Designation:E 797–95 (Reapproved 2001) Designation: E797 – 05

Standard Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method[1]

This standard is issued under the fixed designation E797; 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 practice[2] provides guidelines for measuring the thickness of materials using the contact pulse-echo method at temperatures not to exceed 200°F (93°C). [93°C].

1.2 This practice is applicable to any material in which ultrasonic waves will propagate at a constant velocity throughout the part, and from which back reflections can be obtained and resolved.

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

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:*[3]

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Examination Testing Instruments and Systems Withoutwithout the Use of Electronic Measurement Instruments

E494 Practice for Measuring Ultrasonic Velocity in Materials

E1316 Terminology for Nondestructive Examinations

2.2 *ASNT Document:*

Nondestructive Testing Handbook, 2nd Edition, Vol 7[4]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, refer to Terminology E 1316E1316.

4. Summary of Practice

4.1 Thickness (*T*), when measured by the pulse-echo ultrasonic method, is a product of the velocity of sound in the material and one half the transit time (round trip) through the material.

$$T = Vt2$$

where:
- *T* = thickness,
- *V* = velocity, and
- *t* = transit time.

4.2 The pulse-echo ultrasonic instrument measures the transit time of the ultrasonic pulse through the part.

4.3 The velocity in the material being examined is a function of the physical properties of the material. It is usually assumed to be a constant for a given class of materials. Its approximate value can be obtained from Table X3.1 in Practice E 494E494 or from the *Nondestructive Testing Handbook*, or it can be determined empirically.

[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 Testing Procedure.

Current edition approved Dec. 10, 1995. Published February 1996. Originally published as E 797–81. Last previous edition E 797–94.

Current edition approved Dec. 1, 2005. Published December 2005. Originally approved in 1981. Last previous edition approved in 2001 as E797 - 95(2001). DOI: 10.1520/E0797-05.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Practice SE-797 in Section II of that Code.

[3] 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* , Vol 03.03.volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from the American Society for Nondestructive Testing, 1711 Arlingate Plaza, Columbus, OH 43228.

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

4.4 One or more reference blocks are required having known velocity, or of the same material to be examined, and having thicknesses accurately measured and in the range of thicknesses to be measured. It is generally desirable that the thicknesses be “round numbers” rather than miscellaneous odd values. One block should have a thickness value near the maximum of the range of interest and another block near the minimum thickness.

4.5 The display element ~~(CRT (cathode ray tube),~~(A-scan display, meter, or digital display) of the instrument must be adjusted to present convenient values of thickness dependent on the range being used. The control for this function may have different names on different instruments, including *range, sweep, material standardize*, or *velocity*.

4.6 The timing circuits in different instruments use various conversion schemes. A common method is the so-called time/analog conversion in which the time measured by the instrument is converted into a proportional d-c voltage which is then applied to the readout device. Another technique uses a very high-frequency oscillator that is modulated or gated by the appropriate echo indications, the output being used either directly to suitable digital readouts or converted to a voltage for other presentation. A relationship of transit time versus thickness is shown graphically in Fig. 1.

5. Significance and Use

5.1 The techniques described provide indirect measurement of thickness of sections of materials not exceeding temperatures of 200°F ~~(93°C).~~[93°C]. Measurements are made from one side of the object, without requiring access to the rear surface.

5.2 Ultrasonic thickness measurements are used extensively on basic shapes and products of many materials, on precision machined parts, and to determine wall thinning in process equipment caused by corrosion and erosion.

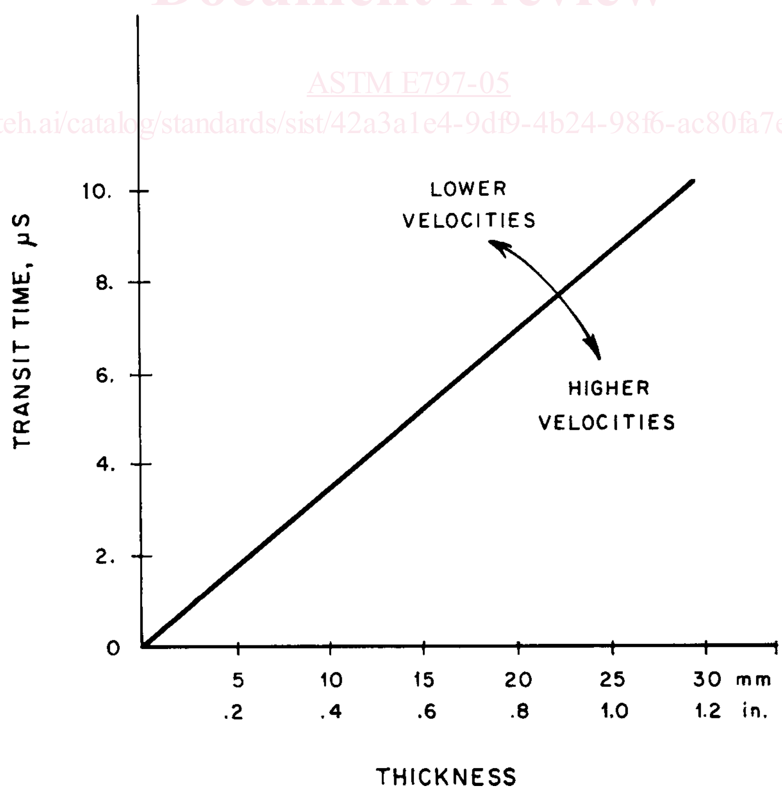
5.3 Recommendations for determining the capabilities and limitations of ultrasonic thickness gages for specific applications can be found in the cited references.[5,6]

6. Apparatus

6.1 *Instruments*—Thickness-measurement instruments are divided into three groups: (*1*~~) Flaw detectors with CRT readout, (~~*) Flaw detectors with an A-scan display readout, (2) Flaw detectors with ~~CRT~~an A-scan display and direct thickness readout, and (3) Direct thickness readout.*

[5] Bosselaar, H., and Goosens, J.C.J., “Method to Evaluate Direct-Reading Ultrasonic Pulse-Echo Thickness Meters,” *Materials Evaluation,* March 1971, pp. 45–50.

[6] Fowler, K.A., Elfbaum, G.M., Husarek, V., and Castel, J., “Applications of Precision Ultrasonic Thickness Gaging,” *Proceedings of the Eighth World Conference on Nondestructive Testing,* Cannes, France, Sept. 6–11, 1976, Paper 3F.5.



NOTE 1—Slope of velocity conversion line is approximately that of steel.

FIG. 1 Transit Time/Thickness Relationship

6.1.1 Flaw detectors with ~~CRT~~ A-scan display readouts display time/amplitude ~~information in an A-scan presentation.~~ information. Thickness determinations are made by reading the distance between the zero-corrected initial pulse and first-returned echo (back reflection), or between multiple-back reflection echoes, on a standardized base line of ~~a CRT.~~ the A-scan display. The base line of the ~~CRT~~ A-scan display should be adjusted for the desired thickness increments.

6.1.2 Flaw detectors with numeric readout are a combination pulse ultrasound flaw detection instrument with ~~a CRT~~ an A-scan display and additional circuitry that provides digital thickness information. The material thickness can be electronically measured and presented on a digital readout. The ~~CRT~~A-scan display provides a check on the validity of the electronic measurement by revealing measurement variables, such as internal discontinuities, or echo-strength variations, which might result in inaccurate readings.

6.1.3 Thickness readout instruments are modified versions of the pulse-echo instrument. The elapsed time between the initial pulse and the first echo or between multiple echoes is converted into a meter or digital readout. The instruments are designed for measurement and direct numerical readout of specific ranges of thickness and materials.

6.2 *Search Units*—Most pulse-echo type search units (straight-beam contact, delay line, and dual element) are applicable if flaw detector instruments are used. If a thickness readout instrument has the capability to read thin sections, a highly damped, high-frequency search unit is generally used. High-frequency (10 MHz or higher) delay line search units are generally required for thicknesses less than about 0.6 mm ~~(0.025 in.).~~[0.025 in.]. Measurements of materials at high temperatures require search units specially designed for the application. When dual element search units are used, their inherent nonlinearity usually requires special corrections for thin sections. (See Fig. 2.) For optimum performance, it is often necessary that the instrument and search units be matched.

6.3 *Standardization Blocks*—The general requirements for appropriate standardization blocks are given in 4.4, 7.1.3, 7.2.2.1, 7.3.2, and 7.4.3. Multi-step blocks that may be useful for these standardization procedures are described in Appendix X1 (Figs. X1.1 and X1.2).

7. Standardization of Apparatus

7.1 *Case I—Direct Contact, Single-Element Search Unit*:

7.1.1 *Conditions*—The display start is synchronized to the initial pulse. All display elements are linear. Full thickness is displayed on ~~CRT.~~ the A-scan display.

7.1.2 Under these conditions, we can assume that the velocity conversion line effectively pivots about the origin (Fig. 1). It may be necessary to subtract the wear-plate time, requiring minor use of delay control. It is recommended that standardization blocks providing a minimum of two thicknesses that span the thickness range be used to check the full-range accuracy.

7.1.3 Place the search unit on a standardization block of known thickness with suitable couplant and adjust the instrument controls (material standardization, range, sweep, or velocity) until the display presents the appropriate thickness reading.

7.1.4 The readings should then be checked and adjusted on standardization blocks with thickness of lesser value to improve the overall accuracy of the system.

7.2 *Case II—Delay Line Single-Element Search Unit*:

7.2.1 *Conditions*—When using this search unit, it is necessary that the equipment be capable of correcting for the time during which the sound passes through the delay line so that the end of the delay can be made to coincide with zero thickness. This requires a so-called "delay" control in the instrument or automatic electronic sensing of zero thickness.

7.2.2 In most instruments, if the material standardize circuit was previously adjusted for a given material velocity, the delay control should be adjusted until a correct thickness reading is obtained on the instrument. However, if the instrument must be completely standardized with the delay line search unit, the following technique is recommended:

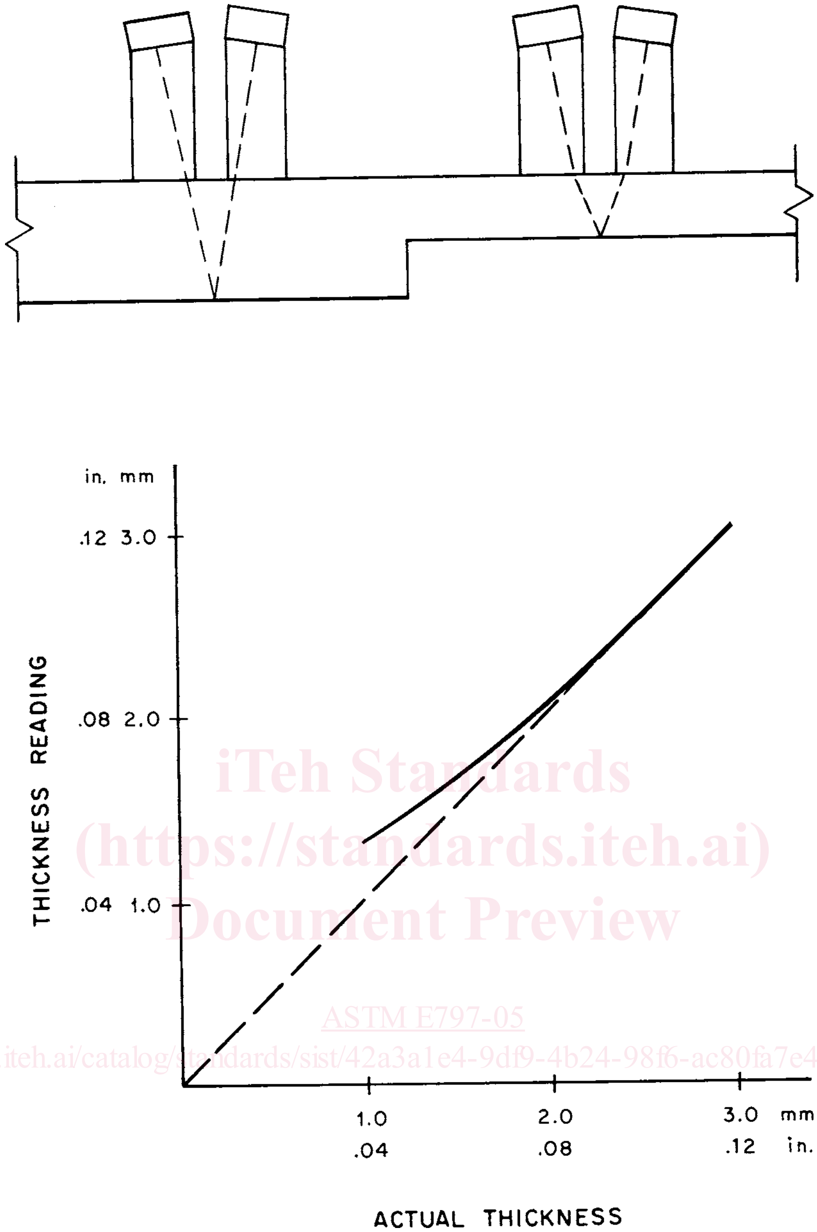
7.2.2.1 Use at least two standardization blocks. One should have a thickness near the maximum of the range to be measured and the other block near the minimum thickness. For convenience, it is desirable that the thickness should be "round numbers" so that the difference between them also has a convenient "round number" value.

7.2.2.2 Place the search unit sequentially on one and then the other block, and obtain both readings. The difference between these two readings should be calculated. If the reading thickness difference is less than the actual thickness difference, place the search unit on the thicker specimen, and adjust the material standardize control to expand the thickness range. If the reading thickness difference is greater than the actual thickness difference, place the search unit on the thicker specimen, and adjust the material standardize control to decrease the thickness range. A certain amount of over correction is usually recommended. Reposition the search unit sequentially on both blocks, and note the reading differences while making additional appropriate corrections. When the reading thickness differential equals the actual thickness differential, the material thickness range is correctly adjusted. A single adjustment of the delay control should then permit correct readings at both the high and low end of the thickness range.

7.2.3 An alternative technique for delay line search units is a variation of that described in 7.2.2. A series of sequential adjustments are made, using the "delay" control to provide correct readings on the thinner standardization block and the "range" control to correct the readings on the thicker block. Moderate over-correction is sometimes useful. When both readings are "correct" the instrument is adjusted properly.

7.3 *Case III—Dual Search Units*:

7.3.1 The method described in 7.2 (Case II) is also suitable for equipment using dual search units in the thicker ranges, above



(*a*) Proportional sound path increases with decrease in thickness.

(*b*) Typical reading error values

FIG. 2 Dual Transducer Nonlinearity

3 mm ~~(0.125 in.).~~[0.125 in.]. However, below those values there is an inherent error due to the Vee path that the sound beam travels. The transit time is no longer linearly proportional to thickness, and the condition deteriorates toward the low thickness end of the range. The variation is also shown schematically in Fig. 2(*a*). Typical error values are shown in Fig. 2(*b*).

7.3.2 If measurements are to be made over a very limited range near the thin end of the scale, it is possible to standardize the instrument with the technique in Case II using appropriate thin standardization blocks. This will produce a correction curve that is approximately correct over that limited range. Note that it will be substantially in error at thicker measurements.

7.3.3 If a wide range of thicknesses is to be measured, it may be more suitable to standardize as in Case II using standardization blocks at the high end of the range and perhaps halfway toward the low end. Following this, empirical corrections can be established for the very thin end of the range.

7.3.4 For a direct-reading panel-type meter display, it is convenient to build these corrections into the display as a nonlinear function.

7.4 *Case IV—Thick Sections*:

7.4.1 *Conditions*—For use when a high degree of accuracy is required for thick sections.

7.4.2 Direct contact search unit and initial pulse synchronization are used. The display start is delayed as described in 7.4.4. All