Designation: B 594 – 97

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 the standard. The SI units in parentheses are for information only.

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:*

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method[2]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[2]

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]

2.3 *American Society for Nondestructive Testing Standard:*

ASNT Recommended Practice for Nondestructive Testing Personnel Qualification and Certification—Ultrasonic Testing Method, SNT-TC-1A[3]

2.4 *Military Standard:*

MIL-STD-410 Certification of Inspection Personnel[4]

3. Terminology

3.1 *Definitions:*

3.1.1 The following definitions of aluminum-alloy wrought products shall be used in conjunction with this practice:

3.1.2 *plate*—a rolled product, rectangular in cross section and form, of thickness equal to or greater than 0.250 in. (6.35 mm) with sawed or sheared edges.

3.1.3 *bar*—a solid product that is long in relation to its cross section which either is a square or rectangle (excluding plate and flattened wire) with sharp or rounded corners, or is a regular hexagon or octagon and in which at least one perpendicular distance between parallel faces is equal to or greater than 0.375 in. (9.53 mm).

3.1.4 *shape*—a wrought product that is long in relation to the dimensions of its cross section which is of a form other than that of sheet, plate, rod, bar, tube, or wire.

3.1.5 *die forging*—a forging that is worked to the required shape and size in impression dies.

3.1.6 *rolled ring*—a cylindrical product of short length in relation to its diameter which is formed by rolling a hollow section in the circumferential direction.

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[1] This practice is under the jurisdiction of ASTM Committee B-7 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 03.03.

[3] Available from American Society for Nondestructive Testing, 3200 Riverside Dr., P.O. Box 5642, Columbus, OH 43221.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

3.1.7 *hand forging*—a forging that is worked to the required shape and size between flat or simply shaped dies by repeated strokes or blows and manipulation of the piece.

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.

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 noncritical 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 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.

TABLE 1 Applicable Reference Block Hole Sizes Used to Standardize Scan Sensitivity and Classify Ultrasonic Discontinuities

Class	Hole Number	Hole Diameter, in. (mm)
AA	2	0.031 (0.79)
A	3	0.047 (1.19)
B	5	0.078 (1.98)
C	8	0.125 (3.18)

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*—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). 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 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).

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.

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]	50[B]	100[B]	80[B]	50[B]
Signal-to-noise ratio, min	65[B]	100[B]	100[B]	100[B]
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[C]	85	85	85	85

[A] % of vertical limit.
[B] ASTM Reference Block 1-0300.
[C] %of horizontal limit.

However, special fixtures for contact scanning may be employed provided their use ensures conformance to the requirements in this practice.

7.3 *Couplant*—Clean water at room temperature, 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 three groups of standard Practice E 127 reference blocks with flat-bottom holes of the three diameters listed in Table 1. Discontinuity indications shall be compared with the response having the same metal distance within ±⅛ in. (±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 (44.5)
2.50 (63.5)	2.25 (57.2)
3.00 (76.2)	2.75 (69.9)
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 may be employed for tests of cylindrical or irregularly shaped products. The type and number of such special blocks are subject to negotiation and agreement between the purchaser and the seller.

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*—If the ultrasonic system is equipped with precision attenuator switches or an attenuator decade switch, these items shall be checked in accordance with the applicable method described below:

7.5.1 *Decade Switch*:

7.5.1.1 With a typical straight-beam transducer, any suitable reference block, and the ultrasonic instrument damping, reject, and pulse length at minimum, adjust the instrument until a response from the back surface of the block has an amplitude of 95 % of the A-scan display height at a switch position of 1X (30 dB). The uncalibrated gain may be adjusted to obtain this response height (Fig. 1, A-scan display 1).

7.5.1.2 Switch to 0.1X (10 dB) position and accept as linear any response height from 6 to 13 % (Fig. 1, A-scan display 2).

7.5.1.3 With the switch at 0.1X (10 dB) position, adjust the uncalibrated gain to get a response height of 10 % (Fig. 1,

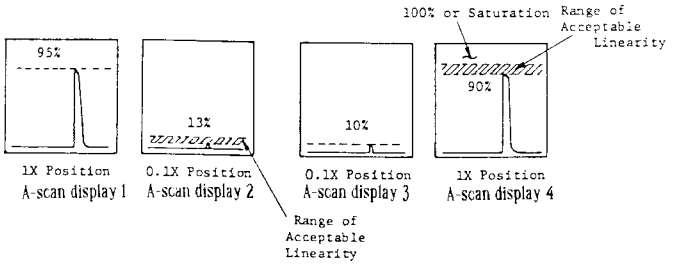


FIG. 1 A-scan Displays Corresponding to Decade Switch Multiplier Check

A-scan display 3). Then switch to 1X (30 dB). Accept as linear any response height from 90 to 100 % or saturation (Fig. 1, A-scan display 4).

7.5.1.4 With the switch at 1X (30 dB), adjust the uncalibrated gain to get a response height of 10 % and then switch to 10X (50 dB). Accept as linear any response from 90 to 100 % or saturation.

7.5.1.5 With the switch at 10X (50 dB), adjust the uncalibrated gain until a response height of 95 % is obtained. Switch to 1X (30 dB) and accept as linear any response from 6 to 13 %.

7.5.1.6 In the previous tests, the A-scan display height should be estimated to the nearest 2½ % of full screen. Table 3 is a summary of the response heights/switch positions.

7.5.2 *Attenuator Switches*:

7.5.2.1 With all dB attenuator switches out, maximize on a 5-0300 block using 5.0 MHz, ¾ in.-ceramic straight-beam search unit. Adjust the receiver gain control for a 100 % signal response from the hole. Fix the gain control position.

7.5.2.2 Using the attenuator switches, add increments of 1 dB attenuation from 1 dB to 21 dB. At each step, record the resultant signal height on the dB attenuator check sheet using the A values (Fig. 2). Also plot the data. The recorded data for each step must be within the limits noted on the check sheet.

7.5.2.3 Reset the attenuator switches for 10 dB-IN. Readjust the gain control to again obtain a 100 % signal response from the hole in the 5-0300 block. Fix this gain control position.

7.5.2.4 Using the attenuator switches, add increments of 1 dB attenuation from 10 dB to 31 dB. At each step, record the resultant signal height on the dB attenuator check sheet using the B values which are shown in parentheses. Also plot the data. The data for each step must be within the limits noted on the check sheet.

7.5.2.5 If the limits cannot be met at each step, corrective action must be taken, and the attenuator calibration shall be rerun.

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		

RECEIVER NO. _____
DATE _____
BY _____

DATA SHEET A (B)

B VALUES IN PARENTHESES

dB OUT	% SCREEN HEIGHT CALC. VALUE	LIMITS MIN.	LIMITS MAX.	RECORDED A	RECORDED B
0 (10)	100.0	-	-	-	-
1 (11)	89.1	85	94		
2 (12)	79.4	75	84		
3 (13)	70.8	66	75		
4 (14)	63.1	59	68		
5 (15)	56.2	52	61		
6 (16)	50.1	46	55		
7 (17)	44.7	40	49		
8 (18)	39.8	35	44		
9 (19)	35.5	31	40		
10 (20)	31.6	27	36		
11 (21)	28.2	24	33		
12 (22)	25.1	21	30		
13 (23)	22.4	18	27		
14 (24)	20.0	15	25		
15 (25)	17.8	13	22		
16 (26)	15.8	11	20		
17 (27)	14.1	10	19		
18 (28)	12.6	8	17		
19 (29)	11.2	7	16		
20 (30)	10.0	5	15		
21 (31)	8.9	4	13		

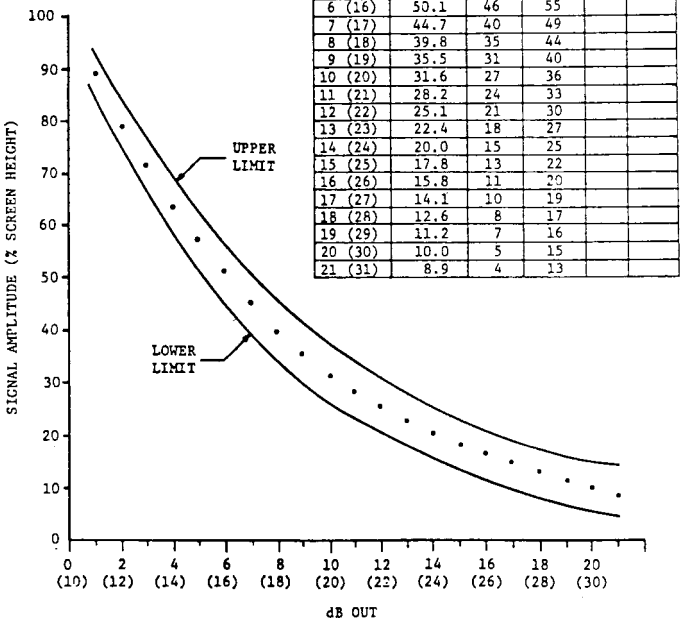


FIG. 2 dB Attenuator Check Data Sheet

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: MIL-STD-410; NAS-410; ASNT CP-89; or a practice meeting the guidelines of ASNT Recommended Practice SNT-TC-1A.

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 shall be between 2.50 and 3.50 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.

10.3 *Scan Sensitivity Standardization*—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. To confirm adequate scan sensitivity throughout the thickness of the inspected part, check the ultrasonic response from the hole of applicable size in additional reference blocks with the shortest resolvable metal distance and with a metal distance nominally equal to one half the thickness of the inspected parts, respectively, within the tolerances specified in 7.4.1. 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 two-hour intervals during continuous operation. If the sensitivity has increased, only those 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, the rate of scan shall not be greater than 10 in./s (254 mm/s) (Note 12).

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.

NOTE 12—Scanning rates greater than 10 in./s (254 mm/s) may be employed if auxiliary monitoring apparatus is used provided a capability to maintain adequate detection reliability is demonstrated.

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 13—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 14).

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 14).

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 14—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 15—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 four categories and are identified as follows:

11.2 *Class AA*:

11.2.1 Indications from a single discontinuity shall not exceed the response for a No. 3 flat-bottom hole at the estimated discontinuity depth.

11.2.2 Multiple indications in excess of the response from a No. 2 flat-bottom hole at the estimated discontinuity depth shall not have their indicated centers closer than 1 in. (25.4 mm).

11.2.3 Indications from a single discontinuity equal to or greater than the response from a No. 2 flat-bottom hole at the estimated discontinuity depth shall not be more than ½ in. (12.7 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 A*:

11.3.1 Indications from a single discontinuity shall not exceed the response from a No. 5 flat-bottom hole at the estimated discontinuity depth.

11.3.2 Multiple indications in excess of the response from a No. 3 flat-bottom hole at the estimated discontinuity depth

shall not have their indicated centers closer than 1.00 in. (25.4 mm).

11.3.3 Indications from a single discontinuity equal to or greater than the response from a No. 3 flat-bottom hole at the estimated discontinuity depth shall not be more than 1.00 in. (25.4 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 B*:

11.4.1 Indications from a single discontinuity shall not exceed the response from a No. 8 flat-bottom hole at the estimated discontinuity depth.

11.4.2 Multiple indications in excess of the response from a No. 5 flat-bottom hole at the estimated discontinuity depth shall not have their indicated centers closer than 1.00 in. (25.4 mm).

11.4.3 Indications from a single discontinuity equal to or greater than the response for a No. 5 flat-bottom hole at the estimated discontinuity depth shall not be more than 1.00 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 variations.

11.5 *Class C*:

11.5.1 This class of discontinuity limits may apply to noncritical areas and to some areas specified in zoned engineering drawings.

11.5.2 Indications from a single isolated discontinuity shall not exceed the response from a No. 8 flat-bottom hole at the estimated discontinuity depth.

11.6 *Permissible Discontinuities*—Evaluated discontinuity indications greater than those included in the three 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 noncritical areas not designated as Class C.

12. Report

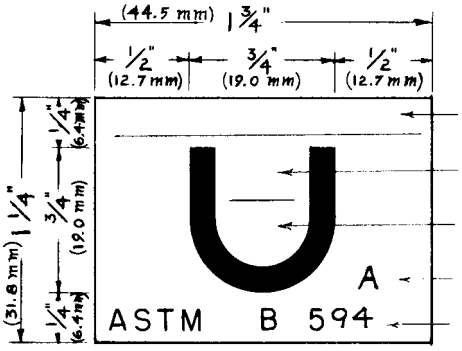
12.1 When required by the purchaser, a report shall be prepared and shall include the date of test and a list of parameters including the type (model number) of instrument and search unit, the test method, frequency, the couplant, and any correction factors employed for the inspection.

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 is shown in Fig. 3.

13. Keywords

13.1 aluminum-alloy wrought products; ultrasonic inspection



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