—a reference standard with specified artificial flaws, used to set up and standardize a remote field system and to indicate flaw detection sensitivity.

3.3.6 *sample rate*—the rate at which data is digitized for display and recording, in data points per second.

3.3.7 *strip chart*, *n*—a diagram that plots coordinates extracted from points on a phase-amplitude diagram versus time or axial position (Fig. 1c).

3.3.8 *zero point*, *n*—a point on the phase-amplitude diagram representing zero detector output voltage.

3.3.8.1 *Discussion*—Data on the phase-amplitude diagram are plotted with respect to the zero point. The zero point is separate from the nominal point unless the detector is configured for zero output in nominal tube. The angle of a flaw indication is measured about the nominal point.

3.4 *Acronyms:*

3.4.1 *RFT*, *n*—remote field testing

4. Summary of Practice

4.1 The RFT data is collected by passing a probe through each tube. The electromagnetic field transmitted from the exciter to the detector is affected by discontinuities; by the dimensions and electromagnetic properties of the tube; and by objects in and around the tube that are ferromagnetic or conductive. System sensitivity is verified using the RFT system reference standard. System sensitivity and settings are checked and recorded prior to and at regular intervals during the examination. Data and system settings are recorded in a manner that allows archiving and later recall of all data and system settings for each tube. Interpretation and evaluation are

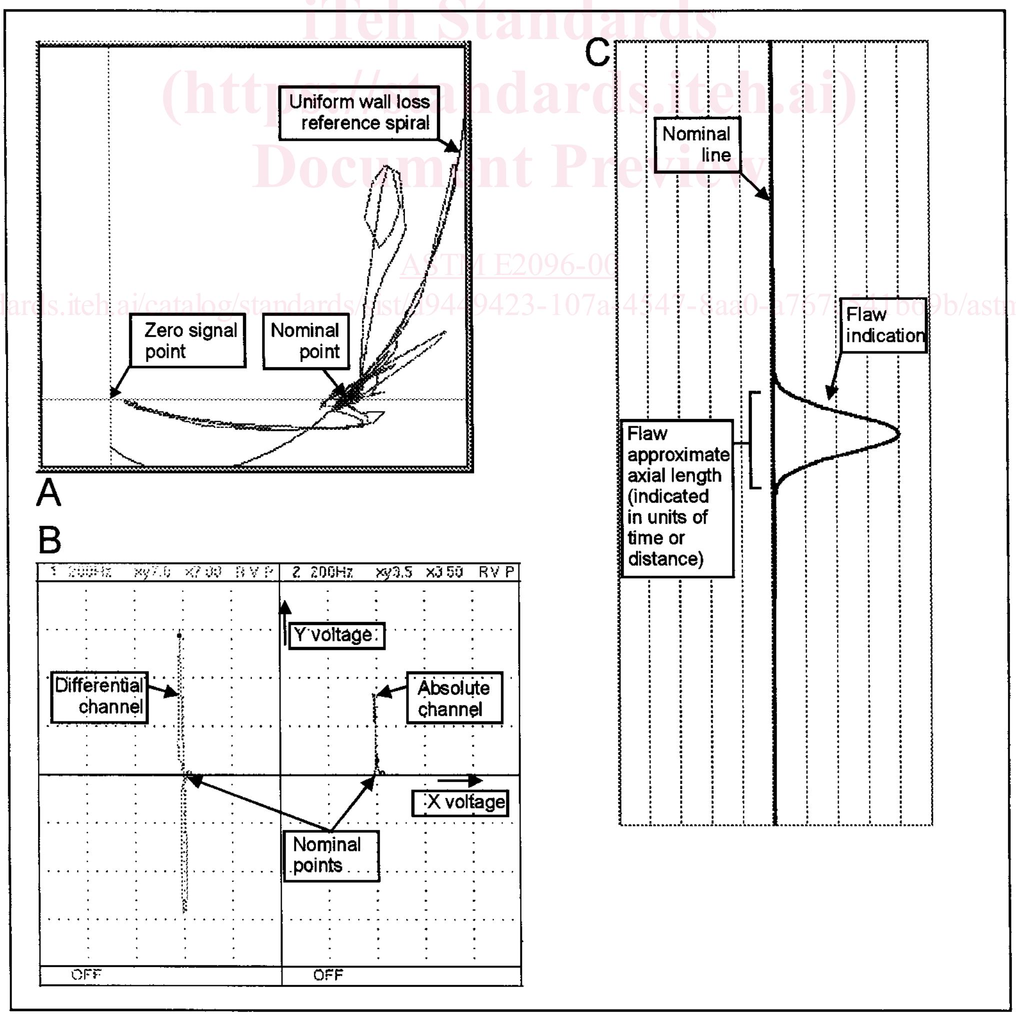


FIG. 1 A and B: Typical Phase-Amplitude Diagrams Used in RFT; C: Generic Strip Chart With Flaw

carried out using one or more flaw characterization standards. The supplier generates a final report detailing the results of the examination.

5. Significance and Use

5.1 The purpose of RFT is to evaluate the condition of the tubing. The evaluation results may be used to assess the likelihood of tube failure during service, a task which is not covered by this practice.

5.2 *Principle of Probe Operation*—In a basic RFT probe, the electromagnetic field emitted by an exciter travels outwards through the tube wall, axially along the outside of tube, and back through the tube wall to a detector[5] (Fig. 2a).

5.2.1 Flaw indications are created when (*1*) in thin-walled areas, the field arrives at the detector with less attenuation and less time delay, (*2*) discontinuities interrupt the lines of magnetic flux, which are aligned mainly axially, or (*3*) discontinuities interrupt the eddy currents, which flow mainly circumferentially. A discontinuity at any point on the through-transmission path can create a perturbation; thus RFT has approximately equal sensitivity to flaws on the inner and outer walls of the tube.[5]

5.3 *Probe Configuration*—The detector is typically placed two to three tube diameters from the exciter, in a location where the remote field dominates the direct-coupling field.[5] Other probe configurations or designs may be used to optimize flaw detection, as described in 9.3.

5.4 *Comparison with Conventional Eddy-Current Testing*—Conventional eddy-current test coils are typically configured to sense the field from the tube wall in the immediate vicinity of the emitting element, whereas RFT probes are typically designed to detect changes in the remote field.

6. Basis of Application

6.1 *Personnel Qualification*:

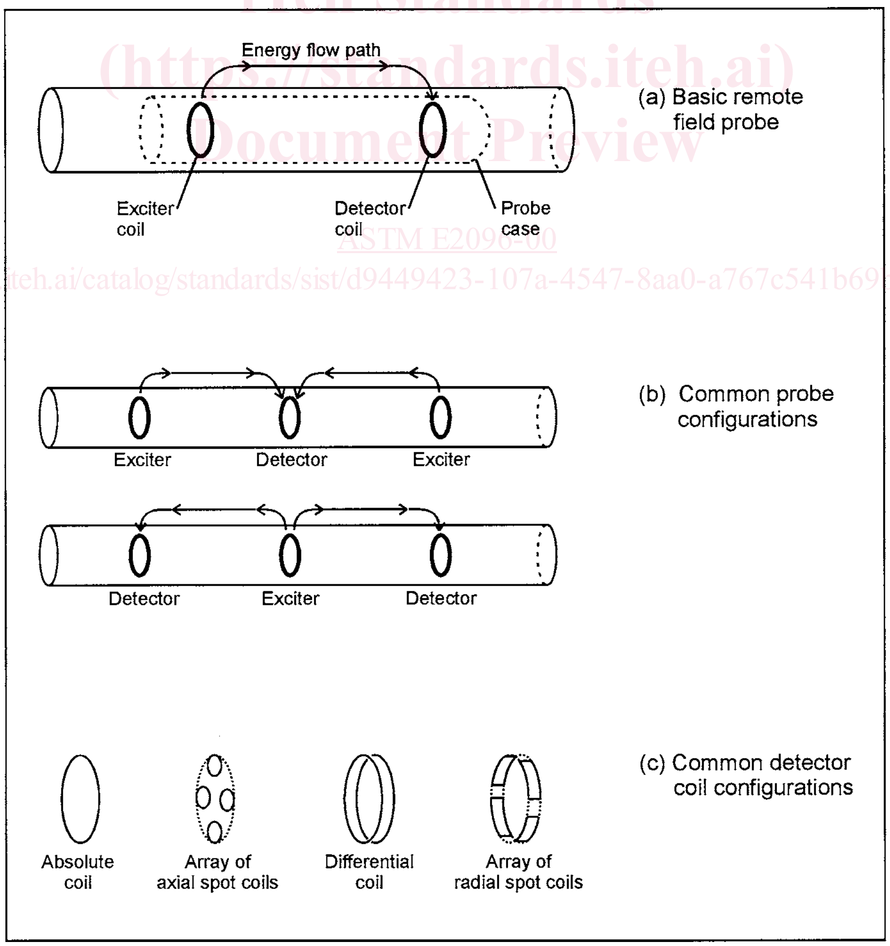
6.1.1 Personnel performing examinations to this practice shall be qualified as specified in the contractual agreement.

6.1.2 Recommendations for qualification as an RFT system operator (Level I) are as follows:

6.1.2.1 Forty hours of RFT (Level I) classroom training.

6.1.2.2 Written and practical examinations similar to those described by ASNT SNT-TC-1A or Can CGSB 48.9712-95.

[5] Schmidt, T. R., "The Remote Field Eddy Current Inspection Technique," *Materials Evaluation*, Vol. 42, No. 2, Feb. 1984, pp. 225-230.



NOTE 1—Arrows indicate flow of electromagnetic energy from exciter to detector. Energy flow is perpendicular to lines of magnetic flux.

FIG. 2 RFT Probes

6.1.2.3 Two hundred and fifty hours of field experience under the supervision of a qualified RFT Level II, 50 % of which should involve RFT instrumentation setup and operation.

6.1.3 Recommendations for qualification as an RFT data analyst (Level II) are as follows:

6.1.3.1 Forty hours of RFT (Level II) classroom training.

6.1.3.2 Written and practical examinations similar to those described by ASNT SNT-TC-1A or Can CGSB 48.9712-95.

6.1.3.3 Fifteen hundred hours of field experience under the supervision of a qualified RFT Level II or higher, 25 % of which should involve RFT data analysis.

NOTE 1—At the time of approval of this practice, no nationally or internationally recognized guideline for personnel qualification in RFT was available.

NOTE 2—Eddy-current training provides some useful background to RFT training. Previous Level II eddy-current certification may count towards 50 % of training and experience hours for RFT Level I, provided that the remaining experience hours are entirely involved in RFT instrumentation setup and operation.

6.2 *Qualification of Nondestructive Testing Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543, with reference to sections on electromagnetic testing. The applicable edition of Practice E 543 shall be specified in the contractual agreement.

7. Job Scope and Requirements

7.1 The following items may require agreement between the using parties and should be specified in the purchase document or elsewhere:

7.1.1 Location and type of tubed component to be examined, design specifications, degradation history, previous nondestructive examination results, maintenance history, process conditions, and specific types of flaws that are required to be detected, if known.

7.1.2 The maximum window of opportunity for work. (Detection of small flaws may require a slower probe pull speed, which will affect productivity.)

7.1.3 Size, material grade and type, and configuration of tubes to be examined.

7.1.4 A tube numbering or identification system.

7.1.5 Extent of examination, for example: complete or partial coverage, which tubes and to what length, whether straight sections only, and the minimum radius of bends that can be examined.

7.1.6 Means of access to tubes, and areas where access may be restricted.

7.1.7 Type of RFT instrument and probe; and description of reference standards used, including such details as dimensions and material.

7.1.8 Required operator qualifications and certification.

7.1.9 Required tube cleanliness.

7.1.10 Environmental conditions, equipment, and preparations that are the responsibility of the purchaser; common sources of noise that may interfere with the examination.

NOTE 3—Nearby welding activities may be a major source of interference.

7.1.11 Complementary methods or techniques (including possible tube removal) that may be used to obtain additional information.

7.1.12 Acceptance criteria to be used in evaluating flaw indications.

7.1.13 Disposition of examination records and reference standards.

7.1.14 Format and outline contents of the examination report.

8. Interferences

8.1 This section describes items and conditions which may compromise RFT.

8.2 *Material Properties*:

8.2.1 Variations in the material properties of ferromagnetic tubes are a potential source of inaccuracy. Impurities, segregation, manufacturing process, grain size, stress history, present stress patterns, temperature history, present temperature, magnetic history, and other factors will affect the electromagnetic response measured during RFT. The conductivity and permeability of tubes with the same grade of material are often measurably different. It is common to find that some of the tubes to be examined are newer tubes with different material properties.

8.2.2 Permeability variations may occur at locations where there was uneven temperature or stress during tube manufacture, near welds, at bends, where there were uneven heat transfer conditions during service, at areas where there is cold working (such as that created by an integral finning process), and in other locations. Indications from permeability variations may be mistaken for, or obscure flaw indications. Effects may be less severe in tubes that were stress-relieved during manufacture.

8.2.3 Residual stress, with accompanying permeability variations, may be present when discontinuities are machined into a reference standard, or during the integral finning process.

8.2.4 The RFT is affected by residual magnetism in the tubing, including residual magnetism created during a previous examination using another magnetic method. Tubes with significant residual magnetism should be demagnetized prior to RFT.

8.3 *Ferromagnetic and Conductive Objects*:

8.3.1 Objects near the tube that are ferromagnetic or conductive may reduce the sensitivity and accuracy of flaw characterization in their immediate vicinity. Such objects may in some cases be mistaken for flaws. Knowledge of the mechanical layout of the component to be examined is recommended. Examples of ferromagnetic or conductive objects include: tube support plates, baffle plates, end plates, tube sheets, anti-vibration bars, neighboring tubes, impingement plates, loose parts, and attachments clamped or welded to a tube.

NOTE 4—Interference from ferromagnetic or conductive objects can be of practical use when RFT is used to confirm the position of an object installed on a tube or to detect where objects have become detached and have fallen against a tube.

8.3.2 *Neighboring Tubes*: