Designation: B 594 – 02

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

This standard is issued under the fixed designation B 594; 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 covers the requirements for pulse-echo ultrasonic inspection and includes criteria used to define applicable quality levels of aluminum-alloy wrought products for aerospace applications 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:*

B 881 Terminology Relating to Aluminum- and Magnesium-Alloy Products[2]

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method[3]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[3]

E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves[3]

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

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 B 881 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.

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[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.

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[2] *Annual Book of ASTM Standards*, Vol 02.02.

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

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

[5] Available from AIA—Aerospace Industries Association, 1250 Eye Street, N.W., Washington, DC, 20005-3922.

***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 E 114 and E 214.

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 E 127 reference block to be used for determining effective beam width shall be in accordance with those listed in Table 1 for the applicable class of inspection. The metal distance of the reference block shall be that which produces the smallest

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.

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 distanceamplitude 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.

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 2 as determined by procedures outlined in Practice E 317. If instrument A-scan display dimensions exceed the 2.5-in. (63.5-mm) vertical limit and the 3.5-in. (88.9-mm) horizontal limit, the instrument shall be considered usable throughout the entire A-scan screen height or width found to be linear with the procedures prescribed in Practice E 317. All other minimum characteristics listed in Table 2 remain applicable.

7.2 *Auxiliary Equipment*—In addition to the ultrasonic test system previously described, the following equipment is necessary:

7.2.1 *Tank*—For tests by the immersion method, any container is satisfactory that will facilitate the accurate, stable positioning of both the search unit and the product to be inspected.

7.2.2 *Scanning Apparatus*—The search unit shall be supported by any one of the following devices:

7.2.2.1 *Manipulator and Bridge*—When a manipulator is used in tests by the immersion method, the manipulator shall adequately support a search tube containing a search unit and

TABLE 2 Minimum Performance Characteristics Required for Ultrasonic Test Systems

NOTE 1—The minimum requirements shown in this table are applicable as indicated only for the selected frequencies used for the inspection. The test system is required to meet the limits only for the test frequencies actually used.

Performance Characteristics	Test Frequency, MHz			
	2.25	5.0	10.0	15.0
Vertical limit, in. (mm), min	2.5 (63.5)	2.5 (63.5)	2.5 (63.5)	2.5 (63.5)
Upper linearity limit, min[A]	95	95	95	95
Lower linearity limit, max[A]	10	10	10	10
Ultrasonic sensitivity, min[A,B]	50	100	80	50
Signal-to-noise ratio, min[B,C]	65:1	100:1	100:1	100:1
Entry surface resolution, in. (mm) of aluminum, max	0.7 (18)	0.5 (13)	0.3 (8)	0.2 (5)
Back surface resolution, in. (mm) of aluminum, max	0.3 (8)	0.2 (5)	0.1 (3)	0.1 (3)
Horizontal limit, in. (mm), min	3.5 (89)	3.5 (89)	3.5 (89)	3.5 (89)
Horizontal linearity, min[D]	85	85	85	85

[A] % of vertical limit.
[B] ASTM Reference Block 1-0300.
[C] Applies to the electrical component.
[D] % of horizontal limit.

shall provide fine adjustment of angle within 1° in two vertical planes that are perpendicular to each other. The bridge shall be of sufficient strength to provide rigid support for the manipulator and shall allow smooth, accurate positioning of the search unit within ±0.05 in. (±1.3 mm). During the inspection procedure, the scanning apparatus shall permit measurement of both the scan distance and the index distance within ±0.1 in. (±2.5 mm).

7.2.2.2 *Special Fixtures*—Special search unit-supporting fixtures such as bubblers and wheel search units may be used provided they meet the requirements prescribed for a manipulator and bridge and provided the test results obtained with special fixtures are equivalent to those obtained by the immersion method.

7.2.2.3 *Contact Scanning Unit*—During tests by the contact method, the search unit usually is supported and positioned manually on the entry surface of the inspected product. However, special fixtures for contact scanning may be employed provided their use ensures conformance to the requirements in this practice.

7.2.2.4 *Manual Immersion Scanning*—When part size or geometry, or both, prevent the use of manipulating equipment, transducer stand-off attachments which provide for the control of water travel distance and sound beam angle shall be used. Provisions shall be made to ascertain that wear of stand-off attachments do not exceed limits which will degrade the test.

7.3 *Couplant*—Clean water at room temperature (see 9.3), free of visible air bubbles that could interfere with the test, is the recommended couplant for tests by the immersion method. Inhibitors or wetting agents, or both, may be used. For tests by the contact method, the recommended couplant is clean, light-grade oil.

NOTE 6—Other coupling liquids may be employed provided their use does not adversely affect either the test results or the product.

7.4 *Reference Standards*—The ultrasonic reference standards required for the inspection of aluminum-alloy products shall be a distance-amplitude set of aluminum-alloy ultrasonic standard reference blocks fabricated and checked in accordance with Practice E 127.

NOTE 7—When side-wall reflections caused by sound-beam divergence prevents the use of Practice E 127 reference blocks, special blocks of the same material as used in Practice E 127 blocks may be used.

7.4.1 The distance-amplitude set shall consist of the appropriate number of groups, as defined by the applicable Class, of Practice E 127 reference blocks (see Table 1). Discontinuity indications shall be compared with the response having the same metal distance within ±⅛in. (±3.2 mm) for metal distances from ¼ in. (6.4 mm) through 1.0 in. (25.4 mm), within ±¼ in. for metal distances from over 1.0 in. through 3.0 in. (76.2 mm), and within ±½ in. (±12.7 mm) for metal distances over 3.0 in. The above requirements can be met optionally with blocks having the hole sizes specified in Table 1 and either of the following sets of metal distances:

in. (mm)	in. (mm)
0.25 (6.4)	0.25 (6.4)
0.50 (12.7)	0.37 (9.4)
0.75 (19.0)	0.62 (15.7)
1.00 (25.4)	0.87 (22.1)
1.50 (38.1)	1.25 (31.8)
2.00 (50.8)	1.75 (44.4)
2.50 (63.5)	2.25 (57.2)
3.00 (76.2)	2.75 (69.8)
4.00 (101.6)	3.25 (82.6)
5.00 (127.0)	4.25 (108.0)
6.00 (152.4)	5.25 (133.4)

7.4.2 *Special Reference Standards*—When required by the contract or purchase order instead of appropriate correction factors, special reference blocks containing curved entry surfaces shall be employed for tests of cylindrical or irregularly shaped products, when specified in the scan plan.

7.4.3 *Ultrasonic Transmission Characteristics*—The transmission characteristics exhibited by the required ultrasonic standard reference blocks shall be within ±40 % of the transmission characteristics of the inspected product as determined with the test frequency and equipment to be used for the inspection (Note 8). Differences in transmission characteristics are determined by comparing the amplitude of a selected back reflection obtained from the inspected product with the amplitude of the equivalent back reflection from a selected reference block at a constant test sensitivity level. The total length of the reference block used for comparison shall be equal to the thickness of the inspected product within ±0.50 in. (±12.7 mm). The back reflection from the block shall be obtained at a location midway between the center and the outside edge of the

block entry surface to avoid an indication from the flat-bottom hole.

NOTE 8—If the transmission characteristics of the reference blocks exceed the specified ±40 % limits, correction for significant differences in the ultrasonic response may be required when adjusting test sensitivity for initial scanning and for discontinuity response evaluation. Techniques for ultrasonic response correction shall be subject to negotiation at the time of quotation or acceptance of the purchase order or contract.

7.5 *Attenuator Decade Switch Check*—The ultrasonic instruments shall meet the requirements of Tables 2 and 3, when evaluated in accordance with Practice E 317.

8. Personnel Requirements

8.1 The testing operator performing the ultrasonic examination prescribed in this practice shall be qualified and certified at least to Level I—Ultrasonic Testing in accordance with at least one of the following: NAS-410; or a practice meeting the guidelines of ASNT Recommended Practice SNT-TC-1A; or applicable customer requirements.

8.2 The required documentation supporting qualification and certification of ultrasonic testing operators shall be established by the certifying agency and shall be available upon request by the purchaser at the location where the testing is being performed.

9. Condition of the Inspected Product

9.1 The entry and back surfaces of the inspected product shall be sufficiently clean, smooth, and flat to maintain a first back reflection amplitude greater than 40 % of the vertical limit while scanning an area in the product that does not contain significant isolated ultrasonic discontinuities.

NOTE 9—At nominal test sensitivities, the amplitude of the first back reflection usually exceeds the vertical limit. Therefore, tests to evaluate the effect of surface conditions should be performed at reduced gain settings to obtain an unsaturated first back reflection. Preferably, the instrument should be equipped with an independent control of the back reflection amplitude.

9.2 The roughness of the entry surface of the inspected part shall not exceed 250 µin., arithmetic average, as measured by a profilometer.

9.3 The temperature of the inspected part shall be 72 ± 30°F (22 ± 15°C) during the test.

10. Procedure

10.1 *Preferred Method*—The ultrasonic tests specified in this practice may be performed by either the direct contact method or the immersion method. However, the immersion method is preferred. For tests by the immersion method, the recommended water distance should be between 2.5 and 3.5 in. (63.5 and 88.9 mm). Other water distances may be used; however, the selected water distance shall be such that the second front reflection from the inspected part does not appear between the first front and back reflection. The water distance shall be constant and not vary more than 0.25 in. (6.4 mm) from the selected water distance for sensitivity standardization, initial scanning, and discontinuity evaluation.

10.2 *Test Frequency*—Of the four frequencies shown in Table 2, select that test frequency which will ensure the most effective detection and evaluation of discontinuities in the inspected product. Other test frequencies between 2.0 MHz and 15 MHz may be used subject to negotiation and agreement between purchaser and seller.

TABLE 3 Allowable Response Height as a Function of the Attenuator/Decade Switch Position

	Decade or Attenuator Switch Positions		
	0.1X 10 dB	1X 30 dB	10X 50 dB
Allowable range for A-scan response height, percent	10→90–100 or saturated	10→90–100 or saturated 6–13←95	6–13←95
	→		
	←		
	Switch direction		

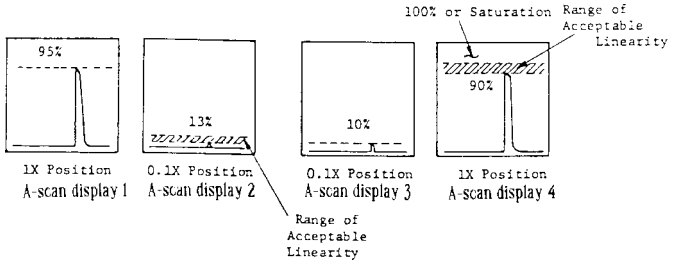


FIG. 1 A-scan Displays Corresponding to Decade Switch Multiplier Check

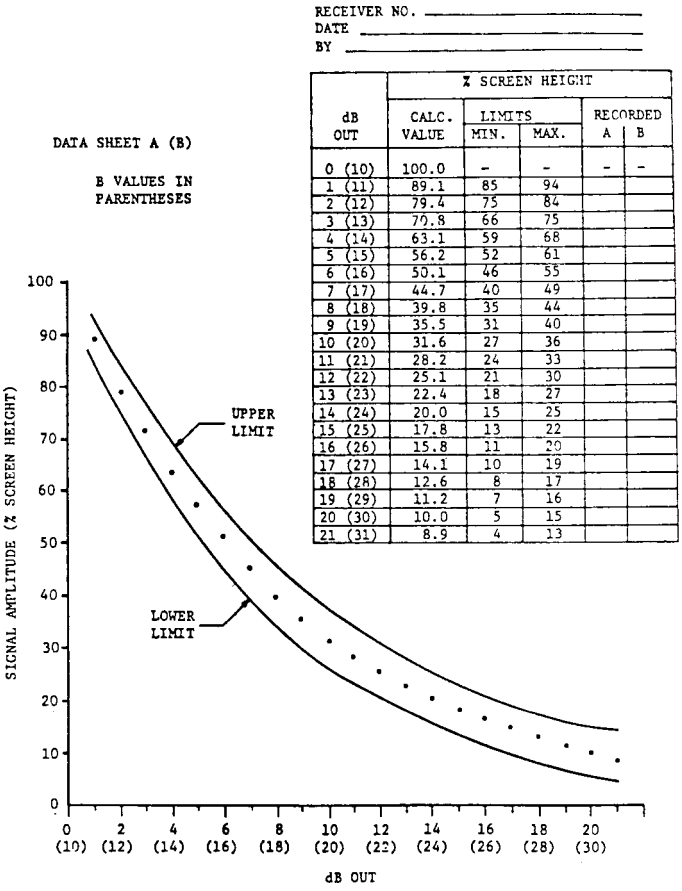


FIG. 2 dB Attenuator Check Data Sheet

TABLE 4 Surface Resolution Requirements

Material thickness (T), in. (mm)	Resolution Requirements, in. (mm)	
	Forgings	Other Product Forms
Up thru 1.249 (31.72)	0.125 (3.18)	0.125 (3.18)
1.250 thru 2.499 (31.75 thru 63.47)	0.188 (4.78)	T/10
2.500 and over (63.50 and over)	T/10, or 0.500 (12.70), whichever is less	

10.3 *Scan Sensitivity Standardization*:

10.3.1 To standardize the scanning sensitivity, select the reference block containing the appropriate hole for the applicable class (see Table 1) with a metal distance nominally equal to the maximum thickness of the inspected product (Note 10). Center the longitudinal axis over the reference block hole in order to avoid the end lobe responses. Adjust the instrument gain control to obtain a maximized response from the hole equal to 80 % of the A-scan vertical limit. Adequate scan sensitivity shall be verified over the full thickness range of the product, from near surface resolution limit to maximum thickness. The response shall be at least equal to the required setup value, as determined from blocks, conforming to 7.4.1, with the appropriate hole size for the class of inspection. The reference blocks used for this verification shall be selected by one of the following procedures:

(a) Determine the three blocks having metal path lengths closest to: (*1*) the near surface resolution limit; (*2*) half of the inspected part thickness; and (*3*) the inspected part thickness; or

(b) Determine the one block which is known (through routine Distance Amplitude checks on the particular instrument, cable, and search unit in use) to be the lowest responding block in the range, as determined from the near surface limit to the maximum thickness of the inspected part.

In all cases, manipulate the search unit to obtain a maximum response from the reference holes. Standardization of systems with respect to sensitivity shall be performed prior to and immediately after each inspection and after any changes in instrument settings, modules, search unit, or cable, and at 2-h intervals during continuous operation. If the sensitivity has increased, only the reportable indications found since the last calibration check need to be reexamined. If the sensitivity has decreased more than 10 % since the last calibration check, the test items examined during the interim shall be reexamined at the correct sensitivity.

NOTE 10—A scan sensitivity level greater than that established by 10.3 may be employed provided excessive ultrasonic noise levels do not interfere with the detection reliability of the test and provided attainable entry surface resolution is not adversely affected.

10.4 *Scanning*—With no further adjustment of the instrument gain controls, locate the search unit over one corner of the inspected part and proceed to scan the entire selected surface of the inspected part at a constant scanning rate. Maintain alignment between the ultrasonic beam and the entry surface at 90 ± 2° during the entire scan. In addition any misalignment which would cause a decrease in the first back reflection to 50 % of the vertical limit or less shall require realignment of the search unit. The inspection shall consist of a complete scan of the product from one selected side (Note 11). When inspecting die forgings, perform the initial scan with the ultrasonic beam oriented perpendicular to the parting plane, wherever possible. During scans of products with irregularly contoured entry surfaces, adjust the position of the search unit as required to maintain perpendicular alignment within ± 3° between the ultrasonic beam and the entry surface.

10.4.1 *Scan Rate*—When the screen pattern on the A-scan indicator is monitored visually by the test operator during the inspection, without the aid of auxiliary alarms, the rate of scan shall not be greater than 10 in./s (254 mm/s). Scanning rates greater than 10 in./s (254 mm/s) may be employed if an auxiliary monitoring apparatus is used, provided a capability to maintain adequate detection reliability is demonstrated.

10.4.2 *Scan Index Distance*—The scan index distance for the inspection prescribed in this method shall not exceed the effective beam width determined previously at the test sensitivity level used for the initial scan. To ensure total coverage and maximum detection reliability, a scan index overlap distance of approximately 10 % of the effective beam width is recommended.

10.4.3 During the scan at the standardized scanning sensitivity, note the occurrence of any one of three significant conditions:

10.4.3.1 Isolated discontinuities exhibiting amplitudes greater than 40 % of the vertical limit,

10.4.3.2 An increase in ultrasonic noise level, or multiple indications, of at least twice the normal level observed during the scan, or

10.4.3.3 A reduction in amplitudes of back reflections to less than 50 % of the vertical limit. To ensure that the loss of back reflection is not caused by surface interference, check the conditions of both the entry and back surfaces of the inspected product.

10.4.4 For subsequent estimation of discontinuity size and evaluation, record the location of the isolated discontinuities and areas exhibiting increased ultrasonic noise or substantial reduction in back reflections on the entry surface of the inspected part.

NOTE 11—Additional scans on opposite or adjacent sides shall be subject to negotiation and agreement between purchaser and seller.

10.5 *Evaluation of Discontinuity Response*—Upon completion of the initial scan, reduce the instrument gain control setting to the sensitivity level established previously for determining the distance-amplitude characteristics of the reference blocks containing the hole sizes used to define the applicable acceptance limits. Relocate the search unit over a discontinuity detected previously and determine its depth location beneath the entry surface using the horizontal sweep calibration established for the distance-amplitude curves.

NOTE 12—In a number of instances, it is desirable to stop the initial scan and to evaluate the discontinuity response immediately upon detection. This alternative procedure is satisfactory provided the procedures outlined in 10.5 are followed.

10.5.1 Angulate and manipulate the search unit to obtain a

maximum amplitude of indication from the detected discontinuity and compare this maximum amplitude with the established distance-amplitude curve defining the applicable acceptance limits. Record the results of the comparison (Note 13).

10.5.2 *Alternative Procedure*—If a pre-established distance-amplitude curve is not used to evaluate discontinuity response, adjust the instrument gain control setting to obtain an unsaturated indication (approximately 50 % of the vertical limit) from the detected discontinuity. Angulate and manipulate the search unit for maximum response, and determine the depth location of the discontinuity beneath the entry surface using a distance-calibrated horizontal sweep. Select an appropriate reference block used to define the applicable acceptance limits with a flat-bottom hole located at a metal distance nominally equal to the depth location of the detected discontinuity within:

±0.12 in. (±3.0 mm) for depths from 0.25 in. (6.4 mm) to 1.00 in. (25.4 mm)
±0.25 in. (±6.4 mm) for depths from 1.00 in. (25.4 mm) to 3.00 in. (76.2 mm)
±0.50 in. (±12.7 mm) for depths from 3.00 in. (76.2 mm) to 6.00 in. (152.4 mm)

Angulate and manipulate the search unit to obtain a maximum response from the selected reference block and compare this response with the maximum response from the detected discontinuity. Record the results of the comparison (Note 13).

10.5.3 Repeat either one of the two procedures to evaluate the indications of each discontinuity detected during the initial scan.

10.5.4 *Curved-Entry Surfaces*—When isolated discontinuities are detected beneath curved-entry surfaces on cylindrical or irregularly shaped products, correction is recommended for the effect of the curved surface upon the estimated size of discontinuity. The correction techniques shall include either the use of established correction factors that account for known losses due to specified radii of curvature or the use of special ultrasonic standard reference blocks containing specified radii of curvature with applicable sizes of flat-bottom holes used to define acceptance limits. The selected method for compensating for the effect of entry-surface curvature shall be subject to negotiation and agreement between the purchaser and the seller.

NOTE 13—If the ultrasonic transmission characteristics of the reference blocks used for this comparison exceed the ±40 % limits established in 7.4.3, corrections for response differences in accordance with Note 6 should be included when indications from discontinuities are evaluated.

10.5.5 *Multiple Discontinuities*—Determine the distance apart of multiple discontinuities by positioning the transducer over the center of each discontinuity where the signal is a maximum. Compare the distance between the centers of any two discontinuities with the minimum allowed in the applicable class described in Section 11.

10.6 *Estimation of Discontinuity Length*—When a discontinuity is detected at the established scanning sensitivity during the initial scan and appears to exhibit length, stop the scan, angulate, and manipulate the search unit to obtain an amplitude of indication equal to 50 % of the vertical limit from one end of the discontinuity. Move the search unit over the length of the discontinuity and determine the distance traversed by the search unit while maintaining an amplitude of indication equal to or greater than 50 % of the vertical limit. Subtract the effective beam width of the search unit in the traversing direction from the total distance traversed by the search unit to establish the estimated length of the discontinuity. Record the apparent length of the discontinuity.

10.7 *Determination of Loss of Back Reflection*—Stop the scan whenever the ultrasonic noise level increases to twice the normal level in an inspected part with parallel surfaces. Determine the amount of back reflection loss attributable to the increased ultrasonic noise as follows:

10.7.1 Manipulate the search unit over an area in the inspected part exhibiting a normal ultrasonic noise level to obtain either a maximum number or amplitudes of back reflections. Adjust the instrument gain control to a sensitivity where the amplitude of first back reflection from the normal area is approximately 80 % of the vertical limit.

10.7.2 Relocate the search unit over the area in the part exhibiting increased ultrasonic noise and manipulate the search unit to obtain a maximum amplitude of first back reflection. Check the condition of both entry and back surfaces to ensure that surface irregularities are not contributing to the loss.

10.7.3 Compare the maximum amplitude of back reflection obtained from the area exhibiting increased ultrasonic noise to the amplitude of back reflection obtained from the area exhibiting normal noise and record the ratio of the former amplitude in percent of the amplitude of the reference back reflection from the normal area in the inspected product.

NOTE 14—Other techniques for determining loss of back reflection may be used providing the resulting determinations are equivalent to those obtained with the foregoing procedures.

11. Discontinuity Class Limits

11.1 The ultrasonic discontinuity limits are classified into five categories (AAA; AA; A; B; and C), as shown in Table 1 and as described in the following:

11.2 *Class AAA*:

11.2.1 Indications from a single discontinuity shall not exceed the response for a 1⁄64 in. (0.40 mm) flat-bottom hole, or 25 % of a 3⁄64 in. (1.19 mm) flat-bottom hole, at the estimated discontinuity depth.

11.2.2 Multiple indications in excess of the response from 10 % of a 3⁄64 in. (1.18 mm) flat-bottom hole, at the estimated discontinuity depth, shall not have any two of these discontinuities with indicated centers closer than 1.0 in. (25.4 mm).

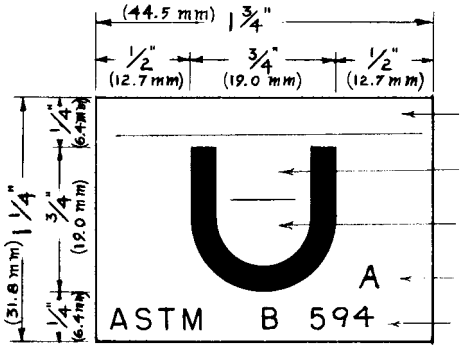
11.2.3 Indications from a single discontinuity equal to or greater than the response from 10 % of a 3⁄64 (1.18 mm) flat-bottom hole, at the estimated discontinuity depth, shall not be more than 0.12 in. (3.0 mm) in length.

11.2.4 Multiple discontinuities shall not be of such size or frequency as to reduce the back reflection to 50 % or less of the back reflection of normal material of the same geometry, when associated with the doubling of the normal noise level, with the ultrasonic beam perpendicular to the front and back surfaces, to ensure that the loss of back reflection is not caused by surface roughness or part geometry variation.

11.3 *Class AA*:

11.3.1 Indications from a single discontinuity shall not exceed the response for a 3⁄64 in. (1.19 mm) flat-bottom hole at the estimated discontinuity depth.

11.3.2 Multiple indications in excess of the response from a



Space for producer's name or trademark.

Space for test operator's identification number or producer's internal code for control purposes.

Space for producer's plant identification code letter or number.

Identification of applicable discontinuity class (A, B, C, or Z for zoned parts containing more than one discontinuity class).

Number of this standard.

FIG. 3 Recommended Identification Stamp for Acceptable Products

2⁄64 in. (0.79 mm) flat-bottom hole at the estimated discontinuity depth shall not have their indicated centers closer than 1.0 in. (25.4 mm).

11.3.3 Indications from a single discontinuity equal to or greater than the response from a 2⁄64in. (0.79 mm) flat-bottom hole at the estimated discontinuity depth shall not be more than 0.5 in. (12.7 mm) in length.

11.3.4 Multiple discontinuities shall not be of such size or frequency as to reduce the first back reflection to 50 % or less of the first back reflection from normal material of the same geometry, with the crystal parallel to the front and back surfaces to ensure that the loss of back reflection is not caused by surface roughness or part geometry variation.

11.4 *Class A*:

11.4.1 Indications from a single discontinuity shall not exceed the response from a 5⁄64in. (1.98 mm) flat-bottom hole at the estimated discontinuity depth.

11.4.2 Multiple indications in excess of the response from a 3⁄64 in. (1.19 mm) flat-bottom hole at the estimated discontinuity depth shall not have their indicated centers closer than 1.0 in. (25.4 mm).

11.4.3 Indications from a single discontinuity equal to or greater than the response for a 3⁄64in. (1.19 mm) flat-bottom hole at the estimated discontinuity depth shall not be more than 1.0 in. (25.4 mm) in length.

11.4.4 Multiple discontinuities shall not be of such size or frequency as to reduce the first back reflection to 50 % or less of the first back reflection from normal material of the same geometry, with the crystal parallel to the front and back surfaces to ensure the loss of back reflection is not caused by surface roughness or part geometry variation.

11.5 *Class B*:

11.5.1 Indications from a single discontinuity shall not exceed the response from a 8⁄64in. (3.18 mm) flat-bottom hole at the estimated discontinuity depth.

11.5.2 Multiple indications in excess of the response from a 5⁄64 in. (1.98 mm) flat-bottom hole at the estimated discontinuity depth shall not have their indicated centers closer than 1.0 in. (25.4 mm).

11.5.3 Indications from a single discontinuity equal to or greater than the response for a 5⁄64in. (1.98 mm) flat-bottom hole at the estimated discontinuity depth shall not be more than 1.0 in. (25.4 mm) in length.

11.5.4 Multiple discontinuities shall not be of such size or frequency as to reduce the first back reflection to 50 % or less of the first back reflection from normal material of the same geometry, with the crystal parallel to the front and back surfaces to ensure the loss of back reflection is not caused by surface roughness or part geometry variations.

11.6 *Class C*:

11.6.1 This class of discontinuity limits may apply to non-critical areas and to some areas specified in zoned engineering drawings.

11.6.2 Indications from a single isolated discontinuity shall not exceed the response from a 8⁄64in. (3.18 mm) flat-bottom hole at the estimated discontinuity depth.

11.7 *Permissible Discontinuities*—Evaluated discontinuity indications greater than those included in the four specified classes shall be permitted in the inspected product if it is established that they will be removed by machining or that they are located in non-critical areas not designated as Class C.

12. Report

12.1 When required by the purchaser, a report shall be prepared and shall include the date of test and a list of parameters including the type (model number) of instrument and search unit, the test method, frequency, the couplant, and any correction factors employed for the inspection.

12.2 Preparation of a drawing showing the location of all significant discontinuities in the inspected product is recommended when the ultimate rejection or acceptance of the product is to be determined by negotiation between the manufacturer and the purchaser.

12.3 The identification of an acceptable product is desirable and is recommended. For this purpose, a suitable stamp should be employed to indicate conformance to this ultrasonic practice. The recommended stamp for identifying acceptable products should contain a symbol "U" and identification of the inspection facility and the inspector. An example is shown in Fig. 3.

13. Precision and Bias

13.1 No information is presented about either the precision or bias of ultrasonic inspection for presence of discontinuities since such inspections are based on comparative classifications against reference blocks.

14. Keywords

14.1 aerospace; aluminum-alloy wrought products; ultrasonic inspection

SUMMARY OF CHANGES

Committee B07 has identified the location of selected changes to this standard since the last issue (B 594 – 97) that may impact the use of this standard.

(1) In 1.4, added current ASTM wording for inch-pounds being standard and SI units noted for information only.
(2) In 2.2, added reference to Terminology B 881.
(3) In Section 2, deleted reference to MIL-STD-410 (a now cancelled document).
(4) In 2.4, added reference to NAS-410 (superseding document to MIL-STD-410).
(5) In Section 3, added reference to Terminology B 881 and deleted separate listing of definitions for product forms.
(6) In 7.2.2, relocated scan apparatus measurement tolerance to 7.2.2.1.
(7) In 7.2.2.1, relocated requirement for scanning apparatus measurement tolerance for index distance and added applicability to scan distance.
(8) In 7.2.2.4, added paragraph to recognize hand scanning when part size or geometry, or both, prevents use of manipulating equipment (duplicate wording from MIL-STD-2154, Para. 5.2.9).
(9) In 7.3, added reference to 9.3, to clarify temperature at time of inspection.
(10) In 7.4.1, clarified wording.
(11) In 7.4.2, clarified requirement that special reference block be specified in the scan plan.
(12) In 7.5, added requirements of Practice E 317, Table 2 and Table 3, thereby enabling deletion of sub-paragraphs.
(13) In 8.1, deleted references to MIL-STD-410 (now cancelled) and ASNT CP-189, which is redundant with addition of NAS-410. Added reference to applicable customer requirements.
(14) In 10.1, clarified recommended water distance.
(15) In 10.3, clarified scan sensitivity verification and expanded procedures for selection of reference blocks used in verification.
(16) In 10.4.1, incorporated previous Note 12 into the text of the requirements. Renumbered subsequent notes accordingly.
(17) In Section 11 and subsections, added Class AAA definitions. For all Classes, replaced hole number references with hole diameter definitions, for compatibility with revised Table 1.
(18) In 12.3, included description of recommended stamp with "U" identification.
(19) In Section 13, added statement of non-applicability.
(20) In Table 1, deleted previous table and replaced with expanded, more comprehensive definitions for Ultrasonic Classes (including addition of Class AAA), based on MIL-STD-2154, Table VI.
(21) In Table 2, revised the signal-to-noise ratio entries to show as ratios (XX:1); Added reference to note (B), Reference Block 1-0300, and new note (C), to clarify that signal-to-noise ratio test frequency is applicable to the electrical component. Revised ultrasonic sensitivity and signal-to-noise ratio entries, note (B) to appear in the first column adjacent to title entries, for editorial consistency.
(22) In Table 4, added new table, based on MIL-STD-2154, Table V and Figure 11.