Designation: B594 – 13

Standard Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products[1]

This standard is issued under the fixed designation B594; 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 the requirements for pulse-echo ultrasonic inspection and includes criteria used to define applicable quality levels of aluminum-alloy wrought products when performance of the ultrasonic test by the producer is specified, or when ultrasonic inspection is performed by the purchaser upon receipt.

1.2 This practice is not applicable if plastic deformation is introduced into the material after delivery.

1.3 The ultrasonic test described in this practice is employed to detect internal discontinuities oriented in a direction parallel to, or nearly parallel to, the surface of the product. The test is performed either by the immersion method or the contact method using pulsed longitudinal waves which are transmitted and received by a search unit containing either a single crystal or a combination of electrically interconnected multiple crystals. Ultrasonic tests employing either the through-transmission or the angle-beam techniques are not included.

NOTE 1—Ultrasonic tests employing angle-beam techniques require special reference blocks, search units, and scanning procedures and are subject to negotiation between the purchaser and the seller when such tests are required by the contract or purchase order.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units which are provided for information only and are not considered standard.

1.5 *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 The following documents of the issue in effect on date of material purchase form a part of this practice to the extent referenced herein:

2.2 *ASTM Standards:*[2]

B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products

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

E127 Practice for Fabrication and Control of Aluminum Alloy Ultrasonic Standard Reference Blocks

E214 Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves (Withdrawn 2007)[3]

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

2.3 *American Society for Nondestructive Testing Standard:*

ASNT Recommended Practice for Nondestructive Testing Personnel Qualification and Certification—Ultrasonic Testing Method, SNT-TC-1A[4]

2.4 *National Aerospace Standard:*

NAS-410 Certification of Inspection Personnel[5]

3. Terminology

3.1 *Definitions*—Refer to Terminology B881 for definitions of product terms used in this practice.

4. Summary of Practice

4.1 The product is inspected ultrasonically by scanning specified entry surfaces with a beam of pulsed longitudinal waves oriented in a direction perpendicular to the entry surface. The ultrasound is transmitted into the product either by the direct contact or the immersion method. During the scan, indications representing discontinuities are displayed on an A-scan screen of the test instrument and may be detected by auxiliary electronic monitors, if used.

[1] This practice is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

Current edition approved May 1, 2013. Published June 2013. Originally approved in 1974. Last previous edition approved in 2009 as B594 – 09. DOI: 10.1520/B0594-13.

[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] The last approved version of this historical standard is referenced on www.astm.org.

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

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

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

4.2 When the test system sensitivity level is appropriately adjusted, detected discontinuities and variations in back reflection patterns are evaluated by comparing amplitudes of indications with the ultrasonic responses from selected ultrasonic standard reference blocks. The evaluated ultrasonic discontinuity responses are then classified and compared with applicable acceptance criteria.

NOTE 2—Additional information describing ultrasonic tests by the direct contact method and by the immersion method is available in Practices E114 and E214.

5. Significance and Use

5.1 A number of factors such as the condition of the entry and back surfaces of the inspected part, the inclination of the ultrasonic beam with respect to the entry surface, and variations in the performance characteristics of the test system may cause significant differences in amplitudes of discontinuity indications and back reflections. These factors can seriously impair the reliability and the quantitative value of the ultrasonic test outlined in this practice.

5.2 Accurate evaluations of discontinuity size are also significantly affected by variations in search unit characteristics and by irregularities in discontinuity surfaces which can influence reflectivity. For these reasons, the discontinuity sizes that may be implied by the ultrasonic comparisons outlined in this practice must be regarded as "apparent" or "estimated" in recognition of the limited quantitative value of the measurement.

5.3 Because numerous interacting variables in a test system can adversely influence the results of an ultrasonic inspection, the actual quantitative effects of detected discontinuities upon the mechanical properties of the inspected product are difficult to establish. Although this practice provides a reliable control of product quality during manufacture, it is not applicable as an exclusive indicator of the ultimate quality and performance of components fabricated from the inspected products covered by this practice.

6. Special Requirements

6.1 When ultrasonic inspection of the finished product is required of the producer, purchase orders or contracts shall include the following information:

6.1.1 *Special Acceptance Limits*—Discontinuity class limits, if other than those defined in Section 11, shall be subject to negotiation between the purchaser and the producer and shall be in accordance with an agreement established between the purchaser and the producer at the time of quotation or acceptance of purchase order or contract.

6.1.2 *Engineering Drawings*—When ultrasonic inspection is specified for alloys, section thicknesses, and weights outside limits established in applicable product specifications, the special discontinuity class limits shall be as negotiated between the purchaser and the producer and shall be indicated on zoned engineering drawings describing the material to be inspected on part machine drawings. The drawings shall also indicate non-critical areas on the material and areas that will be removed by machining.

6.1.3 *Special Testing Procedures*—Cylindrical sections or specified areas of parts containing fillets may require additional inspections employing special ultrasonic testing procedures (for example, angle-beam, shear-wave technique) not covered by this practice. Such special testing procedures and acceptance limits shall be established by negotiation and agreement between the purchaser and producer.

7. Apparatus

7.1 The required ultrasonic test system shall consist of the following:

7.1.1 *Basic Test Instrument*—Any electronic device that produces electrical pulses to activate a search unit and displays pulses representing ultrasonic reflections on an A-scan screen is satisfactory if the minimum performance characteristics specified in 7.1.3 are met. The instrument shall provide stable linear amplification of received pulses at a selected test frequency and required sensitivity levels within the specified minimum performance limits.

7.1.2 *Search Unit*—The recommended search unit is the flat nonfocusing type and contains a piezoelectric crystal which generates and receives longitudinal waves at the rated frequency when connected to the test instrument through a suitable coaxial cable. A dual-crystal search unit containing both a transmitting and a receiving crystal in one container may be used provided the test instrument will accommodate two-crystal operation. Special tests employing focusing search units may be used provided such tests are established by negotiation and agreement between purchaser and producer.

7.1.2.1 *Search Unit Size*—Any search unit of either circular or rectangular configuration may be used for initial scanning. For a circular configuration that provides an effective crystal area greater than 1.00 in.^{2} (6.45 cm^2) and for all rectangular search units a documented method of providing a uniform entry surface for the full extent of the sound beam shall be agreed upon between the purchaser and producer. A search unit containing a circular crystal of an effective diameter no greater than 0.75 in. (19.0 mm) is required to evaluate the ultrasonic response from detected discontinuities. When connected to the test instrument and used for initial scanning and evaluating responses from discontinuities, the search unit shall meet or exceed the required minimum performance characteristics at the selected test frequency. Search units used only for initial scanning of a part prior to evaluation of suspect discontinuities shall, as a minimum, have adequate performance of sensitivity and signal to noise ratio appropriate to the class of inspection described in Section 11.

NOTE 3—The same search unit used for initial scanning may also be used for evaluating discontinuities provided its effective crystal diameter is no greater than 0.75 in. (19.0 mm) and minimum test system performance requirements are satisfied. Rectangular search units may be used for evaluation if the method of use is established in writing by the producer and approved by the purchaser.

7.1.2.2 *Effective Beam Width*—The effective beam width of the search unit shall be established by determining the total traverse distance over which response is maintained within limits specified below. The hole size in the standard Practice E127 reference block to be used for determining effective beam width shall be in accordance with those listed in Table 1 for the

TABLE 1 Ultrasonic Classes

Class	Single Discontinuity Response in. (mm)[A,B]	Multiple Discontinuities in. (mm)[C,B]	Linear Discontinuity Length–Response in. (mm)[D]	Loss of Back Reflection (%)[E]	Noise in. (mm)[F]
AAA	1/64 (0.40) or 25 % of 3/64 (1.19) response	10 % of 3/64 (1.19) response	0.12 (3.0)–10 % of 3/64 (1.19) response	50	10 % of 3/64 (1.19) response
AA	3/64 (1.19)	2/64 (0.79)	0.5 (12.7)–2/64 (0.79) response	50	alarm level
A	5/64 (1.98)	3/64 (1.19)	1.0 (25.4)–3/64 (1.19) response	50	alarm level
B	8/64 (3.18)	5/64 (1.98)	1.0 (25.4)–5/64 (1.98)	50	alarm level
C	8/64 (3.18)	Not applicable	Not applicable	50	alarm level

[A] Any discontinuity with an indication greater than the response from a reference flat-bottom hole or equivalent notch at the estimated discontinuity depth of the size given (inches diameter) is not acceptable.
[B] NIST certified blocks are not available for 1/64 in. (0.40 mm) and 2/64 in. (0.79 mm) hole diameters. The following substitutions and correction factors are approximations based on the area-amplitude relationships and shall be applied as follows:
A 3/64 in. hole reference block may be substituted for a 1/64 in. hole reference block by using a correction factor of 19 dB.
A 3/64 in. hole reference block may be substituted for a 2/64 in. hole reference block by using a correction factor of 7 dB.
[C] Multiple discontinuities with indications greater than the response from a reference flat-bottom hole at the estimated discontinuity depth of the size given (inches diameter) are not acceptable if the centers of any two of these discontinuities are less than 1.0 in. apart. Not applicable to class C.
[D] Any discontinuity longer than the length given with maximum indications greater than the response given (flat-bottom hole or equivalent notch response) is not acceptable. Not applicable to class C.
[E] Loss of back reflection greater than the percent given, when compared to non-defective material in a similar or like part, is not acceptable when this loss of back reflection is accompanied by an increase in noise signal (at least double the normal background noise signal) between the front and back surface. Applicable only to straight beam tests.
[F] Noise which exceeds the alarm level setting is not acceptable, except for re-forging stock.

applicable class of inspection. The metal distance of the reference block shall be that which produces the smallest clearly resolved hole indication. The same water distance to be used for scanning shall be used to determine effective beam width.

(a) For round search units, a maximum indication shall be obtained from the hole and then the instrument gain control shall be adjusted to obtain a hole indication that is equal to 80 % of the vertical limit. The effective beam width shall be the traverse distance in the index direction over which the indication from the flat-bottom hole equals or exceeds 40 % of the vertical limit.

(b) For rectangular search units, an indication shall be obtained from the hole at any point along the longitudinal axis of the search unit and then the instrument gain control shall be adjusted to obtain a hole indication that is equal to 80 % of the vertical limit. The effective beam width shall be the traverse distance in the index direction over which the indication from the flat-bottom hole equals or exceeds 40 % of the vertical limit. The effective beam width establishes the maximum allowable index distance used during the initial scan sensitivity for each inspection.

7.1.2.3 *Distance-Amplitude Characteristics*—The distance-amplitude characteristics shall be established and recorded for each search unit by obtaining the ultrasonic response from a complete distance-amplitude set of ultrasonic standard reference blocks containing the No. 5 (0.078-in. diameter (1.98-mm diameter)) flat-bottomed holes (see 7.4) at a nominal sensitivity level to be used for evaluating the estimated size of detected discontinuities. When using the search unit during testing, a check of the established distance-amplitude characteristics shall be conducted at least once per 8-h shift and shall be performed by noting the ultrasonic response from at least three selected No. 5 distance-amplitude reference blocks at the established sensitivity level. If the response from any block differs by more than ±10 % of the original distance-amplitude curve established for the selected search unit, the performance of the search unit shall be reevaluated and the test system shall be restandardized to ensure proper conformance to the requirements in this practice, and all metal tested since the previous standardization shall be retested.

When testing metal to requirements that necessitate ultrasonic reference standards other than No. 5 reference standards for inspection and/or evaluation (i.e., class AAA, AA, A, B, or C), it is acceptable to offset the distance amplitude curve by a built-in or internally connected attenuator calibrated in decibels. Attenuators must affect only the return ultrasonic signal. Correction factors to be used after standardization on No. 5 ultrasonic reference standards are shown in Table 2.

NOTE 4—The distance amplitude curve may be established on one or more sets of ultrasonic standard reference blocks, containing other than No. 5 flat bottomed holes, when justified by the inspection class of Section 11.

NOTE 5—This section is not applicable when using the alternative procedure allowed by 10.5.2.

7.1.2.4 *Uniformity of Response for Rectangular Search Units*—Rectangular search units shall exhibit beam uniformity within ±10 % of the mean amplitude of indication from the flat-bottomed hole during a traverse along the longitudinal axis of the search unit at the scanning sensitivity established with reference blocks for the applicable class (exclusive of end lobe responses).

7.1.3 *Test System Performance*—When used with appropriate auxiliary equipment described in subsequent paragraphs, the test system shall be capable of meeting or exceeding the minimum performance characteristics listed in Table 3 as

TABLE 2 Ultrasonic Reference Hole Correction Factors

Ultrasonic Reference Hole inch (mm)	Correction Factor from No. 5 Reference Hole	Percentage of No. 5 Hole Signal Amplitude
1/64 (0.40)	–28 dB	4%
2/64 (0.79)	–16 dB	16%
3/64 (1.19)	–9 dB	36%
5/64 (1.98)	0 dB	100%
8/64 (3.18)	+8 dB	256%