Designation: E 664 – 93 (Reapproved 2000)

Standard Practice for the Measurement of the Apparent Attenuation of Longitudinal Ultrasonic Waves by Immersion Method[1]

This standard is issued under the fixed designation E 664; 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 describes a procedure for measuring the apparent attenuation of ultrasound in materials or components with flat, parallel surfaces using conventional pulse-echo ultrasonic flaw detection equipment in which reflected indications are displayed in an A-scan presentation.

1.2 The measurement procedure is readily adaptable for the determination of relative attenuation between materials. For absolute (true) attenuation measurements, indicative of the intrinsic nature of the material, it is necessary to correct for specimen geometry, sound beam divergence, instrumentation, and procedural effects. These results can be obtained with more specialized ultrasonic equipment and techniques.

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 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves[2]

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

E 1316 Terminology for Nondestructive Examinations[2]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, see Terminology E 1316.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent attenuation*—the *observed* ultrasound energy loss. In addition to the true loss, the apparent attenuation may also include losses attributable to instrumentation, specimen configuration, beam divergence, interface reflections, and measurement procedure.

3.2.2 *attenuation*—a factor that describes the decrease in ultrasound intensity with distance. Normally expressed in decibels per unit length.

NOTE 1—The attenuation parameter is sometimes expressed in nepers (Np) per unit length. The value in decibels (dB) is 8.68 times the value in nepers. If the loss over a path is 1 Np, then the amplitude has fallen to 1/e of its initial value (e = 2.7183. . .).

3.2.3 *decibel (dB)*—twenty times the logarithmic expression of the ratio of two amplitudes.

$$dB = 20 \log_{10} (\text{amplitude ratio})$$

3.2.4 *true attenuation*—that portion of the observed ultrasound energy loss which is intrinsic to the medium through which the ultrasound propagates. True attenuation losses may be attributed to the basic mechanisms of absorption and scattering.

4. Summary of Practice

4.1 This practice describes a procedure for determining apparent attenuation by measuring the decay of multiple back reflections of longitudinal ultrasonic waves introduced into specimens with flat, parallel surfaces by the immersion technique.

5. Significance and Use

5.1 The measurement of apparent attenuation in materials is useful in applications such as the comparison of heat treatments of different lots of material or the assessment of the degradation of materials due to environment.

5.2 Several different modes of wave vibration can be propagated in solids. This practice is concerned with the attenuation associated with longitudinal waves introduced into the specimen by the immersion method.

5.3 This practice allows for the comparison of the apparent attenuations of geometrically similar specimens.

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[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing, and is the direct responsibility of Subcommittee E 07.06 on Ultrasonic Method.

Current edition approved Sept. 15, 1993. Published November 1993. Originally published as E 664 – 78. Last previous edition E 664 – 78 (1989)ε [1].

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

5.4 For the determination of apparent attenuation, the procedures described herein are valid only for measurements in the far field of the ultrasonic beam.

6. Apparatus

6.1 *Ultrasonic Flaw Detection System*— A system capable of generating, receiving, and displaying electrical pulses at the frequency of interest. Display shall be an A-scan presentation.

6.1.1 *Performance Characteristics*—The vertical linearity limits shall be determined as specified in Practice E 317. All measurements shall be made only within the linear ranges of the system.

6.2 *Search Unit*—The size and frequency should be determined to suit the application, and only non-focused search units may be used.

6.3 *Couplant*—Normally water. See Practice E 214 for alternatives.

6.4 *Reference Block*—The use of a reference block is suggested to evaluate the stability of the measurement system if measurements will be made over a period of time. The reference block should have acoustic properties similar to those of the examined material in the frequency range of interest.

7. Specimen

7.1 *Geometric Similarity*—When comparing the apparent attenuations of two or more materials or components, the specimens used must be geometrically similar. They must be flat and parallel within 0.008 in. (0.20 mm)/in. (25.4 mm) of diameter or cross section and differ in thickness by no more than a factor of 2. The cross section of each specimen must meet the requirements of 7.2.

7.2 *Minimum Dimensions*—The thickness of the specimen (parallel to the ultrasonic beam) shall be of a dimension so that at least two back surface reflections can be resolved at the frequency of interest. The dimensions normal to the ultrasonic beam shall be much greater than the beam width and wavelength (at least three times the transducer dimension) so that side wall echoes do not interfere with the measurements.

NOTE 2—For the determination of true attenuation, careful consideration must be made of parameters such as front surface and back surface parallelism, surface finish, etc. However, useful apparent attenuation information can be obtained if the requirements of 7.1 and 7.2 are satisfied.

8. Procedure

8.1 Measure the thickness of the specimen to an accuracy of ±0.001 in. (±0.03 mm) or ±0.1 %, whichever is greater.

8.2 Place the sample in a suitable immersion tank.

8.3 Place the search unit in a fixture suitable for manipulating the sound entry angle and lateral position. Position the search unit over the sample, and angulate the beam to obtain the maximum number of back reflections. See Fig. 1. The water path should be such that the entry surface is in the far field of the ultrasonic beam.

NOTE 3—If the frequency and diameter of the transducers available do not readily permit the top surface of sample to be in the far field, this method may be used provided the back reflections measured and recorded are in the far field of the sound beam.

8.3.1 With the reject level set at zero, measure and record the amplitudes of any two back reflections that show decreasing amplitude with increase in back reflection number.

NOTE 4—If the apparent attenuation of two or more materials or components are to be compared, the same two back reflections should be selected for each sample.

8.3.2 Determine the apparent attenuation by the relationship indicated below. The apparent attenuation will be in terms of decibels per unit length as defined by the units of thickness.

$$\text{Apparent attenuation} = \frac{20 \log_{10} \frac{A_m}{A_n}}{2\,(n - m)\,T}$$

where:

A_m and A_n = amplitudes of the mth and nth back reflections ($n > m$), and

T = specimen thickness.

NOTE 5—When instruments are used that have dB calibrated gain control, the measurements in decibels may be used instead of amplitude measurements. The dB control is used to bring the amplitude of the nth reflection up to the amplitude of the mth reflection and the gain in decibels

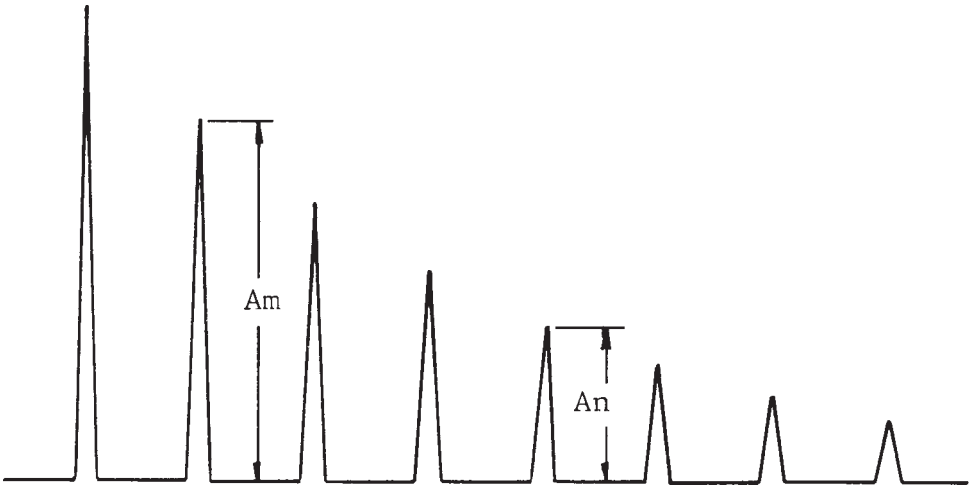

FIG. 1 Typical A-Scan Presentation Showing Multiple Back Reflections for Evaluation of Apparent Attenuation.

is substituted for the numerator in the attenuation formula. The formula then becomes:

$$\frac{dB}{2\,(n-m)\,T}$$

9. Report

9.1 The report should include the following:

9.1.1 Instrument make, model, and serial number,

9.1.2 Pertinent equipment settings such as gain, pulse length, damping, etc.,

9.1.3 Search unit type, frequency, serial number and transducer size,

9.1.4 Specimen dimensions,

9.1.5 Amplitudes and numbers of each of the back reflections used to calculate the attenuation parameter,

9.1.6 Attenuation parameter, and

9.1.7 Water path length.

10. Precision and Bias

10.1 *Precision*—Measurements of apparent attenuation are reproducible to within ±15 %.

NOTE 6—Many characteristics of ultrasonic systems affect the measurements described herein. These include the pulse shape and frequency spectrum of the driving pulse, the frequency spectrum, damping, etc., of the search unit, and others. Since these characteristics are not specified here, the reproducibility of measurements on different systems is uncertain. Caution should be exercised when comparing data gathered on different, although nominally identical, systems.

10.2 *Bias*—As mentioned throughout, this procedure is concerned only with comparative values between specimens. Therefore, there is no correct value for comparison.

11. Keywords

11.1 apparent attenuation; attenuation; immersion method; nondestructive examination; ultrasonic examination