



Designation: E1001 – 06

# Standard Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves<sup>1</sup>

This standard is issued under the fixed designation E1001; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This practice describes procedures for the ultrasonic examination of bulk materials or parts by transmitting pulsed, longitudinal waves through a liquid couplant into the material and observing the indications of reflected waves (see Fig. 1). It covers only examinations in which one search unit is used as both transmitter and receiver (pulse-echo) and in which the part or material being examined is coupled to the test part by a liquid column or is totally submerged in the couplant (either method is considered to be immersion testing). This practice includes general requirements and procedures which may be used for detecting discontinuities and for making a relative or approximate evaluation of the size of discontinuities.

1.2 This practice replaces Practice E214 and provides more detailed procedures for the selection, calibration, and operation of an inspection system and for evaluation of the indications obtained.

1.3 *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:<sup>2</sup>

**C1212** Practice for Fabricating Ceramic Reference Specimens Containing Seeded Voids

**C1336** Practice for Fabricating Non-Oxide Ceramic Reference Specimens Containing Seeded Inclusions

**E127** Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks

**E317** Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

**E428** Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing

**E543** Specification for Agencies Performing Nondestructive Testing

**E1316** Terminology for Nondestructive Examinations

### 2.2 ASNT Documents:<sup>3</sup>

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 Aerospace Industries Association Document:

NAS-410 Certification and Qualification of Nondestructive Testing Personnel<sup>4</sup>

NOTE 1—For DoD contracts, unless otherwise specified the issues of the documents, which are DoD adopted, are those listed in the issue of the DoDISS (Department of Defense Index of Specifications Standards) cited in the solicitation.

## 3. Terminology

### 3.1 Definitions:

3.1.1 For definitions of terms used in this practice, see Terminology **E1316**.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *effective beam diameter*—that distance through which a search unit can be traversed across a calibration reflector so that the corresponding echo amplitude is at least one half (–6 dB) of the maximum amplitude. The effective beam diameter is not a characteristic of the search unit alone, but is dependent on propagating medium, distance to the discontinuity, reflector geometry, etc.

3.2.2 *scan index*—the length of the step created by indexing the scan of the search unit over the part, that is continuously

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

Current edition approved Dec. 1, 2006. Published January 2007. Originally approved in 1984. Last previous edition approved in 2004 as E1001 – 04. DOI: 10.1520/E1001-06.

<sup>2</sup> 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.

<sup>3</sup> Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlington Ln., Columbus, OH 43228-0518.

<sup>4</sup> Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

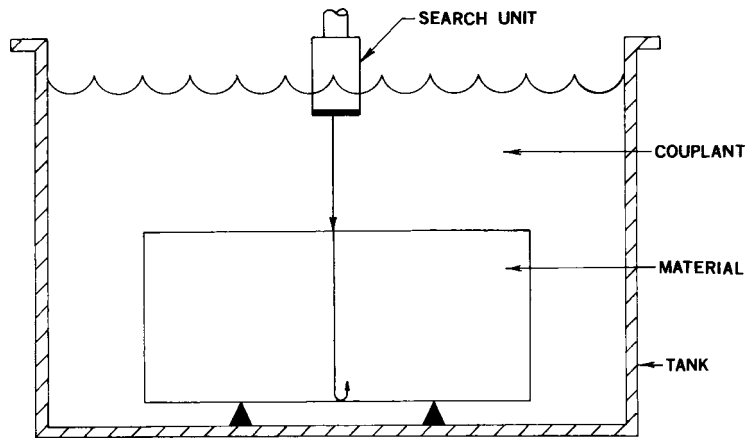


FIG. 1 Basic Immersion Setup

scanning in one direction, then stepping in the direction perpendicular to the scan or making a linear advance per rotation (pitch) for rotary scan of cylindrical parts. The allowable scan index should be correlated with the search unit effective beam diameter to ensure full coverage of the part as described in 8.2 below.

3.2.3 *transfer*—a change in scanning gain to compensate for differences in attenuation of the reference standard and the part or material being inspected.

#### 4. Summary of Practice

4.1 This practice describes a means for obtaining an evaluation of discontinuities in materials by immersed examination with longitudinal ultrasonic waves. Equipment, reference standards, examination and evaluation procedures, and documentation are described in detail.

#### 5. Basis of Application

5.1 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, or a similar document 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.

5.2 *Written Procedure*—A detailed written procedure shall be used for the performance of ultrasonic examinations in accordance with this practice. The written procedure should address all applicable portions of this practice, for the purposes of consistency in application and the repeatability of the examination results. Specific requirements regarding preparation and approval of the written procedure should be determined by purchaser and supplier agreement.

#### 6. Significance and Use

6.1 This practice provides guidelines for the application of immersed longitudinal wave examination to the detection and quantitative evaluation of discontinuities in materials.

6.2 Although not all requirements of this practice can be applied universally to all inspection situations and materials, it

does provide a basis for establishing contractual criteria between suppliers and purchasers of materials for performing immersed pulse-echo examination, and may be used as a general guide for writing detailed specifications for particular applications.

6.3 This practice is directed towards the evaluation of discontinuities detectable at normal beam incidence. If discontinuities at other orientations are of concern, alternate scanning techniques are required.

#### 7. Apparatus

7.1 *Electronic Equipment*—The electronic equipment should be capable of producing and processing electronic signals at frequencies in the range of search unit frequencies being used. The equipment and its display should be capable of meeting the requirements to be completed in Table 1, as agreed upon between the supplier and the purchaser, and as measured in accordance with procedures described in Practice E317 or equivalent procedures (see Note 2). These requirements are applicable only for the frequencies required for the inspection. Also, the equipment, including the search unit, should be capable of producing echo amplitudes of at least 60 %, of full scale, with the noise level no greater than 20 %, from the appropriate reference reflector at a material distance equal to the thickness of the part to be inspected. Alternatively, if these

TABLE 1 Minimum Equipment Requirements (Longitudinal Wave)

| Instrument Characteristics                                                      | Ultrasonic Test Frequency, MHz |     |      |      |
|---------------------------------------------------------------------------------|--------------------------------|-----|------|------|
|                                                                                 | 2.25                           | 5.0 | 10.0 | 15.0 |
| Vertical limit, in. [mm], trace to peak or percent of full screen height        |                                |     |      |      |
| Upper linearity limit, in. [mm], trace to peak or percent of full screen height |                                |     |      |      |
| Lower linearity limit, in. [mm], trace to peak or percent of full screen height |                                |     |      |      |
| Ultrasonic sensitivity, reflector size, material distance, in. [mm]             |                                |     |      |      |
| Signal-to-noise ratio                                                           |                                |     |      |      |
| Entry surface resolution, in. [mm]                                              |                                |     |      |      |
| Back surface resolution, in. [mm]                                               |                                |     |      |      |
| Horizontal limit, in. [mm] or percent of full screen width                      |                                |     |      |      |
| Horizontal linearity range, in. [mm] or percent of full screen width            |                                |     |      |      |



conditions can be met at one half the part thickness, the part may be inspected from both sides. The instrument must have a pulser of the sufficient voltage, repetition rate and waveshape to provide total volume coverage at the desired scanning speed.

**NOTE 2**—Significantly higher frequencies than those shown in **Table 1** (for example, 50 MHz) may be necessary for the smaller critical flaw size of advanced ceramics.

**7.2 Voltage Regulator**—If fluctuations in line voltage cause variations exceeding  $\pm 5\%$  of the vertical limit in an indication with an amplitude of one half the vertical limit, a voltage regulator should be required on the power source. This requirement is not applicable to battery-operated units.

**7.3 Search Units**—The search unit selected should be compatible with the electronic equipment being used and with the material to be inspected. The search units should be of the immersion type. Only straight-beam (longitudinal) search units, with flat or focused acoustic lenses, should be used. Focused or dual element search units may provide better near-surface resolution and detection of small discontinuities. Generally, round or rectangular search units are used for examination whereas round search units with symmetrical sound beam patterns are used for evaluation.

**7.4 Alarm**—For the examination of parts or material with regular shape and parallel surfaces, such as plate, machined bar stock, and forgings, an audible alarm should be used in preference to a visual alarm, since the examination process can be accomplished at a speed which prevents reliable visual monitoring of the instrument screen. As a matter of practicality, an audible alarm should be used in conjunction with visual monitoring wherever possible. The alarm should be adjustable to allow triggering at any commonly required level of indication amplitude and depth of material. During operation the audible or visible signal produced by the alarm should be easily detectable by the operator.

**NOTE 3**—Alarm requirements are not applicable if recording equipment is used unless otherwise specified in the contractual agreement.

**7.4.1 Alarm Gate Synchronization**—To ensure that the alarm gate tracks the inspection area, the gate should lock on the first interface pulse from the test piece rather than on the initial pulse from the system. Gating from the initial pulse can result in either partial loss of the inspection area from the gate, or the inclusion of the back reflection and interface signal in the gated area. This will trigger the gate as would an imperfection.

**7.5 Manipulating Equipment** should be provided to adequately support a search tube, containing the search unit, and to allow angular adjustment in two mutually perpendicular, vertical planes. A manipulator may be attached between the search tube and search unit to provide the necessary angular adjustments. The scanning and indexing apparatus should have sufficient structural rigidity to provide support for the manipulator and should allow smooth, accurate positioning of the search unit. This apparatus should permit control of the scan in accordance with **9.3.1** and control of the index in accordance with **9.2.1**. Also, the scanning apparatus should be sufficiently rigid to keep search unit backlash to within tolerances as specified in the contractual agreement. Water-path distances should be continuously adjustable.

**7.6 Tank**—The container or tank should permit accurate positioning of the search unit, reference blocks, and part or material to be examined in accordance with the requirements of **Section 8**.

**7.7 Reference Standards**—Ultrasonic reference blocks, or reference specimens, are used to standardize the ultrasonic equipment and to evaluate the indications received from discontinuities within the test part. The ultrasonic characteristics of the reference standards such as attenuation, noise level, surface condition, and sound velocity, should be similar to the material being inspected. Metal reference standards should not be used for examining advanced ceramics because of the large differences in attenuation velocity and acoustic impedance. Standardization (1) verifies that the instrument/search unit combination is performing as required, and (2) establishes a detection level for discontinuities. Reference blocks as described in Practices **E127** and **E428** have been used as standards for calibrating system performance, and may continue to be so used in cases where much empirical evidence has shown that satisfactory inspection results are obtained. However, it is more desirable in the general case to use a part identical in shape, dimensions and material properties to the parts to be inspected. (See Ref. (1)<sup>5</sup>.)

**7.7.1 Flat Blocks**—The three most commonly used sets of reference blocks are (1) area-amplitude blocks, containing blocks with the same material path and various sizes of reference reflectors; (2) distance-amplitude blocks containing blocks with one-size reference reflector at various material paths; and (3) a combination including both area-amplitude and distance-amplitude blocks in one set. These sets are described in Practice **E127**. However, in general their use is not recommended for system calibration (see **7.7** above). Other types of reference blocks may be used when mutually agreed upon between the supplier and the purchaser. Practices **C1212** and **C1336** containing seeded voids and seeded inclusions may be used for advanced ceramics.

**7.7.2 Curved Surfaces**—Reference blocks with flat surfaces should not be used for establishing gain settings for examinations on test surfaces with radii of curvature less than about 8 in. [200 mm]. For test surfaces with radii of curvature less than 5 in., reference blocks with the same nominal curvature should be used, unless otherwise agreed upon between the supplier and the purchaser. (See (2).)

**7.8 Reference Reflectors (Targets)**—Flat-bottom holes, (FBH), or other artificial discontinuities, located either directly in the test part or material, in a representative sample of the part or material, or, if previously found to yield satisfactory inspection, in reference blocks, should be used to establish the reference echo amplitude or to perform distance-amplitude correction, or both. For most examinations, the bottom surface of a suitable diameter flat-bottom hole is the common reference reflector. However, other types of artificial discontinuities (notches, side-drilled holes, etc.) may be used when mutually agreed upon between the supplier and the purchaser. Seeded

<sup>5</sup> The boldface numbers in parentheses refer to a list of references at the end of this standard.