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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 E1901; 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 E114 by providing more detailed procedures for the selection and standardization of the examination system and for evaluation of the indications obtained.

1.3 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.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E127 Practice for Fabrication and Control of Flat Bottomed Hole 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

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Standard:*[3]

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

2.3 *ANSI/ASNT Standard:*[3]

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

2.4 *Aerospace Industries Association Document:*[4]

NAS-410 NAS Certification and Qualification of Nondestructive Test Personnel

2.5 *ISO Standard:*[5]

ISO 9712 Non-destructive testing — Qualification and certification of NDT personnel

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, see Terminology E1316.

[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] 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.

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

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

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

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

4. Basis for Application

4.1 *Contractual Agreement*—The cognizant engineering organization and the suppliers should agree on the applicable procedural requirements listed in 4.1.1 through 4.1.12, 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 examination).

4.1.3 Surface finish requirements.

4.1.4 Search unit size, frequency and type.

4.1.5 Couplant,

4.1.6 Automated turning, fixturing or scanning, or both, as applicable.

4.1.7 Type of reference block standards including surface curvature.

4.1.8 Standardization details, including attenuation compensation and DAC techniques.

4.1.9 The surfaces to be examined and the scanning path.

4.1.10 Acceptance standards.

4.1.11 Personnel certification level.

4.1.12 Instrument characteristics.

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

4.3 *Personnel Qualifications*—If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, ISO 9712 or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used, and its applicable revision, should be identified in the contractual agreement between the using parties.

4.4 If specified in the contractual agreement, NDT agencies should be qualified and evaluated as described in Practice E543.

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 examinations, 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 should include the following:

7.1.1 *Electronic Equipment*—The electronic equipment should 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 should 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 E317. The equipment, including the search unit, should 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.

TABLE 1 Minimum Equipment Requirements (Longitudinal Wave)

Instrument Characteristics	Ultrasonic Test Frequency MHZ (Record)
Vertical limit, percent of full screen height	
Upper vertical linearity limit, percent of full screen height	
Lower vertical linearity limit, percent of full screen height	
Ultrasonic sensitivity, Reflector size, in. (mm)	
Entry surface resolution, in. (mm)	
Back surface resolution in. (mm)	
Horizontal limit, percent of full screen width	
Horizontal linearity range, in. (mm) or percent of full screen width	

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

7.1.3 *Search Units*—The contact search unit selected should be capable of transmitting and receiving ultrasound at the required frequencies and energy levels necessary for discontinuity detection in the material being examined. 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 should 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 unless the transducer is specially designed for "dry" coupling by the manufacturer. 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 should 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.

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 Distance Gain Size (DGS, also known as AVG in German translation), 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 Practice E127.

7.3.3 *Curved Surfaces*—Reference blocks with flat surfaces may be used for establishing gain settings for examinations on concave 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 should be used.

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

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

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 should not exceed 250 µin. (6.4 µm) rms and should 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 the areas in question by machining, grinding, or other means prior to the examination. During examination and evaluation ensure that entry surface free from loose scale, grinding particles, or other loose matter.

8.2 *Coverage*—In all examinations, perform scanning to locate discontinuities that are oriented parallel with the entry surface, or plane, or both, approximately normal to the major propagation direction that is parallel to the grain flow of the part.

8.3 *Resolution and Penetration*—When the complete standardization cannot be accomplished due to excessive noise levels (based on 3:1 signal-to-noise ratio) or material thicknesses, the examinations should be performed from opposite sides. Examinations conducted from opposite sides should provide for examination of a minimum of one-half material thickness and should provide for the resolution and penetration necessary to detect the minimum size reflector at the minimum and maximum metal path distance.

8.4 *Ultrasonic Frequency*—In general, the higher frequencies provide a more directive sound beam and provide better resolution throughout the material cross section. The lower frequencies provide better penetration and better detection of misaligned planar discontinuities. For a particular examination select the frequency based on the material, the anticipated type of discontinuities, and other specified examination requirements.

9. Standardization of Equipment

9.1 Prior to examination, standardize the system in accordance with the written procedure. Reference standard material travel distance is normally selected for the thickness to be examined, or in the case of large cross sections, half-thickness examinations from opposing entry surfaces may be more appropriate. Reference standards may be selected from the distance-amplitude sets listed in Practice E127.

9.2 Where there is a difference in acoustic attenuation between the reference block and the production item, an attenuation correction is required to compensate for the difference. The attenuation correction is accomplished by noting the difference between signals received from the back surfaces of the reference block and the production material having equal thickness, and correcting for this difference.

9.3 *Initial Standardization:*

9.3.1 Standardization using the production part as the reference standard. Examinations may be conducted using the production part as the reference standard. This technique generally applies to simple solid shapes with parallel or diametrically opposing surfaces. Using the gain control, the amplitude of the initial back echo reflection is established as a percent of full screen height, normally 80 %, and this setting is used to examine the part. This technique is suitable for the detection of planar discontinuities generally parallel to the entry surface and having a minimum extent equal to an appreciable fraction of the cross sectional area of the transducer beam.

9.3.1.1 For some materials, attenuation curves on overlays that fit over the display, and charts, such as (AVG/DGS) showing distance-amplitude relationships of known reflectors are available. These techniques utilize information derived theoretically or empirically and are specific to search unit size and frequency. The AVG-DGS system provides a summary of the anticipated behavior of small and large reflectors and can be used to analyze the reflecting area of discontinuities as compared to the back-echo reflection.

9.3.2 *Standardization*—Determine the distance amplitude relationship for the required set of distance-amplitude reference blocks by positioning the search unit over the reference block that provides the greatest amplitude response from the reference reflector. Adjust the instrument controls (for the instruments so equipped), that is: pulse length, pulse repetition rate, damping, frequency, and tuning to achieve the required resolution. The reject control should be in the off position. Maximize the indication from the reference block which provides the greatest amplitude response from the reference reflector by carefully positioning the transducer; adjust the gain control to set the amplitude response at 80 % of the upper vertical linearity limit. Without changing the instrument controls, maximize the amplitude of the reference reflector from each of the remaining reference blocks in the set and mark their amplitude and horizontal sweep positions on the display. Connect these points to form a curve. A typical distance amplitude curve is shown in Fig. 1.

NOTE 1—A common practice is to connect the adjacent amplitude points with straight lines. Normally, the curve is extrapolated to form a smooth curve or a straight line continuing at the same slope as the previous data points until meeting the base line.

9.3.2.1 *Distance/Amplitude Gate (DAG)*—If the instrumentation includes a flaw-gate alarm system in which the alarm threshold can be time-varied as a function of target depth, the gate can serve both as an alarm and means for distance-amplitude compensation. The alarm level is adjusted to correspond to the distance-amplitude curve established by the procedure in 9.3.2. The method used depends on the specific features provided and the related operational instructions. In a system which directly displays the alarm level on an alternate trace at the corresponding screen amplitude, then it is (only)