AEROSPACE MATERIAL SPECIFICATION	AMS2632™	REV. C
	Issued 1974-03 Reaffirmed 1995-03 Revised 2022-06 Superseding AMS2632B	

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

RATIONALE

AMS2632C is the result of a Five-Year Review and update of the specification. The revision updates reference specifications (3.2.4.3.1, 3.3, 8.6), updates Figure 7 to be consistent with other AMS-UT specifications, adds Figure 8 as an example and adds reference to it (3.2.4.7.1, 3.2.4.7.2), and deletes recording of UT references (4.3.5) to standardize between other AMS-UT specifications.

1. SCOPE

1.1 Purpose

This specification covers the procedure for ultrasonic inspection of flat, contoured, round, and hollow cylindrical products having a cross-sectional thickness of 0.02 to 0.50 inch (0.5 to 12.7 mm). This specification does not apply to inspection of composite materials.

1.2 Application

This process 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 form 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.

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.

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

AMS5070 Steel, Bars and Forgings, 0.18 - 0.23C (SAE 1022)

AS7766 Terms Used in Aerospace Metals Specifications

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 E213 Ultrasonic Inspection Testing of Metal Pipe and Tubing

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

ASTM E1065 Evaluating Characteristics of Ultrasonic Transducers

ASTM E1316 Standard Terminology for Nondestructive Examinations

2.3 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS410 Certification and Qualification of Nondestructive Test Personnel

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, Inc., 1711 Arlingate Plaza, Caller #28518, Columbus, OH 43228-0518, https://www.asnt.org/.

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

2.6 Airlines for America (A4A) Publications

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

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

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 by 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. The ultrasonic test facility equipment shall include, but not be limited to, the basic ultrasonic test instrument, transducers, appropriate ultrasonic references, couplant materials, fixtures, reference specifications, immersion tanks where applicable, and documentation necessary to verify the qualification of equipment and test personnel.

3.2 Ultrasonic Test System

3.2.1 Basic Ultrasonic Test Instrument

Shall be capable of producing, receiving, amplifying, and displaying high-frequency signals at specific frequencies as required by the ultrasonic test. The ultrasonic instrument shall be of a pulse-reflection (echo), pulse-transmission type capable of operation at frequencies from 2.0 to 10.0 MHz. The instrument shall be capable of being adapted with electronic circuitry, such as flaw gates, distance amplitude corrections, and alarms, that can aid in testing and interpretation of flaw signals. The instrument shall have a minimum dynamic range of 30 dB and shall have a transmit/receive crosstalk separation of at least 40 dB.

3.2.1.1 Instrument Requirements

The instrument performance characteristics shall be evaluated in accordance with ASTM E317 as follows:

Table 1 - Instrument performance requirements

Characteristic	Requirement
Signal to noise[(1)]	2:1
Vertical linearity	±5%
Horizontal linearity	±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 Transducers

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

3.2.2.1 Transducer Dimension and Styles

3.2.2.1.1 For testing thin materials, a variety of contact and immersion styles may be used. The choice is dependent on the test and the approved test procedure. Immersion flat and focused, contact, angle beam, liquid delay, phased array, and pressurized-couplant transducer systems may be used.

3.2.2.1.2 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.

3.2.2.1.3 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.

A procedure for evaluation of indications detected during scan shall be made using transducers that meet the requirements of 3.2.2.1.1.

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

No specific restrictions are imposed; however, use of frequencies below 5 MHz for longitudinal wave inspection shall be approved by purchaser prior to testing.

3.2.2.3 Ultrasonic Beam Profiles

For immersion testing, the waterpath used shall assure that testing is performed in the far field, past the Y_0 point. 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 empirical 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 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 ball target. Larger diameter balls may be used when agreed upon by purchaser and vendor.

3.2.2.3.3 For contact testing and immersion tests performed in the near zone, the exit point and exit angle of ultrasonic energy and depth profile of the sound beam shall be established for angle-beam transducers. Transducers 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 re-identifying the unit to the correct new beam angle. The International Institute of Welding (IIW) ultrasonic reference block (see Figure 1) or an appropriate substitute may be used to test the exit angle of angle-beam transducers. The history of an angle-beam transducer shall include the type, style, size, frequency, serial number, and vendor or receiving acceptance tests.

3.2.3 Couplants

Couplants shall be used for all tests.

3.2.3.1 Immersion

Couplant for immersion 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 material under test. No fluid may be used which stains, etches, or otherwise affects the surface of the material 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, columnators, squirters, ultrasonic wheels, and immersion tanks.

3.2.3.2 Contact

Couplants 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 commercial couplants or oils for various surface finishes. Rubber-like wear membranes may be used between the transducer and the test part to prevent excessive transducer wear provided such use is approved by purchaser. The contact technique is defined to include direct contact of a transducer 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 References (Standards)

Ultrasonic reference standards are required for all inspections to establish the performance of the inspection system and to interrelate the test results with reference reflectors. Because thin material testing involves many special problems in various type of materials, it is mandatory that the materials used for fabrications of ultrasonic references have the same ultrasonic properties as 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, of surface roughness, flatness, or contour, of the ultrasonic reference should approximate that the product or part to be tested. When product or part radius of curvature is less than 5 inches (127 mm), it may be necessary to use a curved surface ultrasonic reference to establish the operating parameters of the test. Requirement for a curved reference depends on type of test, direction of test, and size of transducer (see 3.2.4). The procedure used shall resolve the near surface FBH to a level of 6 dB from the front reflection.

3.2.4.3 Straight Beam Ultrasonic References

3.2.4.3.1 Where the part thickness is greater than 0.125 inch (3.18 mm), the procedures established under ASTM E127, shall be used for manufacturing ultrasonic references for straight beam testing; these specifications describe the manufacture of flat-bottom holes (FBH) in aluminum alloys and other materials. Use of more compatible material is required where the ultrasonic transmission characteristic differs from that of the product to be tested by more than 25%.

3.2.4.3.2 Ultrasonic references may be made from thin materials, e.g., 0.125 inch (3.18 mm) or less, by drilling appropriate flat-bottom holes of appropriate sizes and depths. The specifications for the flat-bottom hole remain the same as described in the ASTM specifications; only the material thickness requirement is altered.

3.2.4.4 Angle Beam Ultrasonic References

For flat product with a part thickness of 0.5 inch (12.7 mm) and under, ultrasonic references in accordance with Figure 2 are required. The reference which most nearly approximates the product or part under test shall be used. Ultrasonic references may be made in a variety of thicknesses; however, a minimum of three are required to cover the range. Tables 3A and 3B describe the applicable dimensions. Use of notches for angle beam ultrasonic reference blocks is preferred.

Table 3A - Angle beam inspection parameters, inch/pound units

Reference Thickness, T Inches	FBH(1) A	FBH(1) B	FBH(1) C	FBH(1) D	Notches(2) E	Notches(2) F	Notches(2) G	Notches(2) H
0.50	#2	#3	#5	#8	0.02D(4) 0.04L	0.03D 0.05L	0.05D 0.10L	0.08D 0.16L
0.25	#2	#3	#5	#8	0.02D 0.04L	0.03D 0.05L	0.05D 0.10L	0.08D 0.16L
0.125	#2	#3	#5	NA(3)	0.02D 0.04L	0.03D 0.05L	0.05D 0.10L	NA NA

(1) Flat-bottom hole (FBH) numbers are based on 1/64 inch diameter hole progression, i.e., #1 means 1/64 inch and #8 means 8/64 inch diameter flat-bottom holes.
(2) Notches are to be generated by electrodischarge machining (EDM) techniques and shall have a maximum width of 0.01 inch. All other dimensions are to be ±0.002 inch. Notches shall be perpendicular to part surface within ±2 degrees.
(3) NA = Not applicable.
(4) D = depth of notch and L = length of notch in inches.

Table 3B - Angle beam inspection parameters, SI units

Reference Thickness, T Millimeters	FBH(1) A	FBH(1) B	FBH(1) C	FBH(1) D	Notches(2) E	Notches(2) F	Notches(2) G	Notches(2) H
12.7	0.8	1.2	2.0	3.2	0.51D(4) 1.02L	0.76D 1.27L	1.27D 2.54L	2.03D 4.06L
6.4	0.8	1.2	2.0	3.2	0.51D 1.02L	0.76D 1.27L	1.27D 2.54L	2.03D 4.06L
3.18	0.8	1.2	2.0	NA(3)	0.51D 1.02L	0.76D 1.27L	1.27D 2.54L	NA NA

(1) Diameter of flat-bottom hole in millimeters.
(2) Notches are to be generated by electrodischarge machining (EDM) techniques and shall have a maximum width of 0.25 mm. All other dimensions are to be ±0.05 mm. Notches shall be perpendicular to part surface within ±2 degrees.
(3) NA = Not applicable.
(4) D = depth of notch and L = length of notch in millimeters.

3.2.4.5 Ultrasonic References for Inspection of Hollow Cylinders

For cylinders of 5 inches (127 mm) radii and greater, the flat ultrasonic references outlined in 3.2.4.3 and 3.2.4.4 are suitable. Where radius of curvature is less than 5 inches (127 mm), the following procedures shall apply:

3.2.4.5.1 Circumferential Shear Inspection

For product and parts 0.125 inch (3.18 mm) and under in thickness, an EDM, or end mill notch or an equivalent reflecting surface shall be used as an ultrasonic reference. Notches shall be generated axially and be perpendicular to the part surface within ±2 degrees. Replicating techniques or their equivalent shall be used to establish perpendicularity. Notch sizes shall be as shown in Table 4 (see Figure 3). Both ID and OD notches may be necessary to ensure full inspection of critical parts. The ultrasonic references for materials 0.125 to 0.50 inch (3.18 to 12.7 mm) thickness shall use flat-bottom holes as reference targets. Target holes shall be placed in the appropriate cylindrical references as shown in Figure 4. Hole sizes shall be as shown in Tables 4A and 4B.

Table 4A - Hole and notch sizes for circumferential shear ultrasonic references, inch/pound units

Material Thickness (T) Inch	FBH A	FBH B	FBH C	FBH D	Notches E	Notches F	Notches G
0.50	#2	#3	#5	#8	--	--	--
0.25	#2	#3	#5	--	--	--	--
0.125 and under(1)	--	--	--	--	0.02D 0.04L	0.03D 0.05L	0.05D 0.10L

(1) Notches for material 0.125 inch and under in thickness are rectangularly dimensioned. When end mill or saw cuts are used, make the reflectors equal in area for each specific size.

Table 4B - Hole and notch sizes for circumferential shear ultrasonic references, SI units

Material Thickness (T) Millimeters	FBH A	FBH B	FBH C	FBH D	Notches E	Notches F	Notches G
12.7	0.8	1.2	2.0	3.2	--	--	--
6.4	0.8	1.2	2.0	--	--	--	--
3.18 and under(1)	--	--	--	--	0.51D 1.02L	0.76D 1.27L	1.27D 2.54L

(1) Notches for material 3.18 mm and under in thickness are rectangularly dimensioned. When end mill or saw cuts are used, make the reflectors equal in area for each specific size.

3.2.4.5.2 Axial Shear Inspection

For product or parts 0.125 inch (3.18 mm) and under in thickness, EDM notches or equivalent reflecting surfaces shall be used. Notches shall be generated circumferentially and be perpendicular to the surface within ±2 degrees. Notch sizes listed in Table 4 shall apply (see Figure 5). Both ID and OD notches may be necessary for full inspection of critical parts. For parts with thickness over 0.125 inch (3.18 mm), the flat-bottom hole shall be used as the target (see Figure 6). Flat-bottom holes shall be placed axially in the cylinder wall and shall be of the sizes specified in Table 4.

3.2.4.6 Surface Wave Inspection

Ultrasonic references for surface wave inspection shall use EDM notches as reference targets. Notches shall be made perpendicular to the inspection surface within ±2 degrees and shall be placed to intersect the ultrasonic beam perpendicular to its projection axis. The sound entry surface shall have a surface roughness of 32 µin (0.8 µm) or smoother. No specific notch sizes are specified; the procedures agreed upon by purchaser and vendor for a particular inspection shall apply. However, the notches specified in Table 3 could be appropriate for flat materials and the notches specified in Table 4 could be appropriate for curved sections.

3.2.4.7 Ultrasonic References for Inspection of Round and Flat Bar

3.2.4.7.1 Straight beam inspection standards shall utilize FBH reflectors. A minimum of one reflector between 1/2 thickness and the back wall is required. An example standard is shown in Figure 8.

3.2.4.7.2 Angle beam inspections shall utilize EDM notches as reference targets. Notches shall be made perpendicular to the inspection surface within ±2 degrees and shall be placed to intersect the ultrasonic beam perpendicular to its projection axis. No specific notch sizes are specified; the procedures agreed upon by purchaser and vendor for a particular inspection shall apply. Figure 8 shows an example standard.

3.2.4.8 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 practices specified for longitudinal, shear, and surface wave inspection. Ultrasonic references made from actual parts or part replicas are recommended, wherever practical.

3.3 Surface Preparation

Visual examination shall be performed on each part to ensure that sound beam entry and exit 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. Surfaces to be inspected shall not be rougher than 125 µin (3.2 µm), defined in accordance with ASME B46.1.

3.4 Testing Procedure

3.4.1 Written Procedure

Ultrasonic inspections shall be detailed in a written procedure. Procedures shall be prepared by the vendor and accepted by purchaser. Procedures shall identify the type of ultrasonic equipment, method(s) of test, ultrasonic test reference, transducer type, style, and frequency, transducer qualification, fixturing, method of reporting indications, and all other instructions that pertain to the actual test. Procedures shall be detailed sufficiently that another qualified investigator could duplicate the test and obtain equivalent information.

3.4.2 Documentation

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 on thin materials, documentation of the inspection plan and the methods of recording and interpreting results becomes 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 and serial numbers (where applicable); stage of fabrication, surface condition, and configuration of the material to be tested.

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

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

3.4.2.4 Transducer qualification tests.

3.4.2.5 Testing plan, including the recording procedure, scanning plan, recording sensitivity, anticipated results, method of interpreting recorded results, and relationship to ultrasonic references.

3.4.2.6 Name and address of testing facility.

3.4.3 Testing Systems

3.4.3.1 The product or part may be inspected by longitudinal, shear, or surface wave techniques or a combination of techniques as will most appropriately disclose material imperfections. The pulse-reflection (echo) pulse-transmission procedures may involve one or more transducers as required for the evaluation.

3.4.3.2 All equipment used for the tests, such as ultrasonic test instruments, ultrasonic transducers, ultrasonic reference standards, and recording system 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 these components shall require requalification 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 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 screen. Sensitivity may be increased during test by a predetermined dB 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 records, such as a C-scan or strip chart, 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 lower than 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 transducer, 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 shall 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 various preselected angles. Once established, the surface entry angle shall not vary more than ±2 degrees.

3.4.5.4 Water Path

Valid tests may be performed in both the Fresnel (near) and Fraunhofer (far) field zones. A variety of sound beams ranging from columnated 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 transducer to the entry surface, shall not vary more than ±0.2 inch (5 mm).

3.4.6 Contact Testing

3.4.6.1 Contact Couplants

Shall be in accordance with 3.2.3.2.

3.4.6.2 Angle Beam Testing

The sound beam entry angle and the testing mode shall be established as part of the test procedure. The transducer qualification tests will establish the exit point and angle of exit. If wear of contact shoes or transducer results in a change in sound beam entry angle of more than ±3 degrees from the established angle, that transducer shall be replaced or repaired.

3.4.6.3 Straight Beam Testing

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

3.4.7.2 Dual Transducers

For thin materials, dual transducer test techniques may be used. Transducer qualification for dual transducers shall be as for contact testing. If wear of the transducer facing results in a change in sound beam entry angle in excess of ±3 degrees, the transducer shall be removed from service and replaced or repaired.

3.4.7.3 Lamb Wave

Lamb wave testing shall be as agreed upon by purchaser and vendor.

3.4.8 Distance Amplitude Correction

Electronic distance amplitude correction is recommended; however, distance amplitude curves plotted on the screen face using distance amplitude reference blocks may be used if the minimum signal height is not less than 1.0 inch (25.4 mm) and the maximum signal height is not greater than 90% of the screen height. 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 Gating and Recording

Wherever possible and practical, automatic signal alarm and recording circuits shall be used, e.g., alarms which alert the inspector, identify depth, or record signal information.

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. Refer to AMS2631 for information on equations related to scan speed and pulse repetition rate.

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 reference 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 7.

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, 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 Inspection

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. Tables 5A and 5B define these classes for inspections involving flat-bottom hole reflectors in ultrasonic references.

Table 5A - Longitudinal WAVE ultrasonic reference inspection classes, 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 to 0.12	50
A1	#3	#2[3]	#2 response to 0.25	50
A	#5	#3	#3 response to 0.50	50
B	#8	#5	#5 response to 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% (or + 19.09 dB) 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% (or + 7.04 dB) of a #3 FBH is equivalent to a #2 FBH and may be used in place of the response from the #2 FBH.

Table 5B - Longitudinal wave ultrasonic reference inspection classes, SI units

Quality Class	Single Discontinuity FBH[1]	Multiple Discontinuities FBH[1]	Linear Discontinuity Millimeters, Max	Loss of Back Reflection % Max
AA	1.2	0.4[2]	0.4 FBH response for 3.0	50
A1	1.2	0.8[2]	0.8 FBH response for 6.4	50
A	2.0	1.2	1.2 FBH response for 12.7	50
B	3.2	2.0	2.0 FBH response for 25.4	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 5A.

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. Tables 6A and 6B define these classes.

Table 6A - Angle beam ultrasonic quality classes, FBH, inch/pound units

Quality Class	Single Discontinuity FBH[(1)]	Multiple Discontinuities FBH[(1)]	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 6B - Angle beam ultrasonic quality classes, FBH, SI units

Quality Class	Single Discontinuity FBH[(1)]	Multiple Discontinuities FBH[(1)]	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	0.8 FBH response for 6.4
A	2.0	1.2	1.2 FBH response for 12.7
B	3.2	2.0	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 (25.4 mm) apart.

4.1.3 Angle Beam Using Reference Notches

Five classes of ultrasonic quality are established for angle-beam inspection, in longitudinal, shear, or surface-wave modes, which involves notches as the ultrasonic reference reflectors. Table 7 defines these classes.

Table 7 - Ultrasonic quality classes, notch

Class	Single Discontinuity Notch Size Inches	Single Discontinuity Notch Size Millimeters	Multiple Discontinuities
AA	E - 0.02D x 0.04L	E - 0.5D x 1.0L	50 % of E response
A1	F - 0.03D x 0.05L	F - 0.8D x 1.3L	E response
A	G - 0.05D x 0.10L	G - 1.3D x 2.5L	F response
B	H - 0.08D x 0.16L	H - 2.0D x 4.1L	G response
C	As established between purchaser and vendor for specific part.		

4.1.3.1 Any discontinuity with a signal indication greater than allowed for the specific class shall be cause for rejecting the part for that class.

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 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 each size and configuration of product, and of each part number. These records shall be made available for inspection by purchaser at any reasonable time.

4.3.2 Personnel Qualifications

It shall be verified that all inspections are performed by personnel qualified in accordance with 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 specified requirements.

4.3.4 Transducer Qualification

Documentation regarding the qualification of transducer 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 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

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

8. NOTES

8.1 Revision Indicator

A change bar (l) 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 testing is so comprehensive that it is necessary that all interested parties fully recognize that 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 transducer
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 transducer 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. When the DA curve is used, the maximum amplitude point on the curve should not exceed 80% and the minimum point should not be less than 20% of the maximum vertical deflection displayed on the display. 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 ±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 DAC curves are applicable to focused and non-focused transducers but are not applicable to testing in the near field of the transducer.

8.4 Commentary on Scan Coverage

8.4.1 Figure 7 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 Reference Publications

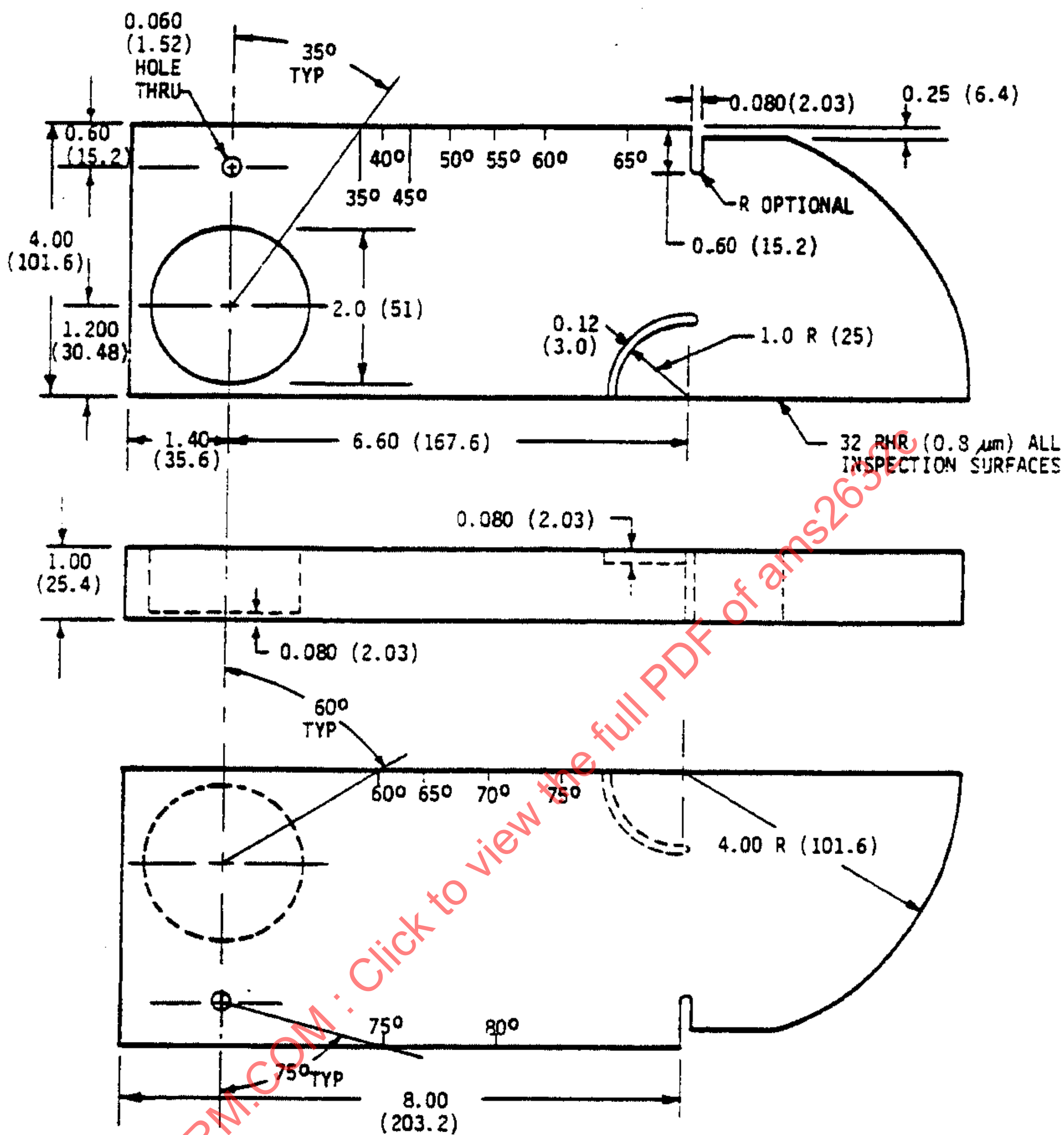
Nondestructive Testing Handbook, edited by Dr. R. C. McMasters, 2012; Ronald Press, 79 Madison Avenue, New York, NY 10016 (Available from ASNT); ISBN: 978-1571171870

Sonics, by T. F. Hueter and R. H. Bolt, 2000; Acoustical Society of America; ISBN 978-1563969556

Ultrasonic Testing of Materials by J. Krautkramer and H. Krautkramer (4th edition), 1990; ISBN 978-3540512318

8.6 Terms used in AMS are defined in AS7766.

8.7 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.



Notes:
1. Linear dimensions in inches (mm), except surface roughness.
2. Material: AMS 5070 steel or equivalent.
3. Other IIW approved reference blocks with slightly different dimensions or distance calibration slot features are permissible.

Figure 1 - International Institute of Welding (IIW) ultrasonic reference block