AEROSPACE MATERIAL SPECIFICATION

AMS2630™	REV. E
Issued 1960-06 Revised 2021-11 Superseding AMS2630D	

Inspection, Ultrasonic
Product Over 0.5 Inch (12.7 mm) Thick

RATIONALE

AMS2630E is the result of a Five-Year Review and update of the specification. The revision updates inspection methodology to be consistent with AMS2631 including changes to criteria (1.3), clarifing instrument requirements (3.2, 3.2.1.1), revising agreement requirements (3.2.2), updating requirements for curved surfaces (3.4.2), updating reference standards and procedure (3.2.4.3), updating and including calculations for electronic gating (3.4.9.1), adding an alternative FBH methodology (4.1.1) and the associated FBH conversion (Table 4), and updating Figure 5 for clarity.

1. SCOPE

1.1 Purpose

This specification covers procedures for ultrasonic inspection, by pulse-echo procedures, of flat, rectangular, round, cylindrical, and contoured products having a thickness or cross-sectional dimension greater than 0.5 inch (12.7 mm), using either contact or immersion methods, and using the longitudinal-wave or shear-wave modes or combinations of the two, as necessary. This specification may apply to testing finished machined parts provided the parts can meet the basic testability requirements, such as size, contour, metallurgical structure, and thickness.

1.2 Parts with section thickness both over 0.5 inch (12.7 mm) and 0.5 inch (12.7 mm) and under may be tested using this procedure and AMS2632, as applicable.

1.3 Cylindrical bar and billet, between nominally 5 inches (127 mm) in diameter and nominally 10 inches (254 mm), may be inspected in accordance with AMS2628 using the acceptance criteria of AMS2628 Class A to satisfy all classes of AMS2630 except Class AA.

1.4 Application

This procedure has been used typically for locating and defining internal defects such as cracks, voids, laminations, and other structural discontinuities which may or may not be exposed to the surface, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS2630E/

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2628 Enhanced Ultrasonic Immersion Inspection for Titanium Alloy and Other Metal Alloy Billets

AMS2631 Ultrasonic Inspection, Titanium and Titanium Alloy Bar, Billet, and Plate

AMS2632 Inspection, Ultrasonic, of Thin Materials, 0.5 Inch (12.7 mm) and Under in Cross-Sectional Thickness

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E127 Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks

ASTM E317 Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments

ASTM E1065 Evaluating Characteristics of Ultrasonic Search Units

ASTM E1316 Standard Terminology for Nondestructive Examinations

2.3 AIA Publications

Available from the Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, www.aia-aerospace.org.

NAS410 Nondestructive Testing Personnel Qualification and Certification

2.4 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

ASME B46.1 Surface Texture

2.5 ASNT Publications

Available from American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Lane, Columbus, OH 43228-0518, 800-222-2768 (inside U.S. and Canada), 614-274-6003 (outside USA), www.asnt.org.

SNT-TC-1A Recommended Practice, Personnel Qualification and Certification in Nondestructive Testing

2.6 A4A Publications

Available from Airlines for America (A4A), 1275 Pennsylvania Avenue, NW, Suite 1300, Washington, DC 20004, 202-626-4062, www.airlines.org.

Spec 105 Guidelines for Training and Qualifying Personnel in Nondestructive Testing Methods

2.7 Other Publications

Nondestructive Testing Handbook, Current Edition: Volume 7, Ultrasonic Testing (UT) (Available from ASNT).

Sonics, by T. F. Hueter and R. H. Bolt, 1955; John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10016.

Ultrasonic Testing of Materials, by J. Krautkramer and H. Krautkramer (Translation of 2nd revised German edition), 1969; Springer-Verlag New York, 175 Fifth Avenue, New York, NY 10010.

3. TECHNICAL REQUIREMENTS

3.1 Qualification

3.1.1 Personnel

Shall be qualified and certified in accordance with NAS410. Alternate procedures, such as SNT-TC-1A or Spec 105, may be used if specified on the drawing or purchase order. It is the supplier's responsibility to ensure that personnel are certified and function within the limits of the applicable specification or procedure.

3.1.2 Facilities

Shall be subject to survey and approval by purchaser of the inspected product. Ultrasonic test facility equipment shall include, but not be limited to, the basic ultrasonic test instrument, search units (transducers), appropriate ultrasonic references, couplant materials, fixtures, reference specifications, and immersion tanks, where applicable. Reference specifications and documentation necessary to verify the qualification of equipment and test personnel shall be available upon request.

3.2 Ultrasonic Test System

3.2.1 Basic Ultrasonic Test Instrument

Shall be capable of producing, receiving, amplifying, and displaying high-frequency electrical pulses at the required frequencies and energy levels. The ultrasonic instrument shall be of a pulse-reflection (echo), pulse-transmission type. Gates, distance-amplitude correction systems, and other electronic aids to ultrasonic testing and interpretation shall be used as required. An alarm system, a recorder, an auto-stop device, or combination of these, may be used.

3.2.1.1 Instrument Requirements

The instrument performance characteristics shall be evaluated in accordance with ASTM E317 or original manufacturer's requirements with acceptance in accordance with Table 1.

Table 1 - Instrument requirements

Characteristic	Requirement
Signal to noise[1]	2:1
Vertical linearity, percent of full scale	≤5
Horizontal linearity, percent of full scale	≤3
Gain or attenuator accuracy	±2 dB per 20 dB of control range
Voltage regulation—Voltage fluctuations shall not cause amplitude variations exceeding:	±5%

[1] ASTM E127 reference block 1-0300.

3.2.1.2 Alarm

3.2.1.2.1 Alarms and visual monitoring of the A-scan are not required when C-scan data collection is used.

3.2.1.2.2 For unrecorded stop on defect inspections, test criteria, and part configuration determine alarm use feasibility. When alarms cannot be used, this must be agreed upon by purchaser and vendor. Audible and/or visual alarms and/or stop on defect systems shall be used in conjunction with visual monitoring to identify signals which exceed the level established for the test. Alarm systems used for this purpose shall be capable of being adjusted to alarm at any point in the display range and shall be automatically triggered by indications exceeding the set level. The sound level produced by an audible alarm during operation shall be sufficiently above ambient to ensure being heard by the operator.

3.2.2 Ultrasonic Search Units

Ultrasonic search units shall have the sensitivity and resolution required to detect the required reference reflectors.

3.2.2.1 Search Unit Dimensions and Styles

For both contact and immersion tests with either longitudinal or shear mode, the choice of transducer dimension, style, type, focusing characteristics, etc., is dependent on the test and the approved test procedure. In general, for immersion testing, flat faced or focused transducers with diameters 3/8 through 1 inch (9.5 through 25.4 mm) or rectangular units with a maximum area of 1 in^2 (6.5 cm^2) are acceptable. Contact units with a maximum area of 1 in^2 (6.5 cm^2) with 1/2 inch (12.7 mm) minimum to 1-1/8 inches (28.6 mm) maximum dimensions are acceptable for longitudinal testing, while 1 in^2 (6.5 cm^2) or 1 x 1/2 inch (25.4 x 12.7 mm) transducers are acceptable for shear testing. Use of a liquid delay, special size, or other special transducer is acceptable when agreed upon by purchaser and vendor.

3.2.2.1.1 Phased Array Transducers

Linear phased array, annular phased array, and 2D array probes may be used for scanning and evaluation of wrought metals.

The written procedures shall include at least the following additional controls for phased array usage:

Virtual probes within the array shall meet the requirements for minimum effective beam diameter in both the scan and index directions. Each virtual probe in the array shall meet the applicable requirements of a conventional probe.

There shall be no more than one dead element in a virtual probe and the array shall not have two adjacent dead elements.

All virtual probes in the array shall exhibit an amplitude response within 1 dB of the mean amplitude.

A virtual probe is defined as a group of individual array elements, pulsed simultaneously or at phasing intervals to generate a larger acoustic aperture.

3.2.2.1.2 Rectangular “Paintbrush” Transducers

Rectangular “paintbrush” transducers shall be allowed for straight beam, immersion initial scanning inspection of plate if it is demonstrated that the transducer provides the required inspection results. The written procedures shall include at least the additional items specified in this section.

A method shall be established for providing a uniform entry surface for the full extent of the sound beam when using test blocks for equipment standardization and adjustments.

A method shall be established for determining a sensitivity profile across the major dimension of the beam to locate the least sensitive area. The scan sensitivity must be established using the least active portion of the transducer at each position of the DAC curve to be used.

A method could be established for masking the ends of the transducer to eliminate over sensitive responses.

Procedures for evaluation of indications detected during scan shall be made using transducers that meet the requirements of 3.2.2.1, including attenuation comparisons.

A procedure for determining effective beam width (major dimensions of the transducer). The scan index shall be based on the beam width so determined.

3.2.2.2 Test Frequencies

The frequency used shall be the highest practical frequency which will provide the penetration and resolution required; frequencies lower than 2.25 MHz when using the longitudinal mode or 1.0 MHz when using a shear mode shall not be used, unless agreed upon by purchaser and inspection source.

3.2.2.3 Ultrasonic Beam Profiles for Immersion Units

The following are recommended, simplified (no special equipment required except a 2.5 to 3 mm ball) methods of finding Y_{+0} (focal length or F_1 per ASTM E1065) and beam profiles. Complete performance parameters of ultrasonic transducers using special equipment are presented in ASTM E1065. Other methods or techniques for obtaining the same or similar data may be used if acceptable to purchaser.

3.2.2.3.1 Axial Beam Profile

The focal length of transducers shall be determined by the manufacturer or user before the transducer is put into service. When focal length measurements are used to determine water path distances without verification during setup, focal length shall be verified on an annual basis. Focal length shall agree with the original value within a tolerance defined by the UT Level 3 for the transducer to be acceptable. This tolerance shall be based on the intended use of the transducer and shall not exceed 20%.

3.2.2.3.2 Cross Section Profile (Beam Symmetry)

Beam symmetry only applies to round transducers. The ratio of beam widths shall be not less than 0.75:1 when measured to the 6 dB points in two directions, 90 degrees apart, across the beam at the Y_{+0} location. The measurements shall be made from energy reflected from a 2.5 to 3.0 mm diameter steel ball. Larger diameter balls may be used when agreed upon by purchaser and vendor.

3.2.2.4 Contact Test Angle-Beam Search Units

The exit point and exit angle of ultrasonic energy and depth profile of the sound beam shall be established for angle-beam search units. Search units with beam angles departing more than ±3 degrees from manufacturer's indicated values shall not be used. Such units may be requalified to a new angle by verifying proper operation and by reidentifying the unit to the correct new beam angle. The International Institute of Welding (IIW) ultrasonic reference block or an appropriate substitute may be used to test the exit angle of angle-beam search units.

3.2.3 Couplant shall be used for all tests.

3.2.3.1 Immersion Method

Couplant for testing by the immersion method may be tap water. Other couplant fluids shall be specified in the procedure. Such fluids may contain wetting agents to improve couplant properties or rust inhibitors to reduce influence of the fluid on the product under test. No fluid may be used which stains, etches, or otherwise affects the surface of the product under test. Any fluid used for immersion testing shall be free of visible air bubbles and shall not exhibit excessive attenuation at the test frequency. The immersion technique is defined to include any liquid delay such as bubblers, collimators, squirters, ultrasonic wheels, and immersion tanks.

3.2.3.2 Contact Method

Couplant for testing by the contact method shall not be injurious to the product being tested. Couplants shall be approved in the test procedure. Table 2 contains a guide for viscosities of comercial couplants or oils for various surface finishes. Rubber-like wear membranes may be used between the search unit and the test part to prevent excessive search unit wear provided such use is approved by purchaser. The contact technique is defined to include direct contact of a search unit with the test surface, use of contour surface wearshoes, and thin-film couplant techniques such as the pressurized fluid (water gap) system.

Table 2 - Couplant viscosity guidance

Approximate Surface Roughness	Couplant Viscosity
5 to 100 Ra (0.1 to 2.5 µm)	SAE 10
50 to 125 Ra (1.2 to 3.2 µm)	SAE 20
100 to 200 Ra (2.5 to 5.1 µm)	SAE 30

3.2.4 Ultrasonic Reference Standards

Ultrasonic reference standards are required for all inspections. Reference standards establish the performance of the inspection system. Reference standards interrelate the test results with reference reflectors. It is mandatory that the materials used for fabrication of ultrasonic references have ultrasonic properties similar to those of the product or part under test. Whenever practical, the ultrasonic references shall be made from the same material and with the same configuration as the part under test.

3.2.4.1 Material

Prior to fabrication, the material used for the ultrasonic reference shall be ultrasonically tested and proven to be free of imperfections that would influence the test. At the frequency selected for the test, the ultrasonic transmission characteristics shall not vary more than ±25% from those of the product or part to be tested.

3.2.4.2 Entry Surfaces

The configuration (surface roughness, flatness) of the ultrasonic reference should approximate that of the product or part to be tested. For testing flat surfaces, flat test blocks shall be used. For testing curved surfaces, use of reference standards with curved entry surfaces shall be required. Generally, curved entry surfaces with radii of 5 inches (127 mm) or greater may be tested using either flat entry surface standards, or curved standards with the curvature ±10% of that of the part being tested. For test surfaces with radii between 2 inches and 5 inches (50.8 mm and 127 mm), a reference standard with a 3 inch (76.2 mm) radius may be used. For test surfaces with radii up to 2 inches (50.8 mm), a reference standard with a 1 inch (25.4 mm) radius may be used. Surface finish of the reference standard shall be the same or rougher to that of the material being tested.

3.2.4.3 Longitudinal Wave Ultrasonic Reference (Straight Beam)

3.2.4.3.1 The procedures established under ASTM E127 are recommended for manufacturing ultrasonic reference blocks for straight beam testing; these specifications describe the manufacture of flat-bottom holes (FBH) in metal alloys.

3.2.4.3.2 Acoustic compatibility between the reference standard material and the material to be tested shall be within 12 dB. If the acoustic compatibility is within 2.5 dB, no gain compensation is required for inspection. If the acoustic compatibility differences are greater than 2.5 dB but less than 12 dB, the instrument sensitivity shall be increased to compensate for the differences in acoustic compatibility. If the acoustic compatibility differences are greater than 12 dB, a different reference standard shall be used. Variations in acoustic response in the material to be tested may exist due to the nature of titanium structure, particularly in large diameter bars and relatively high thickness rectangles. Due to this variation, measurement of acoustic compatibility may be performed as necessary on individual pieces within a lot of material, or sections of those pieces, and instrument sensitivity increased in accordance with those measurements.

3.2.4.3.3 Compare acoustic compatibility by comparing the first unsaturated back reflection from the reference standard and the part being tested. The dB per inch (25.4 mm) comparison using back reflections is also frequently used. Other acoustic compatibility comparison measurements may be used when permitted by purchaser.

3.2.4.3.4 Instrument sensitivity increases may be applied in dB per inch (25.4 mm) for instruments with that capability using the formula: dB correction divided by the sound path to the reflector. Negative attenuation shall only be applied using the dB per inch (25.4 mm) technique.

3.2.4.4 Shear Wave Ultrasonic Reference Standards (Angle Beam)

May be of several distinct types as follows; because of the variety of types and sizes of acceptable shear wave reference standards, the shear wave standard(s) to be used shall be acceptable to purchaser:

3.2.4.4.1 Flat-bottom holes drilled at approximately 45 degrees to the entry surface may be used to test flat surfaces (see Figure 1).

3.2.4.4.2 For testing hollow cylinders, flat-bottom holes drilled in the center of the wall and perpendicular to the radius of the cylinder may be used. Figures 2 and 3 illustrate two types of construction.

3.2.4.4.3 Side-drilled holes (SDH) may be used for shear wave standardization for both flat and curved entry surfaces. A 0.020 inch (0.51 mm) side-drilled hole 0.25 inch (6.4 mm) long is approximately equivalent to a #3 (1.2 mm diameter) FBH, while the same diameter side-drilled hole 0.50 inch (12.7 mm) long is roughly equivalent to a #5 (2.0 mm diameter) flat-bottomed hole (FBH) (see Figure 4). Comparisons of SDH to FBH sensitivity should include consideration of the actual beam diameter intercepting the SDH. For example, if the beam diameter is only 0.25 inch (6.4 mm), then the sensitivity would be approximately equivalent to a #3 FBH even if the SDH is 0.5 inch (12.7 mm) long.

3.2.4.4.4 Various styles of notches may be used; these include V-notches, usually with a 60-degree included angle, square, or “U” bottomed notches, and slots. The sizes of the notches are generally equated to the test area thickness (typically, 1 inch (25.4 mm) maximum length x 3% of the part thickness) or the notch area is equated to a flat-bottom hole area; as an example, a 5/64 inch (2.0 mm) FBH has an area of 0.0047 in^2 (3.03 mm^2) and a slot with a depth of 0.050 inch (1.27 mm) and a length of 0.10 inch (2.5 mm) has an area of 0.005 in^2 (3.2 mm^2); therefore, the notch and FBH are approximately equal.

3.2.4.5 Special Ultrasonic References

Where the part geometry dictates the need for using the actual part or part replica as an ultrasonic reference, all simulated defects shall be machined in accordance with the practices specified for longitudinal and shear wave inspection. Ultrasonic references made from actual parts or part replicas are recommended wherever practical. The standard design shall be subject to approval by the purchaser.

3.3 Surface Preparation

Visual examination shall be performed on each part to ensure that sound beam entry surfaces are free from loose scale, oxides, oil, grease, machining or grinding particles, excessive machining or grinding marks, and other surface conditions that could interfere with the sound beam and affect the test. Surface textures for machined parts shall be determined in accordance with ASME B46.1. Surfaces to be inspected shall be not rougher than 63 µin (1.6 µm) for Class AA. Classes A1 and A longitudinal wave tests and most shear wave tests require surfaces no rougher than 125 µin (3.2 µm). A surface texture up to 250 µin (6.35 µm) is acceptable for testing to Class B. Surface textures for testing to Class C become part of the Class C agreement. Unmachined part surfaces should have a texture approximately equivalent to that of machined surfaces as required for each class. When permitted by purchaser, inspections may be made on surfaces that are rougher than those specified herein, provided that the ultrasonic reference standards have a comparable surface finish. Sound beam exit surface (back face) requirements vary greatly, dependent on the tests performed. Some tests require back reflection surfaces to meet conditions similar to those required for the entry surfaces while on other types of parts, particularly fabrications and castings, it may be impractical to change the surface quality and in some cases it may even be impossible to examine the exit surface.

3.4 Testing Procedure

3.4.1 Written Procedure

Ultrasonic inspections performed in accordance with this specification shall be detailed in written procedures. Unless otherwise specified, procedures shall be prepared by the vendor and shall be subject to approval by the purchaser. Procedures shall identify the type of ultrasonic equipment, method(s) of test, ultrasonic test reference, search unit type, style, frequency, method of reporting indications, and all other instructions that pertain to the actual test. Procedures shall be detailed sufficiently such that another investigator could duplicate the test and obtain equivalent information.

3.4.2 Documentation

Shall provide for the complete inspection procedure for each product (size, shape, and alloy) or part to be inspected. Documentation format is flexible, but sketches, photographs, and graphics are recommended wherever practical. Because of the variety and complexity of tests that can be performed, the documentation of the inspection plan and the methods of recording and interpreting results become very important. This specification is not intended to restrict documentation beyond that which provides valid and reproducible quality control tests. As a minimum, the procedure shall specify:

3.4.2.1 Specific product or specific part number (where applicable), stage of fabrication, surface condition, and configuration of the product to be tested.

3.4.2.2 Manufacturer and model numbers of instrumentation modules, recording equipment if used, fixturing, tanks, manipulators, and coupling means used in the test.

3.4.2.3 The type of ultrasonic references used to standardize equipment and the standardization procedure.

3.4.2.4 Testing plan, including the recording procedures, scanning plan, sensitivity, method of interpreting results, and relationship to ultrasonic references.

3.4.2.5 Name and address of testing facility.

3.4.3 Testing System

3.4.3.1 The product or part may be inspected by longitudinal or shear wave techniques or a combination of techniques as will most appropriately disclose material imperfections.

3.4.3.2 All equipment used for the tests, such as ultrasonic test instrument, ultrasonic search units, ultrasonic references, recording system, and electronic gates, shall be assembled in one location and evaluated as a complete system. Once assembled, they shall remain together as part of the test equipment until the tests are completed. Any substitution of electronic gates, displays, search units, and other similar equipment for any reason shall require re-standardization of the complete system.

3.4.4 Qualification Standardization of Test System

Before inspecting any product or part, the test system shall be qualified by adjusting the sensitivity, pulse duration, damping, or other external controls so that the signals reflected from known discontinuities in appropriate ultrasonic references can be clearly identified as separate and discrete indications. During initial standardization, signal amplitude (sensitivity) from a known reference discontinuity may be set within the range of 20 to 90% of the vertical height of the display. Sensitivity may be increased during test by a predetermined decibel level to ensure an adequate test; however, when interpreting results, the sensitivity shall be returned to the original setting.

3.4.4.1 Standardization Record

When permanent c-scan records are established as part of the test plan, standardization of the test system shall include a record of the appropriate ultrasonic reference reflector. This shall be at a minimum the reflector with the smallest effective beam width.

3.4.4.2 Standardization Check

To ensure valid results, a standardization check shall be made prior to the test of each part configuration or start of each shift of operation and at the completion of each inspection lot or shift, as appropriate. Standardization checks performed at the start of an immediately subsequent shift shall satisfy end of shift requirements.

For this requirement, testing shifts shall not exceed 8 hours.

At the completion of an inspection shift or lot, the amplitude of each reference reflector shall be verified to be within ±10% of reference level. If any response is undersensitive by greater than 10%, all material since the last standardization shall be re-inspected. If any response is oversensitive by greater than 10%, all rejected indications since the last standardization may be re-evaluated.

During standardization checks, sensitivity shall be adjusted to reference level when found to be different from the reference level.

3.4.5 Immersion Inspection

3.4.5.1 Immersion Fluid shall be as specified in 3.2.3.1.

3.4.5.2 Longitudinal (Straight) Beam Testing

The sound beam entry angle shall be adjusted until the sound beam is perpendicular to the test surface. Where appropriate, the maximum signal amplitude from the entry surface may be used to determine this condition. Where not appropriate, e.g., a highly focused search unit, an alternate procedure such as multiple reflections may be used. During testing, the angle established shall not vary more than ±2 degrees. When contoured parts are being inspected, a surface or contour follower may be employed so that the surface entry angle is maintained perpendicular within ±2 degrees.

3.4.5.3 Angle Beam Testing

Products may be inspected with both longitudinal and shear wave motions at preselected angles. Once established, the surface entry angle shall not vary more than ±2 degrees.

3.4.5.4 Water Path

When practicable, the test shall be standardized and run using water paths that result in inspection being performed in the far field. A variety of sound beams, ranging from collimated to highly focused, may be used. Special interpretation of test results may be necessary to characterize the discontinuity. A variety of test zones are possible but changing the test zone by varying the water path during test may present serious complications. During the test, the established water path (i.e., the distance from the face of the search unit to the entry surface) shall not vary more than ±0.25 inch (±6.4 mm) from that used for standardization.

3.4.6 Contact Testing

3.4.6.1 Angle Beam Testing

The sound beam entry angle and the testing mode shall be established as part of the test procedure. The search unit qualification tests will establish the exit point and angle of exit. If wear of contact shoes or search unit results in a change in sound beam entry angle of more than ±3 degrees from the established angle, that search unit shall be replaced, repaired, or requalified to a new angle in accordance with 3.2.2.4. The wedge or contact shoes shall be examined visually for signs of poor contact between the transducer piezoelectric element and wedge or shoe. At any sign of insufficient coupling, the search unit assembly shall be taken apart, the contact surfaces cleaned, new couplant applied, and the unit reassembled.

3.4.6.2 Straight Beam Testing

Search unit qualification tests shall establish the sound beam character for the straight beam search unit. Visual inspection of the search unit shall be made to verify that the wear face surface is intact. Periodic visual inspections shall be made during tests to ensure that the search unit facing has not degraded. Any cracking, chipping, break-up, or uneven wear conditions shall disqualify the search unit and the test.

3.4.7 Special Testing

3.4.7.1 Surface Wave

Special attention shall be given to ensuring surface cleanliness before and during a surface wave test. Every precaution shall be exercised to remove excess couplant, foreign material, and other matter that could influence the test.

3.4.7.2 Dual Search Units

For high-resolution, near-zone testing, dual search unit techniques may be used. The qualification for dual search unit shall be the same as for contact testing. If wear of the search unit results in a change in sound beam entry angle greater than ±3 degrees, the search unit shall be removed from service and replaced or repaired.

3.4.8 Distance Amplitude Correction (DAC)

Electronic distance amplitude correction is recommended; however, distance amplitude curves plotted on the display using distance amplitude reference blocks may be used if the minimum signal height is not less than 20% and the maximum signal height is not greater than 80% of the vertical limit. For signal heights greater than 80%, the DAC curve is extended parallel to the baseline at a predetermined vertical limit level, usually 80%. Multiple curves shall be established for those areas above the predetermined level to properly evaluate discontinuities in the area. Testing using the highest sensitivity from the distance amplitude reference blocks and evaluating to the proper metal travels is also permitted provided noise levels do not obscure required information.

3.4.9 Electronic Alarm Gating and Recording

Wherever possible and practical, automatic alarms shall be used. Automatic recording of test results may be used but is not required except as a special requirement that should be agreed upon by purchaser and vendor.

3.4.9.1 Electronic Gating

3.4.9.1.1 Electronic gating shall be used for immersion inspections.

3.4.9.1.2 At the instances required in 3.4.4.2, detection of the ultrasonic reference standard reflector exhibiting the smallest effective beam diameter shall be dynamically detected at planned operating speeds and instrument settings.

3.4.9.1.3 When a dynamic check of the reference standard is not possible, the procedure shall document how scan speed and pulse repetition rate are controlled to assure detection of indications exceeding evaluation level. Actual scan speed shall not exceed the scan speed as determined in both 3.4.9.1.4.1 and 3.4.9.1.4.2.

3.4.9.1.4 Determine the maximum scanning speed (S), using Equations 1 and 2, based on smallest effective beam width (EBW) as determined in 3.5.3.1 or 3.5.3.2, the pulse repetition rate (PRR), the number of times the reference standard FBH with the smallest effective beam width is to be detected (N), and the monitor count function (C). Note (N) is equal to a minimum of 2.

3.4.9.1.4.1 The monitor count function is a control available in some instruments that allows the user to set up the number of alarm pulses that must be present before an alarm circuit provides a positive alarm output. For instruments that do not have this control, C = 1.

$$S = \frac{(EBW \times PRR)}{(N \times C)} \quad \text{(Eq. 1)}$$

3.4.9.1.4.2 Measure the EBW in the scan direction on all FBHs used for setup. Determine the maximum scanning speed (S) based on the pulse repetition rate (PRR) and EBW as measured in the scan direction (EBWS).

$$S = EBWS \times PRR \quad \text{(Eq. 2)}$$

3.4.9.2 Recording

When permanent recording of the test is used, documentation of the recorders ability to dynamically detect indications at the maximum operating speed of the system shall be documented.

3.4.9.3 Scanning Index

In determining the index for 100% coverage, the effective beam width (EBW) shall first be measured. Using the assigned reference standards, proper standardization gains, and water travel; measure the traversing distance across the reference reflectors according to the alarm level to be used. When the alarm level is to be set at 50% of the response height from the reference reflector, measure the EBW through which no less than 50% of the reference response is obtained. When the alarm level is set higher than 50%, but less than 80% of the response from the reference reflector, measure the EBW through which no less than a response equal to the (alarm level/reference amplitude) of the reference response is obtained. Do not set the alarm level higher than 80% of the reference response. This distance will vary for each reference reflector, dependent on the metal travel to the test hole. The least of the distances is the EBW. The maximum default scanning increment shall not exceed 70% of the EBW. Scanning increments up to 80% of EBW may be used when 100% scan coverage is documented per 8.4 and Figure 5.

3.4.9.4 Scan Speed

Maximum scanning speed shall be determined by readability or recordability of the applicable ultrasonic reference. At the maximum speed used, the reference discontinuities shall be clearly discernible. If distortion related to scanning speed is observed, the scan speed shall be reduced until distortion is eliminated.

For automated scanning with alarms or recording, the maximum surface speed shall be 20 inches (508 mm) per second. Higher speeds may be used when the procedure defines the criteria for pulse repetition rate to be used in determining the scan coverage per 3.4.9.3, or the dynamic check of 3.4.9.1.2 is performed.

For manual scanning and visual reading of the display, the maximum surface speed is 6 inches (152.4 mm) per second. Higher scanning speeds may be possible and, when suitably demonstrated, may be used when agreed upon by purchaser and vendor.

3.4.9.5 Gain Settings for Scanning

For automatic scanning inspection, the gain setting as established from the ultrasonic reference shall be used. The alarm shall be set to activate at a signal level equal to that determined in 3.4.9.3 for the material zone being inspected. If electronic distance amplitude correction (DAC) is employed, alarm activation level shall be set at that determined in 3.4.9.3. For manual scanning which monitors the amplitude of reflections from internal discontinuities, the gain level from the ultrasonic reference shall be established and 6 dB added, provided the added sensitivity does not increase the noise level more than the alarm level determined in 3.4.9.3. When alarm systems are used with manual scanning, the alarm trigger level is normally set as for automatic scanning and it is not necessary to add extra sensitivity.

4. QUALITY ASSURANCE PROVISIONS

4.1 Acceptance Classes

4.1.1 Longitudinal Wave Inspection Using Flat-Bottom Holes (FBH)

Five classes of ultrasonic quality are established for longitudinal wave inspection. Table 3 defines these classes for inspections involving flat-bottom hole reflectors in ultrasonic references. In the event the hole diameter for the applicable class is not available, adjustments mey be made to the sensitivity in decibles in accordance with Table 4.

Table 3A - Longitudinal wave inspection parameters, inch/pound units

Quality Class	Single Discontinuity FBH Size[1]	Multiple Discontinuities FBH Size[1]	Linear Discontinuity Inches, Max	Loss of Back Reflection %, Max
AA	#3	#1[2]	#1 response for 0.12	50
A1	#3	#2[3]	#2 response for 1.00	50
A	#5	#3	#3 response for 1.00	50
B	#8	#5	#5 response for 1.00	50
C	As established by purchaser and vendor for specific part.			

[1] FBH numbers indicate diameter in multiples of 1/64 inch of FBH in ultrasonic reference.
[2] 11% of a #3 FBH is equivalent to a #1 FBH and may be used in place of the response from the #1 FBH.
[3] 44% of a #3 FBH is equivalent to a #2 FBH and may be used in place of the response from the #2 FBH.

Table 3B - Longitudinal wave inspection parameters, SI units

Quality Class	Single Discontinuity FBH Size[1]	Multiple Discontinuities FBH Size[1]	Linear Discontinuity Millimeters, Max	Loss of Back Reflection %, Max
AA	1.2	0.4[2]	0.4 response for 3.0	50
A1	1.2	0.8[2]	0.8 response for 25	50
A	2.0	1.2	1.2 response for 25	50
B	3.2	2.0	2.0 response for 25	50
C	As established by purchaser and vendor for specific part.			

[1] Diameter of flat-bottom hole in millimeters.
[2] Percentage equivalents of the 1.2 mm FBH may be used. See Notes 2 and 3 in Table 3A.

Table 4 - dB conversion for FBH size

To FBH Diameter	From FBH Diameter							
		1/64	2/64	3/64	4/64	5/64	6/64	8/64
1/64	**0**	+12	+20	+24	+28	+31	+36	
2/64	-12	**0**	-7	+12	+16	+19	+24	
3/64	-20	-7	**0**	+5	+9	+12	+17	
4/64	-24	-12	-5	**0**	+4	+7	+12	
5/64	-28	-16	-9	-4	**0**	+3	+8	
6/64	-31	-19	-12	-7	-3	**0**	+5	
8/64	-36	-24	-17	-12	-8	-5	**0**	

dB change = 20*log(A1/A2), where A1 and A2 are the area of the respective FBHs.

4.1.1.1 Any discontinuity with a signal indication greater than allowed for the specific class shall disqualify the part for that class.

4.1.1.2 Multiple discontinuities with indications greater than the response from a reference flat bottom hole at the estimated discontinuity depth of the size given are not acceptable if the centers of any two of these discontinuities are less than 1 inch (25.4 mm) apart.

4.1.1.3 Loss of unsaturated back reflection pattern greater than 50%, when compared with non-defective material in the same, similar, or like product, is not acceptable when this loss of back reflection pattern is accompanied by any increase in signal, at least double the normal background noise signal, between the front and back surfaces.

4.1.2 Angle Beam Tests Using Flat-Bottom Holes (FBH)

Five classes of ultrasonic quality are established for angle beam inspection, in either shear or longitudinal modes, which involves flat-bottom holes for ultrasonic reference reflectors. Table 5 defines these classes.

Table 5A - Angle beam ultrasonic inspection parameters, inch/pound units

Quality Class	Single Discontinuity FBH Size[1]	Multiple Discontinuities FBH Size	Linear Discontinuity Inches, Max
AA	#2	50% of #2 response	50% of #2 response for 0.12
A1	#3	#2	#2 response for 0.25
A	#5	#3	#3 response for 0.50
B	#8	#5	#5 response for 1.00
C	As established by purchaser and vendor for specific part.		

[1] FBH numbers indicate diameter in multiples of 1/64 inch of FBH in ultrasonic reference.

Table 5B - Angle beam ultrasonic inspection parameters, SI units

Quality Class	Single Discontinuity FBH Size[1]	Multiple Discontinuities FBH Size	Linear Discontinuity Millimeters, Max
AA	0.8	50% of 0.8 FBH response	50% of 0.8 FBH response for 3.0
A1	1.2	0.8 FBH	0.8 FBH response for 6.4
A	2.0	1.2 FBH	1.2 FBH response for 12.7
B	3.2	2.0 FBH	2.0 FBH response for 25.4
C	As established by purchaser and vendor for specific part.		

[1] Diameter of flat bottom hole in millimeters.

4.1.2.1 Any discontinuity with a signal indication greater than allowed for the specific class shall disqualify the part for that class.

4.1.2.2 Multiple discontinuities with indications greater than the response from a reference flat-bottom hole or equivalent notch 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 inch (25 mm) apart.

4.1.3 Angle Beam Testing Using Reference Notches

The acceptance classes used to determine quality levels using various types of notches or side-drilled holes shall be as agreed upon by purchaser and vendor.

4.2 Disposition

4.2.1 Product exhibiting evaluated indications not in excess of limits for its specified quality class may be accepted without remedial operations.

4.2.2 Product exhibiting evaluated indications in excess of limits for its specified quality class, but in a location which will be removed during manufacturing operations, may be approved by the cognizant quality assurance activity for acceptance.

4.2.3 Product containing discontinuities in excess of limits for its specified quality class and not covered by 4.2.2 shall be rejected.

4.3 Records

4.3.1 General

The testing source shall prepare and maintain on file, for the time specified by purchaser, records of the requirements and techniques for either each size and configuration of product and of each part number or general records covering families of products. These records shall be made available for inspection by purchaser upon request.

4.3.2 Personnel Qualifications

It shall be verified that all inspections are performed by personnel qualified as in 3.1.1. A list of qualified personnel shall be maintained for purchaser's review upon request.

4.3.3 Instrument and System Qualification

It shall be verified that the instrument and system used in the inspection meet the requirements set forth herein.

4.3.4 Search Unit Qualification

Documentation regarding the qualification of search unit performance shall be maintained. Qualification tests shall be related to the time of actual test.

4.3.5 Procedure Verification

Copies of the written testing procedure shall include the type and response of the ultrasonic reference to be used and shall be maintained as part of the documentation. The procedure shall be reviewed periodically by vendor's cognizant supervisor to ensure that inspection is in compliance with this specification.

5. PREPARATION FOR DELIVERY

Not applicable.

6. ACKNOWLEDGMENT

A vendor shall mention this specification number its revision letter, and acceptance class in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Product not inspected in accordance with this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

8.1 Revision Indicator

A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Test Conditions

It is essential that thorough understanding be developed between purchaser and vendor regarding interpretation of the results of inspection and how they shall be recorded and reported. Ultrasonic indications may appear which do not reflect conditions detrimental to use of the product. Purchaser and vendor should establish agreement on the following parameters prior to acceptance testing:

Surface finish
Internal structure
Location and extent of areas to be scanned and applicable quality class
Size of transducer and type of search unit
Test frequency
Type and grade of couplant
Method of standardization of equipment

8.3 Distance Amplitude Correction

The following discussion relates to and defines terms and procedures recommended in 3.4.8.

8.3.1 Distance Amplitude (DA) Curve

The ultrasonic sound beam propagated from the search unit will vary in accordance with physical laws. Specific size holes at different depths within the material will reflect proportionately different energies and the display will record a corresponding progression of signal amplitudes. The curve plotted on the display is referred to as the distance amplitude (DA) curve.

8.3.2 Distance Amplitude Correction (DAC) Circuitry

To normalize the inherent influence resulting from the distance amplitude curves, electronic circuits known as distance amplitude corrections (DAC) are employed. These electronic circuits provide a variable gain versus depth function which normalizes the distance amplitude curve signals displayed on the display to a preselected amplitude.

8.3.3 Applications

8.3.3.1 DA curves and DAC circuitry may be utilized for straight-beam, angle-beam, and surface-wave tests. A minimum of three points are required to establish a DA curve; two points are acceptable for round bar under 2 inches (50.8 mm) diameter. When the DA curve is used, the maximum amplitude point on the curve should not exceed 80% and the minimum point should be not less than 20% of the maximum vertical deflection displayed on the CRT. If these limits cannot be maintained, multiple curves should be used to cover the range of material being inspected. Once the DA curve is established for an appropriate set of ultrasonic references, reflections may be recorded as percentages of this curve or the sensitivity may be adjusted to establish a ±dB relationship between the unknown discontinuity and the known reference.

8.3.3.2 For automatic recording systems, use of DAC circuitry is recommended. Care should be exercised to ensure that the DA curve falls within the linear sensitive range of the electronic recording gate; 50% vertical amplitude display is recommended.

8.3.3.3 DA curves are applicable to focused and non-focused search units but are not as accurate for testing in the near field of the search unit.

8.4 Commentary on Scan Coverage

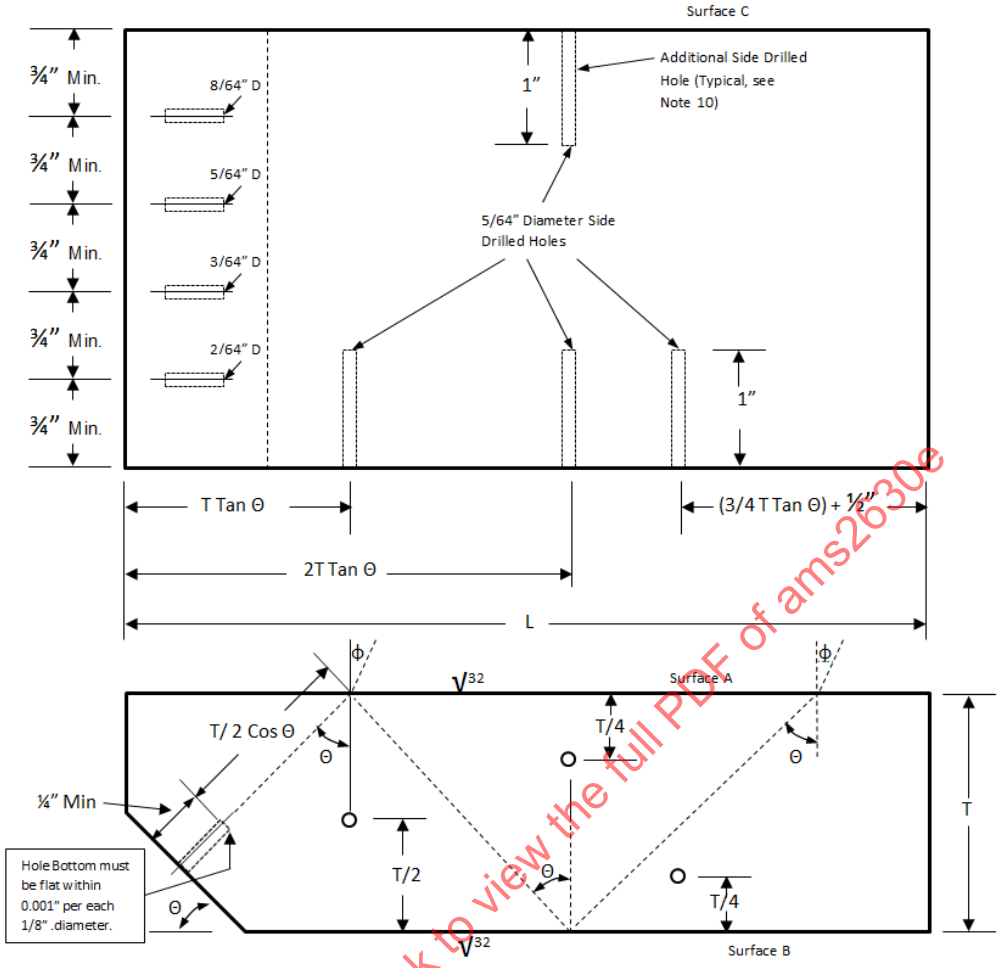
8.4.1 Figure 5 is a coverage diagram for spherically focused transducers showing unacceptable gaps of under-inspection and acceptable coverage with no gaps.

8.4.2 For cylindrical focus and paintbrush transducers, the different beam profiles shall be considered.

8.4.3 For inspections where beam width measurement in the scan direction cannot be performed, the dynamic check of 3.4.9.1.2 shall be used to verify adequate scan direction coverage. An example would be some helical bar testing systems where beam width can be measured for the index direction but the beam width in the circumferential direction is not encoded and cannot be measured.

8.5 Terms used in AMS are clarified in ARP1917.

8.6 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.



Note: All dimensions are in inches unless otherwise stated.

Thickness (t), of Part of Material to be Tested	T t= Part Thickness	L Minimum (inches)
Up to and including 1 inch	3/4 inches or t	(3 T Tan Θ +1)
Over 1 inch to 2 inches	1 - 1/2 inches or t	
Over 2 inches to 4 inches	3 inches or t	
Over 4 inches to 6 inches	5 inches or t	
Over 6 inches	t + 1 inches	

(1) A block fabricated with flat-bottom holes with diameters as shown will cover all classes in this practice. A narrower block with fewer holes may be used if the block is to be used for a fewer number of classes.
(2) Side-drilled holes (SDH) shall not be used for T less than 3⁄4 inch.
(3) A shorter block than shown may be used for thicker materials when only 1⁄2 or 1 vee-path examining distance is to be used. For shorter reference blocks the SDHs shall be relocated along L so that each hole lies at least 3⁄4 inch from all sound beam paths used for other holes.
(4) D = hole diameter for applicable class.
(5) Θ is the nominal angle ±2 degrees of the sound beam in the part with respect to the normal to the sound entry surface.
(6) ϕ is the angle of the entering sound beam with respect to the normal to the sound entry surface.
(7) All dimensions are in inches.
(8) All dimensions ±0.03 inch except for hole diameters which are ±3% of diameter specified.
(9) Surface A and Surface B must be flat and within 0.001 inch per inch.
(10) For blocks thicker than one inch, additional 5⁄64-inch diameter side-drilled holes shall be drilled from Surface C with the axes of these holes located 1⁄4 inch, 1⁄2 inch, 1 inch, 1-1⁄2 inch, 2 inch, etc. from surface A until the T/4 distance is reached. No specific location along L is required for these holes except that they shall be located at least 3⁄4 inch from the sound beam paths used for the flat bottom hole and at least 3/8 inch from sound beam paths used for other side-drilled holes.
(11) All holes shall be permanently plugged in a manner to ensure that they are water-tight and that an air-metal interface is preserved.

Figure 1A - Standard ultrasonic test block for angle beam examination, inch/pound units