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Standard Guide for Detection and Evaluation of Discontinuities by Contact Pulse-Echo Straight-Beam Ultrasonic Methods[1]

This standard is issued under the fixed designation E 1901; 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 guide covers procedures for the contact ultrasonic examination of bulk materials or parts by transmitting pulsed ultrasonic waves into the material and observing the indications of reflected waves. This guide covers only examinations in which one search unit is used as both transmitter and receiver (pulse-echo). This guide includes general requirements and procedures that may be used for detecting discontinuities, locating depth and distance from a point of reference and for making a relative or approximate evaluation of the size of discontinuities as compared to a reference standard.

1.2 This guide complements Practice E 114 by providing more detailed procedures for the selection and calibration of the inspection system and for evaluation of the indications obtained.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI units given in brackets are for information only.

1.4 *This guide 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 guide to establish the appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method[2]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[2]

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Examination Instruments and Systems without the Use of Electronic Measurement Instruments[2]

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection[2]

E 543 Practice for Agencies Performing Nondestructive Testing[2]

E 1158 Guide for Material Selection and Fabrication of Reference Blocks for the Pulsed Longitudinal Wave Ultrasonic Examinations of Metal and Metal Alloy Production Materials[2]

E 1316 Terminology for Nondestructive Examinations[2]

2.2 *ASNT Standard:*

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

2.3 *ANSI/ASNT Standard:*

CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel [3]

2.4 *Military Standard:*

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, see Terminology E 1316.

4. Basis for Application

4.1 *Contractual Agreement*—The using parties shall agree on the applicable procedural requirements, as listed herein, prior to the examination of any material.

4.1.1 Materials, sizes, and shapes examined,

4.1.2 Stage of manufacture when examined (time of test),

4.1.3 Surface finish requirements,

4.1.4 Minimum equipment requirements, as in Table 1 herein,

4.1.5 Search unit size, frequency and type,

4.1.6 Couplant,

4.1.7 Automated turning, fixturing or scanning, or both, as applicable,

4.1.8 Type of reference block standards including surface curvature,

4.1.9 Standardization details, including attenuation compensation and DAC techniques,

[1] This guide is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[4] Available from Standardization Documents Order Deck, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111–5094, Attn: NPODS.

TABLE 1 Minimum Equipment Requirements (Longitudinal Wave)

Instrument Characteristics	Ultrasonic Test Frequency MHZ (Record)
Vertical limit, in. [mm] or percent of full screen height	
Upper vertical linearity limit in. [mm] or percent of full screen height	
Lower vertical linearity limit in. [mm] or percent of full screen height	
Ultrasonic sensitivity, hole size, 64 ths, distance, in [mm]	
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	

4.1.10 The surfaces to be examined and the scanning path,

4.1.11 Acceptance standards,

4.1.12 Personnel certification level, and

4.1.13 Instrument characteristics.

4.2 *Written Procedure*—Ultrasonic examinations performed in accordance with this guide shall be detailed in a written procedure. Documentation of procedure qualification shall be maintained by the preparer. Procedures shall be sufficiently detailed so that other qualified examiners may duplicate the examination and obtain equivalent results.

4.3 *Personnel Qualifications*—Personnel performing ultrasonic examinations in accordance with this guide shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard; such as SNT-TC-1A, ANSI/ASNT CP-189, MIL-STD-410, or a similar document. The practice or standard used and its applicable revision shall be specified in the contractual agreement between the using parties.

4.4 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E 543.

5. Summary of Guide

5.1 This guide describes a means for obtaining an evaluation of discontinuities in materials by contact examination using longitudinal waves. Equipment, reference standards, examination and evaluation procedures, and documentation of results are described in detail.

6. Significance and Use

6.1 This guide provides procedures for the application of contact straight-beam examination for the detection and quantitative evaluation of discontinuities in materials.

6.2 Although not all requirements of this guide can be applied universally to all inspections, situations, and materials, it does provide basis for establishing contractual criteria between the users, and may be used as a general guide for preparing detailed specifications for a particular application.

6.3 This guide is directed towards the evaluation of discontinuities detectable with the beam normal to the entry surface. If discontinuities or other orientations are of concern, alternate scanning techniques are required.

7. Apparatus

7.1 Apparatus shall include the following:

7.1.1 *Electronic Equipment*—The electronic equipment shall be capable of producing and processing electronic signals at frequencies in the range of the search unit frequencies being used. The equipment and its display shall provide characteristics as listed in Table 1, that are suitable for the specific application at the specified frequency, as determined in accordance with the procedures and tolerances described in Practice E 317. The equipment, including the search unit, shall be capable of producing echo amplitudes of at least 60 % of full screen height from the reference reflector required for the examination, with the material noise level, from front to back surface not exceeding 20 % of full screen height. Alternatively, if these conditions can be met at one half the part thickness, the part may be inspected from both sides.

NOTE 1—The using parties should agree on the minimum instrument characteristics prior to conducting an examination.

7.1.2 *Voltage Regulator*—If fluctuations in line voltage cause indication amplitude variations exceeding ±½ dB, a voltage regulator shall be required on the power source. This requirement is not applicable to battery-operated units.

7.1.3 *Search Units*—The search unit selected shall be capable of transmitting and receiving ultrasound at the required frequencies and energy levels necessary for discontinuity detection in the material being examined. The search units shall be of the contact type. Only longitudinal wave, straight beam, non-focused search units should be used. 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. Typical search unit sizes range from ⅛ in. [3.2 mm] in diameter to 1-⅛ in. [28.6 mm] in diameter with other sizes and shapes available for special applications. Search units may be fitted with contoured shoes to enhance coupling with curved surfaces.

7.1.4 *Alarm(s)*—For the examination of parts with regular shape and parallel surfaces such as machined cylinders, rounds, bars, forgings, etc. an audible/visual alarm may be used in conjunction with visual monitoring of the display for the detection of discontinuities or for the monitoring and detection of loss of back surface reflection, or both. The alarm should be adjustable to allow triggering at commonly required indication amplitudes, back-echo heights, and depths. During examination the audible visual alarm shall be easily detectable by the operator.

7.1.4.1 When reduction in the amplitude of back-surface reflection is monitored simultaneously with the detection of lower amplitude signals from small, discrete discontinuities, two separate gate/alarm systems are required. The negative slaved alarm system may also provide for a significantly lower receiver gain at the gated depth to avoid back-echo saturation. See 10.1 and 10.4.

7.1.4.2 For some applications it may be advantageous to utilize a flaw gate system in which the echo-amplitude alarm level can be varied as a function of target depth. Refer to distance/amplitude gate (DAG) in 9.3.2.1.

7.2 *Couplant*—A couplant, usually a liquid or semi-liquid, is required between the face of the search unit and the examination surface to permit transmittance of ultrasound from the search unit into the material under examination. Typical couplants include water, cellulose gel, oil and grease. Corrosion inhibitors or wetting agents or both may be used. Couplants selected must not be detrimental to the product or the process. The same couplant used for standardization shall be used for the examination. During the performance of a contact ultrasonic examination, the couplant layer between search unit and examination material must be maintained such that the contact area is held constant while maintaining adequate couplant thickness. Lack of couplant that will reduce the effective contact area, or excess couplant, will reduce the amount of energy transferred between the search unit and the examination surface. These couplant variations, in turn, result in examination sensitivity variations.

7.2.1 The couplant should be selected such that its viscosity is appropriate for the surface finish of the material to be examined. The examination of rough surfaces generally requires a high-viscosity couplant and will result in some deterioration of near-surface discontinuity detection. The temperature of the material surface can change the couplant's viscosity as in the case of oil and grease. See Table 2 for the suggested viscosity of oil couplants for given surface roughnesses.

7.2.2 At elevated temperatures as conditions warrant, heat-resistant coupling materials such as silicone oils, gels, or greases should be used. Further, intermittent contact of the search unit with the part surface or auxiliary cooling of the search unit may be necessary to avoid temperature changes that affect the ultrasonic characteristics of the search unit. At higher temperatures, certain couplants based on inorganic salts or thermoplastic organic materials, high-temperature delay materials (shoes) and search units that are not affected by high temperatures may be required.

7.2.3 Where constant coupling over large areas is required, as in automated examination, or where severe changes in surface roughness are found, other methods of coupling such as liquid gap coupling will usually provide a better examination. In this case, the search unit does not contact the examination surface, but is separated by a distance of about 0.02 in. [0.5 mm] filled with couplant. Liquid flowing through the search unit mechanism fills the gap. The flowing liquid provides the coupling path and has the additional advantage of cooling the search unit if the examination surface is warm.

7.2.4 Another means of direct contact coupling is provided by the wheel search unit. The search unit is mounted at the correct angle to a stationary axle about which rotates a liquid-filled flexible tire. A minimum amount of couplant provides for ultrasonic transmission into the examination surface since the elastic tire material is in rolling contact and conforms closely to the surface.

TABLE 2 Suggested Viscosities-Oil Couplants

NOTE 1—This table is a guide and is not meant to exclude the use of a particular couplant that is found to work satisfactorily on a surface.

Approximate Surface Roughness Average (Ra) µin. [µm]	Equivalent Couplant Viscosity Weight Motor Oil
5-100 [0.1 to 2.5]	SAE 10
50-200 [1.3 to 5.1]	SAE 20
100-400 [2.5 to 10.2]	SAE 30
250-700 [6.4 to 17.8]	SAE 40
Over 700 [18+]	Cup Grease

7.3 *Reference Standards*—The production item itself may be an adequate standard using the height of the back-wall echo for reference. For more quantitative information, charts such as (AVG-DGS) representing distance-amplitude relationships of known reflector sizes for a particular search unit, frequency and material may be used for standardization and evaluation of discontinuities.

7.3.1 *Reference Blocks*—Ultrasonic reference blocks, often called test blocks, are used to standardize the ultrasonic equipment and to evaluate the indications received from discontinuities within the part. The ultrasonic characteristics of the reference blocks such as attenuation, noise level, surface condition, and sound velocity, should be similar to the material to be examined. Standardization verifies that the instrument search unit is performing as required and establishes a detection level for discontinuities.

7.3.2 *Flat Blocks*—The three most commonly used sets of reference block are area-amplitude set, containing blocks with the same material path and various sizes of reference reflectors; distance-amplitude set, containing blocks with one size reference reflector at various material distances; and a combination including both area-amplitude and distance-amplitude blocks in one set. These sets are described in Practices E 127 and E 428.

7.3.3 *Curved Surfaces*—Reference blocks with flat surfaces may be used for establishing gain settings for examinations on concave test surfaces and convex surfaces with radii of curvature 4 in. [101.6 mm] or greater. For convex surfaces with radii of curvature less than 4 in. [101.6 mm] it is recommended that reference blocks with approximately the same nominal radius of curvature shall be used. Guide E 1158 illustrates typical curved entry surface blocks.

7.4 *Reference Reflectors*—Flat-bottomed holes, (FBH), or other artificial discontinuities, located directly in the material, in a representative sample of the part or material, or in reference blocks, should be used to reference echo amplitude or to perform distance-amplitude correction (DAC), or both. For most examinations, the bottom surface of a suitable flat-bottom hole is the common reference reflector. However, other types of artificial discontinuities (notches, side-drilled holes, areas of unbond or lack of fusion, etc.) may be used.

8. General Examination Requirements

8.1 *Material Condition*—Unless otherwise agreed upon, the surface finish of the article under examination shall not exceed 250 µin. [6.4 µm] rms and shall be free from waviness that may affect the examination. Ultrasonic examination should be performed in the simplest configuration possible and after all operations that may cause a discontinuity. Examinations of parts or material prior to machining is acceptable provided surface roughness and part geometry are within the tolerance specified in the written procedure. When it is determined that surface roughness or waviness, or both, precludes adequate detection and evaluation of subsurface discontinuities, smooth