Designation: E 114 – 95 (Reapproved 2001)

Standard Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method[1]

This standard is issued under the fixed designation E 114; 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 standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice[2] covers ultrasonic examination of materials by the pulse-echo method using straight-beam longitudinal waves introduced by direct contact of the search unit with the material being examined.

1.2 This practice shall be applicable to development of an examination procedure agreed upon by the users of the document.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *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:*

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Examination Systems Without the Use of Electronic Measurement Instruments[3]

E 543 Practice for Agencies Performing Nondestructive Testing[3]

E 1316 Terminology for Nondestructive Examinations[3]

2.2 *ASNT Standards:*

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 *Other Documents:*

NAS-410 NAS Certification & Qualification of Nondestructive Test Personnel [5]

3. Terminology

3.1 Refer to Terminology E 1316 for definitions of terms used in this practice.

4. Basis of Application

4.1 *Purchaser-Supplier Agreements*:

The following items require agreement between the using parties for this practice to be used effectively:

4.1.1 *Qualification of Nondestructive Testing Agencies*—Agreement is required as to whether the nondestructive testing agency, as defined in Practice E 543 must be formally evaluated and qualified to perform the examination. If such evaluation and qualification is specified, a documented procedure such as Practice E 543 shall be used as the basis for evaluation.

4.1.2 *Personnel Qualification*—Nondestructive testing (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, NAS-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.

4.1.3 *Extent of Examination*—The extent of the examination shall be determined by agreement of the using parties.

4.1.4 *Time of Examination*—The time of examination shall be determined by agreement of the using parties.

4.1.5 *Interpretation Criteria*—The criteria by which the ultrasonic signals and part acceptability will be evaluated and shall be determined by agreement of the using parties.

5. Significance and Use

5.1 A series of electrical pulses is applied to a piezoelectric element (transducer) which converts these pulses to mechanical energy in the form of pulsed waves at a nominal frequency. This transducer is mounted in a holder so it can transmit the

[1] 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.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Practice SE-114 in Section II of that Code.

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

[4] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[5] Available from Aerospace Industries Association of America, 1250 Eye Street, N.W., Suite 1200, Washington, D.C. 20005-3924 .

waves into the material through a suitable wear surface and couplant. The assembly of transducer, holder, wearface, and electrical connnector comprise the search unit.

5.2 Pulsed energy is transmitted into materials, travels in a direction normal to the contacted surface, and is reflected back to the search unit by discontinuity or boundary interfaces which are parallel or near parallel to the contacted surface. These echoes return to the search unit, where they are converted from mechanical to electrical energy and are amplified by a receiver. The amplified echoes (signals) are usually presented in an A-scan display, such that the entire round trip of pulsed energy within the resolution of the system may be indicated along the horizontal base line of the display by vertical deflections corresponding to echo amplitudes from each interface, including those from intervening discontinuities. By adjustment of the sweep (range) controls, this display can be expanded or contracted to obtain a designated relation between the displayed signals and the material reflectors from which the signal originates. Thus a scaled distance to a discontinuity and its displayed signal becomes a true relationship. By comparison of the displayed discontinuity signal amplitudes to those from a reference standard, both location and estimated discontinuity size may be determined. Discontinuities having dimensions exceeding the size of the sound beam can also be estimated by determining the amount of movement of a search unit over the examination surface where a discontinuity signal is maintained.

NOTE 1—When determining the sizes of discontinuities by either of these two practices, only the area of the discontinuity which reflects energy to the search unit is determined.

5.3 Types of information that may be obtained from the pulsed-echo straight-beam practice are as follows:

5.3.1 Apparent discontinuity size (Note 2) by comparison of the signal amplitudes from the test piece to the amplitudes obtained from a reference standard.

5.3.2 Depth location of discontinuities by calibrating the horizontal scale of the A-scan display.

5.3.3 Material properties as indicated by the relative sound attenuation or velocity changes of compared items.

5.3.4 The extent of bond and unbond (or fusion and lack of fusion) between two ultrasonic conducting materials if geometry and materials permit.

NOTE 2—The term "apparent" is emphasized since true size depends on orientation, composition, and geometry of the discontinuity and equipment limitations.

6. Apparatus

6.1 Complete ultrasonic apparatus shall include the following:

6.1.1 *Instrumentation*—The ultrasonic instrument shall be capable of generating, receiving, and amplifying high-frequency electrical pulses at such frequencies and energy levels required to perform a meaningful examination and to provide a suitable readout.

6.1.2 *Search Units*—The ultrasonic search units shall be capable of transmitting and receiving ultrasound in the material at the required frequencies and energy levels necessary for discontinuity detection. Typical search unit sizes usually range from ⅛ in. (3.2 mm) in diameter to 1⅛ in. (28.6 mm) in diameter with both smaller and larger sizes available for specific applications. Search units may be fitted with special shoes for appropriate applications. Special search units encompassing both a transmitter and a receiver as separate piezoelectric elements can be utilized to provide some degree of improved resolution near the examination surface.

6.1.3 *Couplant*—A couplant, usually a liquid or semi-liquid, is required between the face of the search unit and the examination surface to permit or improve the transmittance of ultrasound from the search unit into the material under test. Typical couplants include water, cellulose gel, oil, and grease. Corrosion inhibitors or wetting agents or both may be used. Couplants must be selected that are not detrimental to the product or the process. The couplant used in 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 reducing the effective contact area or excess couplant thickness will reduce the amount of energy transferred between the search unit and the examination piece. These couplant variations in turn result in examination sensitivity variations.

6.1.3.1 The couplant should be selected so 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. The temperature of the material's surface can change the couplant's viscosity. As an example, in the case of oil and greases, see Table 1.

6.1.3.2 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 surface or auxiliary cooling of the search unit may be necessary to avoid temperature changes that affect the ultrasonic wave characteristics of the search unit. At higher temperatures, certain couplants based on inorganic salts or thermoplastic organic materials, high-temperature delay materials, and search units that are not damaged by high temperatures may be required.

6.1.3.3 Where constant coupling over large areas is needed, as in automated examination, or where severe changes in surface roughness are found, other couplants 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 0.2 in. (0.5 mm) filled with

TABLE 1 Suggested Viscosities—Oil Couplants

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

Approximate Surface Roughness Average (Ra), μin. (μm)	Equivalent Couplant Viscosity, Weight Motor Oil
5–100 (0.1–2.5)	SAE 10
50–200 (1.3–5.1)	SAE 20
100–400 (2.5–10.2)	SAE 30
250–700 (6.4–17.8)	SAE 40
Over 700 (18–)	cup grease

couplant. Liquid flowing through the search unit 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 hot.

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

6.1.4 *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, machined artificial reflectors (discontinuities) or charts representing distance-amplitude relationships of known reflector sizes for a particular search unit and material may be used for standardization. These artificial reflectors may be in the form of flat-bottom holes, side-drilled holes, or slots. An alternate method of fabricating a reference standard may be the introduction of known discontinuities during the fabrication process of a production item or other convenient configuration. The surface finish of the reference standard should be similar to the surface finish of the production item (or corrected; see 7.3). The reference standard material and the production material should be acoustically similar (in velocity and attenuation). The reference standard selected shall be used by the examiner as the basis for signal comparisons.

7. Standardization of Apparatus

7.1 If quantitative information is to be obtained, vertical or horizontal linearity or both should be checked in accordance with Practice E 317 or another procedure approved by the users of the document. An acceptable linearity performance may be agreed upon by the users of the document.

7.2 Prior to examination, standardize the system in accordance with the product specification.

7.3 Where the surface finishes of the reference standard and the production item do not match, or where there is an acoustic difference between the standard and the production item, an attenuation correction should be made to compensate for the difference. The attenuation correction is accomplished by noting the difference between signals received from the same reference reflector (that is, back reflection) in the basic standardization (reference) block and in the production material, and correcting for this difference.

7.4 It should be recognized that near-field effects may cause sensitivity inconsistencies when searching for inhomogeneities smaller than the effective beam diameter. Suitable delay line search units or other means such as examining from both sides of the item may be considered where the application warrants fine scrutiny. When performing examinations in the far-field, it is recommended that compensation be made for the acoustic attenuation of the test material with respect to a certain reference standard. This compensation may be accomplished with multiple depth reference reflectors, electronically, with attenuation curves drawn on the face of the A-scan display, or with charts for distance-amplitude relationships of known reflectors. For optimum examination performance, compensations should be made for both near and far-field effects.

7.5 Unless otherwise specified, the initial pulse and at least one back reflection shall appear on the A-scan display while examining for discontinuities in materials having parallel surfaces. The total number of back reflections depends upon equipment, geometry and material type, information desired, or operator preference. Reduction of the back reflection during scanning is indicative of increased attenuation or sound scattering discontinuities provided that front and back surface roughness and parallelism of the production piece are approximately the same as that of the standard. For non-parallel surfaces, the time trace of the display shall be standardized by using standards that include the maximum thickness of the production item being examined.

7.6 For bond/unbond (fusion/lack of fusion) examinations, a reference standard should be used similar to the production item being examined containing areas representing both bonded (fused) and unbonded (lack of fusion) conditions, if geometry and material permit.

7.7 Standardization with respect to reference standards should be periodically checked to ensure that the ultrasonic system standardization is not changing. As a minimum, the standardization shall be checked each time there is a change of operators, when search units are changed, when new batteries are installed, when equipment operating from one power source is changed to another power source, or when improper operation is suspected.

8. Procedure

8.1 When ultrasonic examinations are performed for the detection or sizing of discontinuities, or both, reflectors not perpendicular to the ultrasonic beam may be detected at reduced amplitudes, with a distorted envelope depending upon the reflector area, whether it is curved or planar, whether it is smooth or rough, perhaps with reflecting facets. Reflector characteristics may also cause rapid shifts in apparent depth as the search unit approaches or moves away from the low amplitude indication. Another effect of these reflectors is the loss of back reflection which occurs when the discontinuity lies directly between the search unit and the back surface. Reflectors detectable due to any of the foregoing phenomena cannot be sized solely on signal amplitude but require special corrections for search unit and flaw characteristics.

8.2 *Examination Surface*—Surfaces shall be uniform and free of loose scale and paint, discontinuities such as pits or gouges, weld splatter, dirt, or other foreign matter which affect examination results. Tightly adhering paint, scale, or coatings do not necessarily need to be removed for examining if they present uniform attenuation characteristics. The examination surface must be adequate to permit ultrasonic examination at the sensitivity specified. If needed, surfaces may be ground, sanded, wire brushed, scraped, or otherwise prepared for examining purposes. Curved surfaces, either concave or convex, may be examined; however, the standardization system should compensate for the effective change in search unit transmitting area between the reference standard and production item. If practical, the reference standard should have the same geometry as the item being examined.

8.3 *Search Unit*—Select a suitable search unit size and frequency after consideration of the acoustic characteristics of material to be examined, the geometry of the production item, and the minimum size and type of discontinuity to be detected. The higher the frequency selected, the higher the resolving capability accompanied with a decrease in penetrating power; conversely, the lower the frequency used, the greater the penetrating power with decreasing resolving capability. Factors limiting the use of higher frequencies are the equipment and the material properties. The limiting use of lower frequencies is the loss in sensitivity level for the examination. Various types of straight-beam search units are available offering advantages for specific applications. The above statements should be considered when choosing the search unit size, type, and frequency. When delay materials are used in the search unit, the standardization and examination surface temperatures should be within 25°F (14°C) to avoid large attenuation and velocity differences.

NOTE 3—The largest diameter and highest frequency search units yielding desired results should be used for maximum resolution and good beam directivity.

8.4 *Scanning*—Scanning may be either continuous or intermittent, depending upon the geometry, application, and requirements of the part being examined. For continuous scanning, the search unit indexing must be adequate to provide 100 % coverage, at uniform examination sensitivity, of the area being examined. Adjust scanning speed or instrument repetition rate or both to permit detection of the smallest discontinuities referenced in the specification and to allow the recording or signaling device to function.

8.4.1 *Manual Scanning*—Hold the search unit in the hand and move over the surface of the production piece.

8.4.2 *Automated Scanning*—The search unit is held by a suitable fixed device and either the production piece moves or is held stationary while the search unit moves mechanically along some predetermined path. For automated scanning, monitor coupling between the search unit and part either electronically or visually to ensure proper examination sensitivity.

8.5 During the evaluation of indications, maintain the same relative sensitivities between the reference standard and the production item. Make an evaluation of ultrasonic indications after response reflections from discontinuities are maximized by search unit manipulation. Map discontinuity extremities larger than the sound beam. A recommended method for mapping, on the surface of the production piece, the apparent size (that is, the reflecting surface seen by the search unit) of discontinuities larger than the search unit is by the half-amplitude method. Position the search unit over the discontinuity for maximum signal response and move in one direction until the signal drops rapidly to the base line on the A-scan display. Then return the search unit to the position where the signal was half the amplitude that it had at the point where the indication began to drop rapidly to the base line. At this point the center of the search unit should approximately coincide with the edge of the discontinuity. Repeat this procedure for other directions as necessary to outline the discontinuity on the surface. Search units of other frequencies and sizes may be used for mapping to obtain greater accuracy. Special consideration should be given to discontinuities when the signal amplitude drops to half the maximum amplitude or less, and remains at the lower level over extended distances (for example, more than half the search unit diameter).

NOTE 4—For rounded surfaces, geometry must be considered when using this method.

9. Examination Data Record

9.1 The following data should be recorded as a minimum for future reference at the time of each examination:

9.1.1 Part number identification,

9.1.2 Operator's name and level (if certified),

9.1.3 Instrument description, make, model, and serial number,

9.1.4 Setup—Couplant, cable type and length, manual/automatic scanning,

9.1.5 Search unit description—Type, size, frequency, special shoes,

9.1.6 Reference standards (and standardization data required to duplicate the examination).

9.1.7 Indication information as specified by the applicable specification, or results of the examination (number, classification, and location of discontinuities). For bond/unbond (fusion/lack of fusion) examinations the extent of unbond (lack of fusion) or bond (fusion) should be reported.

10. Interpretation of Results

10.1 Advance agreement should be reached by users of this document as applicable regarding the interpretation of the results of the examinations and how they shall be recorded. All discontinuities having signals that exceed the rejection level as defined by the material specification, drawing, or purchase order shall be rejected unless it is determined from the machine part drawing that the rejectable discontinuities will not remain in the finished part.

11. Report

11.1 The report shall include the information agreed upon by users of this document.

12. Keywords

12.1 contact; examination; nondestructive testing; pulse-echo; straight-beam; ultrasonic