



AEROSPACE MATERIAL SPECIFICATION

Society of Automotive Engineers, Inc.
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ULTRASONIC INSPECTION OF THIN MATERIALS 0.5 Inch (13 mm) and Thinner

1. SCOPE:

1.1 Purpose: This specification covers the procedure for ultrasonic inspection of flat, contoured, and cylindrical products having a cross sectional thickness of 0.02 - 0.5 in. (0.5 - 13 mm). This specification does not apply to inspection of composite materials.

1.2 Application: Primarily 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.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

AMS 5070 - Steel Bars and Forgings, 0.18 - 0.23C (SAE 1020)

2.1.2 Aerospace Standards:

AS 1355 - Ultrasonic Transducers, Immersion and Contact, Performance Parameters

2.1.3 SAE Standards and Recommended Practices:

SAE J300 - Crankcase Oil Viscosity Classification

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

ASTM E127 - Fabricating and Checking Aluminum Alloy Ultrasonic Standard
Reference Blocks

ASTM E317 - Evaluating Performance Characteristics of Pulse-Echo Ultrasonic
Testing Systems

ASTM E428 - Fabrication and Control of Steel Reference Blocks Used in Ultrasonic
Inspection

2.3 ANSI Publications: Available from American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.

ANSI B46.1 - Surface Texture

2.4 ASNT Publications: Available from American Society for Nondestructive Testing, Inc., 914 Chicago Avenue, Evanston, Illinois 60202.

SNT-TC-1A - Ultrasonic Testing Method

3. TECHNICAL REQUIREMENTS:

3.1 Qualification:

3.1.1 Personnel: Operators shall be certified to SNT-TC-1A, Level I. Personnel who establish test procedures, calibrate equipment, and interpret and evaluate indications as they relate to applicable codes and specifications shall be certified to SNT-TC-1A Level II or Level III.

3.1.2 Facilities: Shall be subject to survey and approval by the purchaser. The 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, 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 on a cathode ray tube (CRT) 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 MHz to at least 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 decibels (dB) and shall have a transmit/receive crosstalk separation of at least 40 dB.

3.2.1.1 Instrument Linearity: The instrument vertical and horizontal linearity shall meet or exceed $\pm 5\%$ as defined in ASTM E317. Where usable CRT dimensions differ from the 2.5 in. (64 mm) vertical dimension or 3.5 in. (89 mm) horizontal dimension, ASTM E317 procedures still apply but in these cases, the graticule display on the CRT screen shall be used to establish the vertical and horizontal dimensions and the instrument shall be proportionately linear in accordance with ASTM E317 procedures.

3.2.1.2 Instrument Sensitivity: Instrument sensitivity or gain shall be calibratable in decibels and shall be accurate within $\pm 10\%$ of the sensitivity setting (e.g., ± 1 dB at 10 dB, or ± 6 dB at 60 dB).

3.2.1.3 Voltage Regulation: If fluctuations in line voltage cause variations in the displayed signal amplitude or sweep length of $\pm 5\%$ or greater, a power source voltage regulator shall be used. If fluctuations persist, proper adjustments to instrument or power source shall be made so that the system will operate within the $\pm 5\%$ limits. Battery powered systems are exempt from this requirement but such systems shall not be operated when the power source is below the level to achieve full vertical and horizontal display as viewed on the CRT graticule.

3.2.1.4 Alarm: Whenever practical, an audible alarm 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 level-adjustable over the display range of the CRT and shall be automatically triggered within $\pm 10\%$ of the level of ultrasonic signal displayed on the CRT. The sound level produced by the alarm during operation shall be sufficiently above ambient to assure being heard by the operator.

3.2.2 Ultrasonic Search Units: Ultrasonic search units shall be of a piezoelectric design, controlled as in AS 1355, capable of both transmitting and receiving ultrasonic signals at the specific frequencies required by the test. When used with the ultrasonic test instrument, the search unit shall be capable of transmitting and receiving ultrasonic energy with a spectral distribution that includes the central frequency specified for the test. The peak of the spectral distribution of ultrasonic energy emitted from the search unit shall fall within $\pm 10\%$ of the specified frequency established for the test.

3.2.2.1 Search Unit Dimension and Styles: 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, and pressurized-couplant search unit systems may be used.

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 the purchaser prior to testing.

3.2.2.3 Ultrasonic Beam Profiles:

3.2.2.3.1 The transmission profile of the search unit shall not deviate more than $\pm 15\%$ of the calculated curve for a search unit of that frequency and dimension. See Fig. 1a. The sound beam of the search unit shall be within ± 2 deg (± 0.035 rad) axial alignment with the outside housing. Both immersion and contact search units are subject to change with use and age. To ensure appropriate test capability, the history of each search unit shall be maintained in an appropriate log. The history on straight-beam search units shall include the type, style, frequency, serial number, size, and vendor or receiving acceptance ultrasonic profile of the ultrasonic beam transmitted from the search unit.

3.2.2.3.2 The history of a focused search unit shall include both an axial profile and a cross sectional profile which establish the focal spot size (dimension of ultrasonic energy) at the peak of the focal zone. The cross sectional dimension recorded for the focal spot shall be measured at the half amplitude level. See Fig. 1b.

3.2.2.3.3 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 deg (± 0.052 rad) 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 (See Fig. 2) or an appropriate substitute may be used to test the exit angle of angle-beam search units. The history of an angle-beam search unit shall include 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: Couplants for immersion may include any appropriate fluid such as tap water, light oils, ethylene glycol, or alcohol. 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: Couplant materials for testing by the contact method shall not be injurious to the material being tested. Couplant materials may include any appropriate fluid such as water, light oils, low viscosity greases, or penetrant emulsifiers. Glycerin shall not be used. Thin 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 the purchaser. The couplant used shall be selected to ensure the best possible sound beam entry into the material under test. As surface roughness influences the sound energy, couplant viscosity may be varied as a function of surface roughness. Table I provides a guide for selection of direct contact couplant materials; other couplants of similar viscosity may be used. The contact technique is defined to include direct contact of a search unit to the test surface, use of contour surface wear shoes, and thin film couplant techniques such as the pressurized fluid (water gap) system.

TABLE I
COUPLANT MATERIALS

Approximate Surface Roughness (ANSI B46.1)	Couplant (SAE J300)
5 - 100 RHR (0.1 - 2.5 μm)	SAE 10W Motor Oil
50 - 125 RHR (1.2 - 3.2 μm)	SAE 20W Motor Oil
100 - 200 RHR (2.5 - 5.0 μm)	SAE 30W Motor Oil

- 3.2.4 Ultrasonic References (Standards): Ultrasonic references are required for all inspection 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 types 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 conformation 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 ± 3 dB from those of the product or part to be tested.
- 3.2.4.2 Entry Surfaces: The configuration (surface roughness, flatness, or contour) of the ultrasonic reference should approximate that of the product or part to be tested. When product or part radius of curvature is less than 5 in. (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 search unit (See 3.2.4.5). The procedure used shall establish a minimum of a 2:1 signal-to-noise ratio with the minimum size reference discontinuity used.
- 3.2.4.3 Straight Beam Ultrasonic References:
- 3.2.4.3.1 Where the part thickness is greater than 0.125 in. (3.18 mm), the procedures established under ASTM E127 and ASTM E428 shall be used for manufacturing ultrasonic references for straight beam testing; these specifications describe the manufacture of flat-bottom holes (FBH) in aluminum-base alloys and steels but the same procedure may be used to manufacture references from other materials. Use of other materials is required where the ultrasonic response of the ultrasonic reference differs from that of the product to be tested by more than ± 3 decibels.
- 3.2.4.3.2 Ultrasonic references may be made from thin materials, e.g., 0.125 in. (3.18 mm), 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 product or part thickness of 0.5 in. (13 mm) and thinner, ultrasonic references in accordance with Fig. 3 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. Table II describes the applicable dimensions.

TABLE II

Reference Thickness, T Inch	FBH ⁽¹⁾				Notches ⁽²⁾			
	A	B	C	D	E	F	G	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

- Notes. 1. Flat-bottom hole (FBH) numbers are based on 1/64 in. diameter hole progression, i. e., #1 means 1/64 in. and #8 means 8/64 in. diameter flat-bottom holes.
2. Notches are to be generated by electrodischarge machining (EDM) techniques and shall have a maximum width of 0.01 in. All other dimensions are to be ± 0.002 in. 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 II (SI)

Reference Thickness, T Millimetres	FBH ⁽¹⁾				Notches ⁽²⁾			
	A	B	C	D	E	F	G	H
12.7					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

- Notes. 1. Diameter of flat-bottom hole in millimetres.
2. Notches are to be generated by electrodischarge machining (EDM) techniques and shall have a maximum width of 0.26 mm. All other dimensions are to be ± 0.05 mm. Notches shall be perpendicular to part surface within ± 0.035 radian.
3. NA = Not applicable.
4. D = depth of notch and L = length of notch in millimetres.

3.2.4.5 Ultrasonic References for Inspection of Cylinders: For cylinders of 5 in. (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 in. (127 mm) the procedures specified below shall apply:

3.2.4.5.1 Circumferential Shear Inspection: For product and parts 0.125 in. (3.18 mm) and thinner, 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 deg (0.035 rad). Replicating techniques or their equivalent shall be used to establish perpendicularity. Notch sizes shall be as shown in Table III (See Fig. 4). Both ID and OD notches may be necessary to ensure full inspection of critical parts. The ultrasonic references for materials 0.125 - 0.50 in. (3.18 - 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 Fig. 5. Hole sizes shall be as shown in Table III.

TABLE III

HOLE AND NOTCH SIZES FOR CIRCUMFERENTIAL SHEAR ULTRASONIC REFERENCES

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

Note. Notches for 0.125 in. and thinner material are rectangularly dimensioned. When end mill or saw cuts are used, make the reflectors equal in area for each specific size.

TABLE III (SI)

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

Note. Notches for 3.18 mm and thinner material 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 in. (3.18 mm) and thinner, EDM notches or equivalent reflecting surfaces shall be used. Notches shall be generated circumferentially and be perpendicular to the surface within ± 2 deg (± 0.035 rad). Notch sizes listed in Table III shall apply (See Fig. 6). Both ID and OD notches may be necessary for full inspection of critical parts. For parts with thickness greater than 0.125 in. (3.18 mm), the flat-bottom hole shall be used as the target (See Fig. 7). Flat-bottom holes shall be placed axially in the cylinder wall and shall be of the sizes specified in Table III.

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 deg (± 0.035 rad) 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 RHR ($0.8 \mu\text{m}$) 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 II could be appropriate for flat materials and the notches specified in Table III could be appropriate for curved sections.

3.2.4.7 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, 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 assure 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 microinches ($3.2 \mu\text{m}$), determined in accordance with ANSI B46.1.
- 3.4 Testing Procedure:
- 3.4.1 Written Procedure: Ultrasonic inspections performed in accordance with this specification shall be detailed in a written procedure. Unless otherwise specified, procedures shall be prepared by the vendor and accepted by the purchaser. Procedures shall identify the type of ultrasonic equipment, method(s) of test, ultrasonic test reference, search unit serial number, type, style, and frequency, search unit qualification, fixturing, method of reporting indications, and all other instructions that pertain to the actual test. Procedures shall be detailed sufficiently that another investigator qualified to SNT-TC-1A, Level II 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 on thin materials, the 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 calibration procedure.
- 3.4.2.4 Search unit 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.
- 3.4.3 Testing System:
- 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 search units as required for the evaluation.
- 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 the like, for any reason shall require requalification of the complete system.

- 3.4.4 Qualification Calibration 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 calibration, signal amplitude (sensitivity) from a known reference discontinuity may be set within the range of 20 - 90% of the vertical height of the CRT screen. Sensitivity may be increased during test by a predetermined dB level to ensure adequate test; however, when interpreting results, the sensitivity shall be returned to the original setting.
- 3.4.4.1 Calibration Record: When permanent records, such as wet or dry paper, x-y recorders, or digital computer, are established as part of the test plan, calibration of the test system shall include a record of the appropriate ultrasonic reference reflector.
- 3.4.4.2 Calibration Check: To ensure valid results, a calibration check shall be made prior to each design configuration test or start of each shift of operation and at the completion of each test or shift, as appropriate. Any change in equipment operation that requires a recalibration of the test system shall require retesting of all material or parts tested since the previous calibration.
- 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 deg (± 0.035 rad). 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 deg (± 0.035 rad).
- 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 deg (± 0.035 rad).
- 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 search unit to the entry surface) shall not vary more than ± 0.2 in. (5 mm).
- 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 deg (± 0.052 rad) from the established angle, that search unit shall be replaced or repaired.
- 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 the 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 thin materials, dual search unit test techniques may be used. Search unit qualification for dual search units shall be as for contact testing. If wear of the search unit facing results in a change in sound beam entry angle in excess of ± 3 deg (± 0.052 rad), the search unit 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 (Cathode Ray Tube) using distance amplitude calibration blocks may be used if the minimum pip height is not less than 1.0 in. (25 mm) and the maximum pip height is not greater than 90% of the screen height. Testing using the highest sensitivity from the distance amplitude calibration 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 may be used for depth and signal recording. Both interface gating and pulse synchronization are applicable. For automatic recording, the gates used shall maintain stable gate positions and gate widths throughout the test. Signal amplitude gates shall record a linear relationship, within $\pm 5\%$ of full scale deflection, between the signal displayed on the CRT and the analog voltage output of the electronic gate over the range of 20 - 80% of the vertical amplitude displayed on the CRT.
- 3.4.9.1.2 At the start of each testing shift, the ultrasonic reference shall be recorded and compared with the acceptance recording. At the completion of the testing shift, a second recording shall be made and this compared with the starting recording. Any deviation in excess of $\pm 15\%$ between start and ending recordings shall require the system to be requalified and that all parts inspected since the last acceptance recording be reinspected. For this requirement, the testing shift shall not exceed 8 hours.
- 3.4.9.2 Recording: Recording may be performed manually in accordance with good engineering practices. Automatic permanent records may utilize line storage display oscilloscopes, photographs of CRT recordings, chart recorders, facsimile recorders (e.g., dry or wet paper), or other equivalent recording devices. No restriction is placed on the type of recorder used except as limited by the instrument characteristics. Such test parameters as scanning speed, amplifier frequency response, electronic gate response, and recorder response may limit the selection of the permanent recorder to be used. During the selection and qualification of the testing system, the vendor shall provide the purchaser with evidence that the recording system is not the limiting component of the system and that reflections from known discontinuities are reliably and repeatably portrayed. If the recorder is established as the limiting system component, the scanning and recording speeds shall be reduced to fall within the limitations of the recorder.
- 3.4.9.3 Scanning Index: In determining the index for 100% coverage, the beam diameter shall first be measured at the near field-far field transition ($Y_0 = r^2/\lambda$, where Y_0 = transition, r = radius of search unit, and λ = wavelength at operating frequency). The scan index shall not exceed the diameter of the sound beam as measured at the half amplitude level (See 3.2.2.3). When focused search units are used, the index shall not exceed the beam diameter as measured at the half amplitude level profiled at the focal point. A closer index is recommended to ensure adequate inspection overlap (See Fig. 1b).
- 3.4.9.4 Scan Speed: Maximum scanning speed is determined by the recordability of the applicable ultrasonic reference. At the maximum recording speed used, the reference discontinuities shall be clearly recorded. If distortion related to scanning speed is observed, the scan speed shall be reduced until distortion is eliminated.

- 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 50% of the distance amplitude curve for the material zone being inspected. If electronic distance amplitude correction (DAC) is employed, alarm activation level shall be set at 50% of the displayed signal. In 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 before proceeding with inspection.

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 IV defines these classes for inspections involving flat-bottom hole reflectors in ultrasonic references.

TABLE IV

Quality Class	Single Discontinuity FBH Size ⁽¹⁾	Multiple Discontinuities FBH Size ⁽¹⁾	Linear Discontinuity Inch, max	Loss of Back Reflection, %, max
AA	#3	#1	#1 response for 0.12	50
A1	#3	#2	#2 response for 0.25	50
A	#5	#3	#3 response for 0.50	50
B	#8	#5	#5 response for 1.00	50
C	As established by purchaser and vendor for specific part.			

Note. 1. FBH numbers indicate diameter in multiples of 1/64 in. of FBH in ultrasonic reference.

TABLE IV (SI)

Quality Class	Single Discontinuity FBH (1)	Multiple Discontinuities FBH (1)	Linear Discontinuity mm, max	Loss of Back Reflection, %, max
AA	1.2	0.4	0.4 FBH response for 3.0	50
A1	1.2	0.8	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.			

Note. 1. Diameter of flat bottom hole in millimetres.

- 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 are defined as two or more indications above the level established for the class that occur within 1 sq in. (645 mm²) of inspected surface.
- 4.1.1.3 Loss of back surface reflection caused by an internal metallurgical condition showing a signal loss more than 50% of the distance amplitude curve established for the material is not acceptable.
- 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 V defines these classes.

TABLE V

Quality Class	Single Discontinuity FBH Size ⁽¹⁾	Multiple Discontinuities FBH Size ⁽¹⁾	Linear Discontinuity Inch, 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.		

Note 1. FBH numbers indicate diameter in multiples of 1/64 in. of FBH in ultrasonic reference.

TABLE V (SI)

Quality Class	Single Discontinuity FBH ⁽¹⁾	Multiple Discontinuities FBH ⁽¹⁾	Linear Discontinuity mm, 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.		

Note 1. Diameter of flat bottom hole in millimetres.

- 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 are defined as two or more indications above the level established for the class that occur within 1 sq in. (645 mm²) of inspected surface.
- 4.1.3 Angle Beam Tests 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 VI defines these classes.

TABLE VI

Class	Single Discontinuity		Multiple Discontinuities
	Notch Size, Inch	Notch Size, mm	
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 disqualify 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 authorized personnel for acceptance and shall be reported to the purchaser.
- 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 the 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 the 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 SNT-TC-1A. 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 Ultrasonic References: Signal indications from ultrasonic references shall be recorded periodically (at least once a year) and results compared to a master record established at initial acceptance.
- 4.3.6 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 the vendor's cognizant supervisor to assure inspection is in compliance with this specification.

5. PREPARATION FOR DELIVERY: Not applicable.

- 6. ACKNOWLEDGMENT: A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.
- 7. REJECTIONS: Material not inspected in accordance with this specification or with authorized modifications will be subject to rejection.

8. NOTES:

- 8.1 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 search unit
Test frequency
Type and grade of couplant
Method of calibration of equipment

- 8.2 Distance Amplitude Correction: The following discussion relates to and defines terms and procedures recommended in 3.4.8.

- 8.2.1 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 CRT is referred to as the Distance Amplitude (DA) Curve.

- 8.2.2 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 CRT to a pre-selected amplitude.

8.2.3 Applications:

- 8.2.3.1 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. 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 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 $\pm$ dB relationship between the unknown discontinuity and the known reference.
- 8.2.3.2 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.)
- 8.2.3.3 DA curves are applicable to focused and non-focused search units but are not applicable to testing in the near field of the search unit.

8.3 Reference Publications:

Nondestructive Testing Handbook, edited by

Dr. R. C. Masters, 1959; Ronald Press, 79 Madison Ave.,
New York, New York 10016 (Available from ASNT)

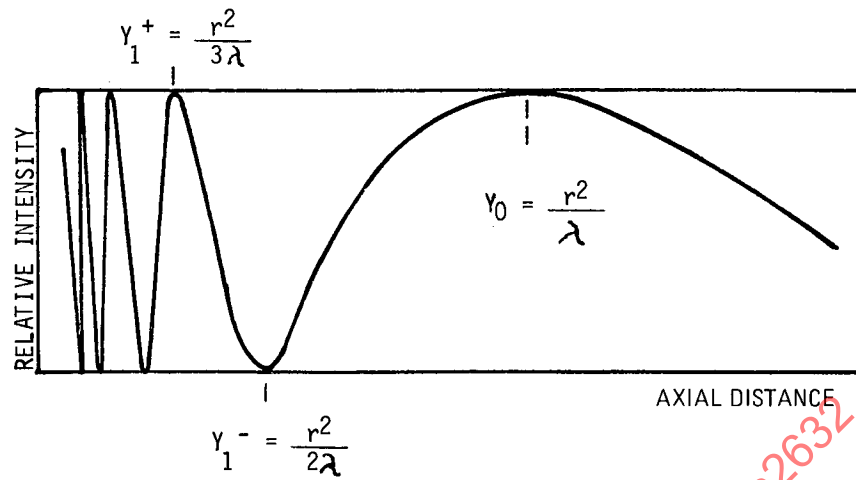
Sonics, by T. F. Hueter and R. H. Bolt, 1955; John Wiley & Sons, Inc.,
605 Third Ave., New York, New York 10016

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

AMS 2631 - Ultrasonic Inspection of Titanium Alloys

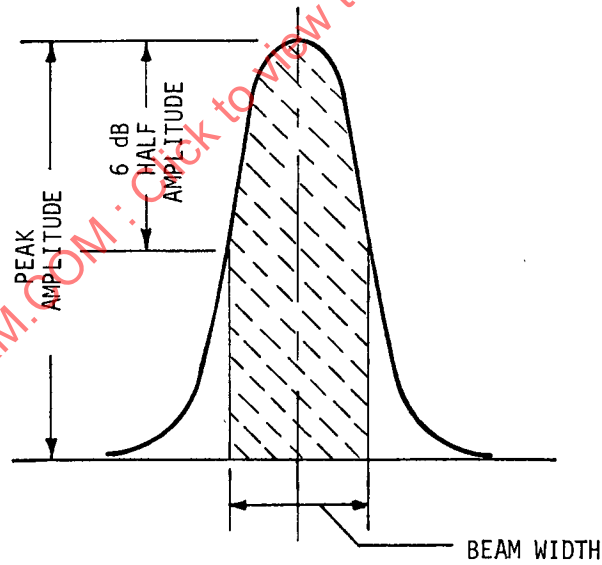
ASTM E213 - Ultrasonic Inspection of Metal Pipe and Tubing for Longitudinal
Discontinuities

SAENORM.COM : Click to view the full PDF of ams2632



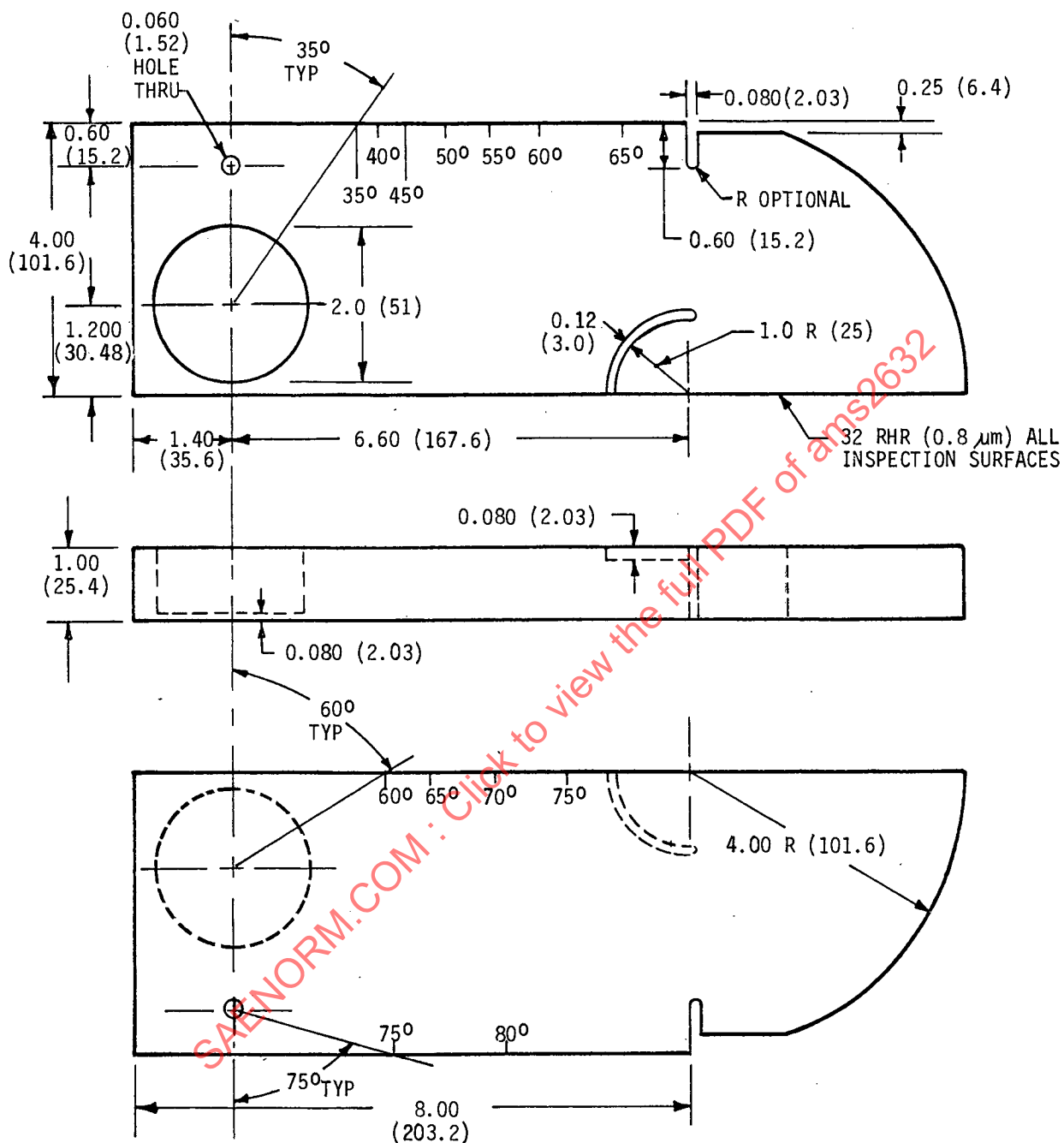
SEARCH UNIT AXIAL DISTANCE AMPLITUDE CURVE
(Profile for Flat Piston Radiator)

FIGURE 1a



CROSS SECTION PROFILE OF SOUND BEAM AT y_0 OR FOCAL POINT

FIGURE 1b



- 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.

INTERNATIONAL INSTITUTE OF WELDING (IIW) ULTRASONIC REFERENCE BLOCK

FIGURE 2