Designation: E494 − 20

Standard Practice for Measuring Ultrasonic Velocity in Materials by Comparative Pulse-Echo Method[1]

This standard is issued under the fixed designation E494; 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 U.S. Department of Defense.

1. Scope*

1.1 This practice covers a test procedure for measuring ultrasonic velocities in materials with conventional ultrasonic pulse echo flaw detection equipment in which results are displayed in an A-scan display. This practice describes a method whereby unknown ultrasonic velocities in a material sample are determined by comparative measurements using a reference material whose ultrasonic velocities are accurately known.

1.2 This procedure is intended for solid materials 5 mm (0.2 in.) thick or greater. The surfaces normal to the direction of energy propagation shall be parallel to at least ±3°. Surface finish for velocity measurements shall be 3.2 µm (125 µin.) root-mean-square (rms) or smoother.

NOTE 1—Sound wave velocities are cited in this practice using the fundamental units of meters per second, with inches per second supplied for reference in many cases. For some calculations, it is convenient to think of velocities in units of millimeters per microsecond. While these units work nicely in the calculations, the more natural units were chosen for use in the tables in this practice. The values can be simply converted from m/s to mm/µs by moving the decimal point three places to the left, that is, 3500 m/s becomes 3.5 mm/µs.

1.3 Ultrasonic velocity measurements are useful for determining several important material properties. Young's modulus of elasticity, Poisson's ratio, acoustic impedance, and several other useful properties and coefficients can be calculated for solid materials with the ultrasonic velocities if the density is known (see Appendix X1).

1.4 More accurate results than those obtained using this method can be obtained with more specialized ultrasonic equipment, auxiliary equipment, and specialized techniques. Some of the supplemental techniques are described in Appendix X2. (Material contained in Appendix X2 is for informational purposes only.)

NOTE 2—Factors including techniques, equipment, types of material, and operator variables will result in variations in absolute velocity readings, sometimes by as much as ±5 %. Relative results with a single combination of the above factors can be expected to be much more accurate (probably within a 1 % tolerance).

1.5 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

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

1.7 *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]

C597 Test Method for Pulse Velocity Through Concrete

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

E797 Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Documents:*[3]

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

[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.

Current edition approved Dec. 1, 2020. Published January 2021. Originally approved in 1973. Last previous edition approved in 2015 as E494 – 15. DOI: 10.1520/E0494-20.

[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 Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

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

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

2.3 *AIA Document:*[4]

NAS-410 Certification and Qualification of Nondestructive Testing Personnel

2.4 *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 practice, see Terminology E1316.

4. Summary of Practice

4.1 Several possible wave modes can propagate in solids. This procedure is concerned with two velocities of propagation, namely those associated with longitudinal (v_l) and transverse (v_t) waves. The longitudinal velocity is independent of sample geometry when the dimensions at right angles to the beam are very large compared with beam width and wave length. The transverse velocity is little affected by physical dimensions of the sample. The procedure described in Section 8 is, as noted in the Scope, for use with conventional pulse echo flaw detection equipment only.

5. Significance and Use

5.1 This practice describes a test procedure for the application of conventional ultrasonic methods to determine unknown ultrasonic velocities in a material sample by comparative measurements using a reference material whose ultrasonic velocities are accurately known.

5.2 Although not all methods described in this practice are applied equally or universally to all velocity measurements in different materials, it does provide flexibility and a basis for establishing contractual criteria between users, and may be used as a general guideline for preparing a detailed procedure or specification for a particular application.

5.3 This practice is directed towards the determination of longitudinal and shear wave velocities using the appropriate sound wave form. This practice also outlines methods to determine elastic modulus and can be applied in both contact and immersion mode.

6. Basis of Application

6.1 The following items are subject to contractual agreement between the parties using or referencing this practice:

6.2 *Personnel Qualification*—If specified in the contractual agreement, personnel performing to this practice shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ASNI/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 shall be identified in the contractual agreement between the using parties.

6.3 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

6.4 *Reporting Criteria*—Reporting criteria for the examination results shall be in accordance with 9.1 unless otherwise specified.

7. Apparatus

7.1 The ultrasonic testing system to be used in this practice shall include the following:

7.1.1 *Test Instrument*—Any ultrasonic instrument comprising a time base, transmitter (pulser), receiver (echo amplifier), and an A-scan indicator circuit to generate, receive, and display electrical signals related to ultrasonic waves. Equipment shall allow reading the on-screen positions of A_k and $A_{l/s}$ (defined in 8.1.4), along the A-scan base line within ±0.5 mm (0.020 in.). For maximum accuracy, the highest possible frequency that will present at least two easily distinguishable back wall reflections, and preferably five, in both materials shall be used.

7.1.2 *Search Unit*—The search unit shall generate and receive ultrasonic waves of an appropriate size, type, and frequency, designed for tests by the contact method. Contact straight beam longitudinal mode shall be used for longitudinal velocity measurements, and contact straight beam shear mode for transverse velocity measurements.

7.1.3 *Couplant*—For longitudinal velocity measurements, the couplant should be the material used in practice, for example, clean light-grade oil. For transverse velocity measurements, a high viscosity material such as resin or solid bond should be used. In some materials isopolybutene, honey, or other high-viscosity materials have been used effectively. Most liquids will not support transverse waves. In porous materials special nonliquid couplants are required. The couplant must not be deleterious to the material.

7.1.4 *Standard Reference Blocks:*

7.1.4.1 *Velocity Standard*—Any material of known velocity, that can be penetrated by the acoustical wave, and that has an appropriate surface roughness, shape, thickness, and parallelism. The velocity of the standard should be determined by some other technique of higher accuracy, or by comparison with water velocity that is known (see Appendix X2.5 and Appendix X4). The reference block should have an attenuation similar to that of the test material.

7.1.4.2 For horizontal linearity check, see Practice E317.

8. Procedure

8.1 *Wave Velocity*—Determine bulk, longitudinal or shear wave velocity ($v_{l/s}$) by comparing the transit time of the wave mode in the unknown material to the transit time of the same mode in a known velocity standard (v_k).

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1250 Eye St., NW, Washington, DC 20005.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

8.1.1 Select samples of unknown and known materials with flat parallel surfaces and measure the thickness of each to an accuracy of ±0.02 mm (0.001 in.) or 0.1 %, whichever is greater.

8.1.2 Align the search unit over each sample and obtain a nominal signal pattern (see Fig. 1) of as many back wall echoes as are clearly defined. The time base (sweep control) must be set the same for both measurements.

8.1.3 Using a scale or caliper, measure the distance at the base line between the leading edge of the first back wall echo and the leading edge of the last back echo that is clearly defined on the known and unknown samples. For better accuracy, adjust the amplitude of the last back echo by means of the gain control to approximately the same height as the first back echo, after the position of the leading edge of the first back echo has been fixed. This allows more accurate time or distance measurements. The position of the leading edge of the last back echo is then determined. The signal has traversed a distance twice the thickness of the specimen between each back echo. The signal traversing the specimen and returning is called a round trip. In Fig. 1, the signal has made six round trips between Echo 1 and Echo 7. Count the number of round trips from first echo used to the last echo measured on both samples. This number will be one less than the number of echoes used. Note that the sample thickness, number of round trips, and distance from front to last back echo measured need not be the same between the measurements in the unknown and known materials.

8.1.4 Calculate the value of the unknown velocity as follows:

$$v_u = \frac{(A_k \quad n_u \quad t_u \quad v_k)}{(A_u \quad n_k \quad t_k)} \tag{1}$$

where:

A_k = distance from first to Nth back echo on the known material, m (in.), measured along the baseline of the A-scan display,
n_k = number of round trips, known material,
t_k = thickness of known material, m (in.),
v_k = velocity in known material, m/s (in./s),
A_u = distance from the first to the Nth back echo on the unknown material, m (in.), measured along the baseline of the A-scan display,
n_u = number of round trips, unknown material, and
t_u = thickness, unknown material, m (in.).

NOTE 3—The units used in measurement are not significant as long as the system is consistent.

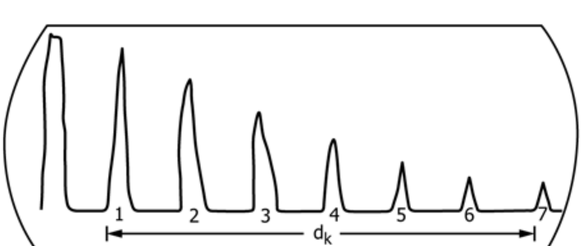

FIG. 1 Initial Pulse and 7 Back Echoes

9. Report

9.1 The following are data which should be included in a report on velocity measurements:

9.1.1 *Longitudinal Wave:*
9.1.1.1 A_k = __________m (in.)
9.1.1.2 n_k = __________
9.1.1.3 t_k = __________m (in.)
9.1.1.4 v_k = __________m/s (in./s)
9.1.1.5 A_u = __________m (in.)
9.1.1.6 n_u = __________
9.1.1.7 t_u = __________m (in.)
9.1.1.8 v_l(using Eq 1) = ___m/s (in./s)

9.1.2 *Transverse Wave:*
9.1.2.1 A_k = __________m (in.)
9.1.2.2 n_k = __________
9.1.2.3 t_k = __________m (in.)
9.1.2.4 v_k = __________m/s (in./s)
9.1.2.5 A_u = __________m (in.)
9.1.2.6 n_u = __________
9.1.2.7 t_u = __________m (in.)
9.1.2.8 v_s (using Eq 1) = ___m/s (in./s)
9.1.2.9 Displacement orientation = __________°

9.1.3 Timebase (sweep control)
9.1.4 Horizontal linearity
9.1.5 Test frequency
9.1.6 Couplant
9.1.7 *Search unit:*
9.1.7.1 Frequency
9.1.7.2 Size
9.1.7.3 Shape
9.1.7.4 Type
9.1.7.5 Serial number
9.1.8 Sample geometry
9.1.9 *Instrument:*
9.1.9.1 Name
9.1.9.2 Model number
9.1.9.3 Serial number
9.1.9.4 Pertinent control settings

10. Technical Hazards

10.1 *Material Properties*—Both the known and unknown samples should be homogeneous, isotropic materials. Measurements should be taken at multiple locations in multiple orientations to ensure consistency. Best results are obtained from samples that are low textured and fine grained.

10.1.1 *Processed Materials*—Rolled or otherwise processed materials may have texture and residual stresses that may limit the accuracy of this method.

10.1.2 *Composite Materials*—Fibrous composite materials should never be considered isotropic. This method may still be useful if both the known and unknown samples have the exact same lay-up. The fiber orientation will not affect the through-thickness longitudinal velocity, but it will affect the shear velocity. Therefore, the displacement of the propagating shear wave should be noted.

10.2 *Shear Measurements*—Shear measurements should generally be performed using a normal incidence shear-wave search unit.