Designation: E2375 – 22

Standard Practice for Ultrasonic Testing of Wrought Products[1]

This standard is issued under the fixed designation E2375; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 *Purpose*—This practice establishes the minimum requirements for ultrasonic examination of wrought products.

NOTE 1—This practice was adopted to replace MIL-STD-2154, 30 Sept. 1982. This practice is intended to be used for the same applications as the document which it replaced. Users should carefully review its requirements when considering its use for new, or different applications, or both.

1.2 *Application*—This practice is applicable for examination of materials such as, wrought metals and wrought metal products having a thickness or cross section equal to 0.250 in. (6.35 mm) or greater.

1.2.1 *Wrought Aluminum Alloy Products*—Examination shall be in accordance with Practice B594. Angle beam scans of wrought aluminum alloy products shall be performed in accordance with this practice as agreed upon by the purchaser and supplier.

1.3 *Acceptance Class*—When examination is performed in accordance with this practice, engineering drawings, specifications, or other applicable documents shall indicate the acceptance criteria. Five ultrasonic acceptance classes are defined in Table 1. One or more of these classes may be used to establish the acceptance criteria or additional or alternate criteria may be specified.

1.4 *Order of Precedence*—Contractual requirements and authorized direction from the cognizant engineering organization may add to or modify the requirements of this practice. Otherwise, in the event of conflict between the text of this practice and the references cited herein, the text of this practice takes precedence. Nothing in this practice, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

1.5 *Measurement Values*—The values stated in inch-pounds are to be regarded as standard. The metric equivalents are in parentheses.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 The following documents form a part of this practice to the extent specified herein:

2.2 *ASTM Standards:*[2]

B107/B107M Specification for Magnesium-Alloy Extruded Bars, Rods, Profiles, Tubes, and Wire

B221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

B241/B241M Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube

B594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products

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

E164 Practice for Contact Ultrasonic Testing of Weldments

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

E543 Specification for Agencies Performing Nondestructive Testing

E1065 Practice for Evaluating Characteristics of Ultrasonic Search Units

E1316 Terminology for Nondestructive Examinations

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Ultrasonic Classes

Class	Single Discontinuity Response[A,B]	Multiple[C] Discontinuities	Linear[D] Discontinuity Length and Response	Loss of Back Reflection Percent[E,F]	Noise[G,H]
AAA[H]	25 % of 3/64 in.FB	10 % of 3/64 in. (0.119 mm) FB	1/8 in. (3.176 mm) long or 10 % of 3/64 in. (0.119 mm) FB	50	alarm level
AA[H]	3/64 in. (1.19 mm) FB	2/64 in.[I] (0.794 mm) FB	1/2 in. (12. 7 mm) long 2/64 in. response (0.794 mm) FB	50	alarm level
A	5/64 in. (1.98 mm) FB	3/64 in. (1.191 mm) FB	1 in. (25.4 mm) long 3/64 in. response (1.19 mm) FB	50	alarm level
B	8/64 in. (3.18 mm) FB	5/64 (1.98 mm) FB	1 in. (25.4 mm) long 5/64 in. response (1.98 mm) FB	50	alarm level
C	8/64 in. (3.18 mm)	Not Applicable	Not Applicable	50	alarm level

[A] Any discontinuity with a response greater than the response from a flat-bottom hole or equivalent notch (see footnote[B]) at the estimated discontinuity depth and the discontinuity size given is not acceptable.
[B] See Fig. 2, Fig. 3, or Fig. 4 for dimensions of notches and holes when these are required for angle beam examination of tube walls and near-surface regions of cylindrical parts and other products.
[C] 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 (diameter) are not acceptable if the centers of any two of these discontinuities are less than one inch apart (not applicable to Class C).
[D] Any discontinuity longer than the length given with indications exceeding the response given (flat-bottom hole or notch response) is not acceptable. Not applicable to Class C.
[E] Loss of back reflection by more than 50 %, when accompanied by an increase in noise level of double the normal background noise signal, compared to non-defective material in the same or a similar part, is not acceptable.
[F] For longitudinal examination of material over 6 in. (152.4 mm) thick in the short transverse direction, any loss of back reflection equal to or greater than 12 dB over an area 2 by 2 in. (50.8 by 50.8 mm) is rejectable. (Noise level is not relevant to this back reflection evaluation).
[G] Noise which exceeds the alarm level setting (see 7.4.10.7), is not acceptable, except for titanium. For titanium alloys, the alarm level may be set just above the noise level, but shall not exceed 70 % of the reference standard response.
[H] When examining titanium, Class AA and Class AAA, no rejection shall be made on the basis of "noise" level, if within the limits specified in footnote[G].
[I] Evaluation may be done by setting up on a 3/64 in. (1.19 mm) hole and adding 7 dB of gain. (Also see Note 5 under Table 5.)

2.3 *ASNT Standards:*[3]
SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing
ANSI/ASNT-CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel
2.4 *SAE Standards:*[4]
AMS 4928 Titanium Alloy, Bars, Wire, Forgings, and Rings 6Al-4V Annealed
AMS 6409 Steel, Bars, Forgings, and Tubing, 0.80 Cr, 1.8 Ni, 0.25 Mo, (0.38 - 0.45 C), (SAE 4340) Special Aircraft Steel Cleanliness, Normalized and Tempered
AMS 6415 Steel, Bars, Forgings, and Tubing, 0.80 Cr, 1.8 Ni, 0.25 Mo (0.38 - 0.43 C) (SAE 4340)
AMS 6484 Steel, Bars, Forgings, and Tubing, 080 Cr, 1.8 Ni, 0.25 Mo (0.38 - 0.43 C) (SAE 4340) Normalized and Tempered
2.5 *AIA Standard:*[5]
NAS 410 Certification and Qualification of Nondestructive Test Personnel
2.6 *Federal Specifications:*[5]
QQ-A-225/6 Aluminum Alloy Bar, Rod, and Wire, Rolled, Drawn, or Cold Finished, 2024
QQ-A-225/9 Aluminum Alloy Bar, Rod, Wire, and Special Shapes, Rolled, Drawn, or Cold Finished, 7075

[3] Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.
[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.
[5] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

2.7 *Military Standards:*[6]

NOTE 2—For DoD contracts, unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS (Department of Defense Index of Specifications Standards) cited in the solicitation.

3. Terminology

3.1 *Definitions*—Definitions relating to ultrasonic examination, which appear in Terminology E1316, shall apply to the terms used in this standard.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *display, n*—the display on which ultrasonic data are presented, including, but is not limited to, cathode ray tubes, liquid crystals, electro-luminescent phosphors, or plasmas.

3.2.2 *full scale deflection (FSD), n*—the maximum displayable signal amplitude on the display device, or any signal reaching or exceeding the 100 % amplitude scale graduation.

3.2.3 *horizontal limit, n*—the maximum readable length of horizontal position that is determined either by electrical or a physical limit in the A-scan presentation of an ultrasonic examination instrument.

3.2.4 *primary reference response, n*—the maximized signal amplitude obtained from the applicable reference reflector that produces the lowest amplitude signal.

[6] Copies of specifications, standards, drawings and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.

4. Significance and Use

4.1 This practice is intended primarily for the examination of wrought metals, forged, rolled, machined parts or components to an ultrasonic class most typically specified in the purchase order or other contract document.

5. Basis of Application

5.1 *Basis of Application*—There are areas in this practice that may require agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization.

6. General Requirements

6.1 *Specifying*—When ultrasonic examination is specified in accordance with this practice, the ultrasonic technique (immersion, contact, angle beam, straight beam, and so forth) and acceptance criteria should be specified. Suggested classes in Table 1 may be specified to establish acceptance criteria. A contract document shall specify zones, when applicable, to indicate different quality level acceptance criteria based on the criticality of each zone. When directions of maximum stressing are indicated on a contract document and configuration allows, ultrasonic examination shall be performed to locate discontinuities oriented perpendicular to the directions of maximum stressing.

6.2 *Personnel Qualification/Certification*—Personnel performing examinations to this practice shall be qualified in accordance with ANSI/ASNT-CP-189, NAS-410, or SNT-TC-1A and certified by the employer or certifying agency as applicable. Other equivalent qualification documents may be used when specified in the contract or purchase order.

6.3 *Agency Evaluation*—If required by contract, evaluation of the agency performing examination shall be in accordance with Specification E543.

6.4 *Written Procedure*—A detailed procedure (general procedure, or part specific technique, or both) shall be prepared for each part and type of examination to be performed. The procedure shall meet the requirements of this practice and shall provide consistency for producing the results and quality level required by this practice and other contractual documents. The procedure shall be approved by an individual qualified and certified as a Level III in the practice of ultrasonic examination. The procedure shall be submitted upon request to the contracting agency for approval, or review, or both (see 8.1). The procedure shall cover all of the specific information required to set-up and perform the examination, such as the following:

6.4.1 Name and address of examination facility,

6.4.2 Number of the procedure including latest revision designation, if applicable, and date.

6.4.3 Number of this standard including latest revision designation letter, if applicable, and date.

6.4.4 Examination method and acceptance criteria to be applied.

6.4.5 Examination zones, if applicable.

6.4.6 Specific part number and configuration or product form for which the procedure is being prepared, including the surface condition of the product and any special handling requirements.

6.4.7 Manufacturer and model numbers of any instrumentation to be used in the examination. Any external recording equipment, alarm equipment and electronic distance-amplitude correction equipment shall be included.

6.4.8 Type and size of search unit. Include frequency, focal length, as applicable, manufacturer, sound beam angle and description of any wedges, shoes, saddles, stand-off attachments, bubblers, or squirters.

6.4.9 Description of manipulating and scanning equipment.

6.4.10 Couplant: type and manufacturer.

6.4.11 Scanning plan which describes, for each portion of the examination, the surfaces from which the examination will be performed, the ultrasonic modes, and directions of the sound beam.

6.4.12 Method of applying transfer (see 7.4.10.4), if applied.

6.4.13 Reference blocks, water path (if applicable) and methods of standardization and scan index determination, maximum scanning speed, and minimum pulse repetition rate.

6.4.14 Method of establishing scan sensitivity for concave and convex surfaces, if applicable.

6.4.15 Discontinuity evaluation procedure.

6.4.16 Any other pertinent data which would be needed to duplicate the original examination.

6.5 *General Procedures*—General procedures are acceptable for common product forms such as plate, bar stock, extrusions, forgings, tubing and cylindrical stock, and designated thickness ranges. The general procedure shall include the applicable items of 6.4.

7. Detail Requirements

7.1 *Couplants:*

7.1.1 *Immersion Method*—For the immersion method (see 7.2.9), water shall be free of air bubbles and other foreign material that could interfere with ultrasonic examinations. A suitable corrosion inhibiting agent, or a wetting agent, or both, shall be added to the water, if necessary. The specific inhibiting and wetting agents including mixing concentrations shall have been previously determined to be compatible with the materials to be examined.

7.1.2 *Contact Method*—For the contact method, a liquid or semi-liquid that forms a thin film between the search unit and the part is required. The couplant material used shall not be injurious to the material to be examined and will permit detection of applicable discontinuity sizes. Glycerin (Pure), silicones and graphite greases shall not be used as couplants, unless specifically permitted by the cognizant engineering organization.

7.2 *Equipment:*

7.2.1 *Electronic Equipment*—The equipment when used with appropriate search units shall be capable of producing ultrasonic examination frequencies as required by the application. The electronic equipment shall be calibrated after any repair or part/component replacement which could affect its response characteristics, or once each year, whichever occurs first. Records of the current calibration shall be retained and available for review.

7.2.1.1 The equipment shall meet the following requirements as directed in Practice E317 or other approved procedure:

(1) Vertical Limit—100 % of full scale.

(2) Horizontal Limit—100 % of full scale.

(3) Vertical Linearity Limit Range—The vertical linearity of the instrument shall meet the requirements of A3.3.

(4) Horizontal Linearity Limit Range—The instrument shall be linear within ±5 % of full scale between 0 and 85 % of the horizontal limit. This step may be omitted if the instrument is used within a limited depth of material and is verified on standards of that depth at each standardization.

(5) Calibrated gain controls shall meet the requirements of A3.2.2 unless an alternate method for verification has been approved by the cognizant engineering organization.

7.2.1.2 Attenuator and decade switches as applicable shall meet the requirements of A3.2.

7.2.2 *Alarm*—An instrument used for other than manual scanning of a part with constant visual observation of the instrument display shall contain a means for automatically indicating the presence of a signal that exceeds a predetermined amplitude threshold within a gated time period. The alarm threshold level shall be adjustable. The alarm means may be an amplitude, visual, stop-on-defect, part marking or sorting, analog or digital recording, or other form of indication of the presence of potential defects. If automatic means are used for detection of rejectable discontinuities, it shall be demonstrated during initial standardization that the speed of response of such means is adequate to detect, at actual scanning speeds, a rejectable amplitude from a target at any depth in the examination range.

7.2.3 *Voltage Regulator*—If fluctuations in line voltage cause an amplitude change greater than ±2.5 % of full scale of a signal of half full-scale amplitude, a voltage regulator shall be required on the power source.

7.2.4 *Search Units*—Search units are acceptable if they provide the required examination characteristics including sensitivity, resolution, and penetration. Search units shall have active dimensions (diameter for circular elements, length for rectangular elements) equal to or greater than 0.25 in. (6.35 mm). For contact examination of all convex surfaces of 1.5 in. (38.1 mm) radius or less, and all concave surfaces of 4 in. (101.6 mm) radius or less, a curved shoe or wedge, made to match as closely as possible the radius of the part being examined, shall be required for examination. All search units shall be serialized. General search unit characteristics are typically evaluated by the methods described in Guide E1065. Records of the evaluation shall be maintained. Such evaluation does not necessarily determine suitability for any specific material evaluation.

7.2.5 *Rectangular "Paintbrush" Search Units*—Rectangular "paintbrush" search units shall be allowed for straight beam longitudinal immersion scanning if it is demonstrated that the search unit provides the required examination characteristics specified in this practice or the contract document. The written procedures (see 6.4) shall include at least the additional items specified in 7.2.5.1 through 7.2.5.3.

7.2.5.1 A method shall be established for determining a sensitivity profile along the major axis of the beam to locate the least sensitive area. Scan sensitivity must be based upon this least sensitive location on the search unit for each portion of the DAC curve to be used.

7.2.5.2 A method may be established for masking the ends of the search unit, if required, to eliminate over-sensitive responses as determined in the sensitivity profile, see A4.1.3.

7.2.5.3 A method shall be established for determining effective beam width. The scan index established in accordance with 7.4.10.8 shall be based on the beam width so determined.

7.2.5.4 The reference standard shall provide a uniform entry surface for the full extent of the sound beam for equipment standardization.

7.2.5.5 A method shall be established to use the least active portion of the search unit to adjust scan sensitivity at each portion of the DAC (Distance Amplitude Correction) curve to be used.

7.2.5.6 Search units meeting the requirements of 7.2.4 shall be used for evaluations of indications detected while scanning with paintbrush search units.

7.2.6 *Array Search Units*—Array search units (multiple-element) may be used for initial immersion scanning provided each element is pulsed independently and produces a beam that sufficiently overlaps each adjacent beam so that the maximum allowable drop in signal amplitude between elements is not more than 3 dB from the peak response (when the peak is set to 80 % of full scale using the primary reference response for the applicable examination as the reference reflector).

7.2.7 *Phased Array Search Units*—Linear phased array probes may be used for scanning and evaluation of wrought metals. The written procedure shall include at least the following additional controls to allow the use of phased array probes:

7.2.7.1 Virtual probes within the array shall meet the requirements for minimum effective beam width as given in 7.2.5.3 in both the scan and index directions.

7.2.7.2 Each virtual probe in the array shall meet the applicable requirements of a conventional probe as defined in 7.2.4.

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

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

7.2.8 *Focused Search Units*—Focused search units may be used unless otherwise specified in the contract or purchase order documentation.

7.2.9 *Tank*—Tanks used for immersion examination shall be of sufficient size to permit submersion of the part, material, or the area of interest to be examined with proper orientation of the search unit and allow sufficient water path.

7.2.9.1 *Attachments*—For special applications attachments may be used with the search unit to provide the required water path distances or coupling.

7.2.10 *Manipulating Equipment*—For immersion examination, manipulating equipment shall adequately support a search unit and shall provide angular adjustment within one degree in two planes and demonstrate control for following

part geometry. Examinations not requiring angulation shall be documented on the scan plan. The bridge shall have sufficient strength to provide rigid support for the manipulator and shall allow smooth, accurate positioning of the search unit. The scanning accuracy of the apparatus shall permit adjustment of the scan index distance within ±0.1 in. (2.54 mm), or unless otherwise specified by the cognizant engineering organization. Water travel distance shall be adjustable. When part size, or configuration, or both, prevent the use of manipulating equipment, search unit stand-off attachments which provide for control of water travel distance and sound beam angle shall be used. Provisions shall be made to ascertain that wear of stand-off attachments does not exceed limits which will degrade the examination.

7.3 *Reference Block Fabrication*—Reference blocks with flat-bottom holes with diameters equal to those specified in the acceptance criteria shall be used for defect detection and evaluation unless alternate hole sizes are used in accordance with 7.3.2. The blocks shall meet the response characteristics of and be certified to the requirements of Practice E127, as specified in 7.3.1 through 7.3.9.6 of this practice, or to the documented requirements of the cognizant engineering organization. IIW-type blocks shall be certified with respect to alloy and dimensions specified on the purchase order.

7.3.1 *Reference Block Materials*—Reference blocks should be fabricated from the same alloy, surface finish and heat treatment as the part to be examined. Where this is not available, or practical, reference blocks may be fabricated from materials listed in Table 2 so that any ultrasonic transmission differences are minimized. Other material may be used for reference blocks provided the velocity and attenuation difference between the reference block and the examination material are within the limits shown below:

7.3.1.1 The back or end surface reflections of the examination material shall be within +4 dB (160 %) to −12 dB (25 %) of the reference block material corrected to the depth of examination. Transfer in accordance with 7.4.10.4 is not allowed if the differences are greater than these limits unless a documented plan adequately compensates for the cause and is approved by the cognizant engineering organization.

7.3.1.2 Material to be used for the fabrication of reference blocks shall be scanned ultrasonically in the mode(s) to be used in the examination at a sufficiently high sensitivity to detect any existing anomalies that might produce signals that could obscure, or be confused with, those from holes, notches or other targets in the reference block to be fabricated.

7.3.2 *Alternate Flat-bottom Hole Sizes*—If blocks with the specified flat-bottom hole sizes are not available, alternative sizes may be used provided the instrument gain is changed by a factor given by the ratio of the areas of the two relevant holes. For cases where only a larger size is available, the gain must be increased by the ratio $(d_r / d_a)^2$, where d_r and d_a are respectively the diameters of the reference and specified acceptance flat-bottom holes (see Table 5, Note 1). With instruments having gain controls calibrated in dB, the required change is given by $40 \times \log(d_r / d_a)$ dB. Table 5 can be used for the extrapolation of gain between any standard hole sizes in the range of 1/64 through 8/64. Gain extrapolation shall be restricted to hole diameters having ratios no greater than 2:1, requiring gain changes no greater than 12 dB. For class AAA only, gain extrapolation shall be restricted to hole diameters having ratios no greater than 3:1, requiring gain changes no greater than 19 dB.

7.3.3 *Curved Surface Reference Blocks*—Blocks used on cylindrically or irregularly shaped products shall meet the following requirements:

7.3.3.1 *Examination of Cylindrical Parts of Greater Than 4 in. (101.6 mm) Radius*—Reference blocks shall be of material specified in 7.3.1 and may be either flat blocks manufactured according to Practice E127 or they may be the stepped type shown in Fig. 1 (with correspondingly larger dimensions) or, of the type specified in 7.3.2 machined to within 10 % of the radius of curvature of the part being examined, or of the alternate type described in 7.3.7 in which case larger holes may be used to clear a holding fixture for the flat-bottom hole drill as described in 7.3.3.2.

7.3.3.2 *Examination of Cylindrical Parts of Less Than 4 in. (101.6 mm) Radius*—Reference blocks shall have a radius of curvature within 10 % of those parts. The blocks shall be, where practical, of full round cross-section. Reference holes may be drilled by using a larger diameter hole drilled to no closer than 0.5 in. (12.7 mm) to the final depth of the flat-bottom hole, permitting the use of a holding fixture for the drill for the flat-bottom holes. An acceptable alternate to full round blocks is the stepped type shown in Fig. 1. Flat-bottom

TABLE 2 Recommended Reference Block Material

Material to be	Reference Material	Typical Specification
Aluminum	7075-T6	ASTM B221 ASTM B241/B241M QQ-A225/9
	2024	ASTM B221 ASTM B241/B241M QQ-A225/6
Magnesium	ZK60	ASTM B107/B107M
Titanium	T1-6A1-4V annealed	AMS 4928
Low-Alloy Steels (4130, 4340); High-Strength Low-Steels (such as NAX, T-300M); Straight Carbon and H-11 Tool	4340 annealed	AMS 6484 AMS 6415 AMS 6409

NOTE 1—Other materials may be used when documented and approved by the cognizant engineering organization.

TABLE 3 Surface Resolution Requirements

Material Thickness (t)	Resolution Requirements	
	Forgings/Re-Forgings	Other Product Forms
Up to 1.25 in. (31.75 mm)	1/4 in. (6.35 mm)	1/8 in. (3.05 mm)
1.25 in.(31.75) and over	1/4 in. (6.35 mm)	1/10 t
2.5 in. (63.5 mm) and over	1/10 t or 1/2 in. (12.7 mm), whichever is less	

NOTE 1—Unless otherwise specified in a contract document.

TABLE 4 Flat Surface Reference Standard Metal Travel

Depth of Discontinuity, in. (mm)	Reference Standard Metal Travel Distance Tolerance, in. (mm)
Up to ¼ (6.35)	±1⁄16 (1.59)
0.250 (6.35) to 1.0 (25.4)	±⅛ (3.18)
1.0 (25.4) to 3 (76.2)	±¼ (6.35)
3.0 (76.2) to 6 (152.4)	±½ (12.7)
Over 6.0 (152.4)	±10 % of metal travel

holes, of the sizes required for the appropriate examination class in accordance with Table 1, shall be placed in the block at the metal travel distances specified in 7.4.7.1. The sizes and depths of the flat-bottom holes shall be verified by calibrated measuring instruments and the holes should be plugged to prevent water entry and to create an air interface at the hole bottom. If it is not possible to use the same material for reference blocks, the provisions of 7.3.1 shall apply.

7.3.3.3 *Alternate Tolerances for Straight-Beam Examination of Cylindrical Parts*—In the case of straight-beam examination only, where detection of indications of the class specified is demonstrated to the satisfaction of the cognizant engineering organization, the cognizant Level 3, and documented, the use of reference standards with greater departure of radius from that of the test material than that listed above, may be permitted.

NOTE 3—The use of round cross-section blocks allows the dynamic verification of instrument and system standardization. Such dynamic verification may be difficult, or not possible, using stepped blocks.

7.3.4 *Rectangular Angle Beam Reference Blocks*—Fig. 2 is the configuration for rectangular angle beam blocks using flat-bottom holes for use with contact examination only. Side-drilled holes may be used to obtain graphic distance-amplitude curves with sensitivity corrected by using the end-drilled holes of the applicable ultrasonic class size (see A1.3.4). Other block configurations and reflectors may be used if they meet the requirements of 7.3.7 and 7.3.8, or comply with documented requirements approved by the cognizant engineering organization. The vee-path options illustrated in Fig. A1.4 shall not be used to obtain standardization of immersion examinations because of the loss of sound energy at the apex of the vee-paths if the block is immersed.

7.3.5 *Hollow Cylindrical Angle Beam Reference Blocks*—Reference blocks for shear wave examination of tubing and ring forgings shall have an outer ring diameter that is within ±5 % of the outside diameter of the examination material and the thickness shall be ±10 % of the examination material. The reference block shall contain reference reflector notches in accordance with Fig. 3 based on the applicable class of examination in accordance with Table 1.

7.3.6 *International Institute of Welding (IIW) Type Reference Block*—Blocks derived from the International Institute of Welding (IIW), Reference Block, Practice E164 Annex A, shall be used for evaluation of contact angle beam search units as an aid in determining proper positioning for contact angle beam examination, and to determine beam exit point from the search units and angle of the sound beam. The material from which the blocks are to be made must be specified by the purchaser.

7.3.7 *Alternate Reference Blocks*—Other reference reflectors, as approved by the cognizant engineering organization may be used.

7.3.8 *Alternate Reference Block Fabrication*—If other types of reference blocks, reflectors and materials are used as approved by the cognizant engineering organization, material for these blocks shall meet the requirements of 7.3.1 and, where applicable, reference targets shall meet the requirements of 7.3.7.

7.3.9 *Additional Fabrication Requirements*—The following additional fabrication/verification requirements apply to reference blocks specified herein:

7.3.9.1 Flat-bottom holes shall be dimensionally evaluated in accordance with Practice E127.

7.3.9.2 The angular alignment of holes in reference blocks shall have a tolerance of ±30 min and be perpendicular to the beam entry surface or other surface or direction as required or intended by the governing specification.

7.3.9.3 Reference standards shall be clearly identified so that the hole size, depth and material type (refracted angle, if used) are discerned on the block or a drawing of the block. If this data is only on the drawing then the reference standard shall be traceable to its drawing.

7.3.9.4 All reference blocks shall be visually examined prior to each use for signs of surface and sealing-plug damage or deterioration. Any block which exhibits significant rusting, corrosion or surface damage, which may interfere with the examination process, shall be either discarded and replaced, or cleaned and recertified in accordance with Practice E127 or the original surface finish requirements as appropriate.

7.3.9.5 After all flat-bottom holes are verified, they shall be plugged as specified in Practice E127 to protect the hole from corrosion when that is a potential problem.

7.3.9.6 Reference standards shall be dried, or couplant removed, or both, after use. Reference standards shall be handled and stored in a manner to preclude damage.

7.4 *Examination Procedures:*

7.4.1 *Visual Examination*—Prior to ultrasonic examination visually examine the part or material for cleanliness, surface roughness, cracks, burrs, nicks, gouges, raised areas, irregular machining and tool tears. Any surface anomalies that will impair ultrasonic examination shall be removed prior to examination. If removal is not possible or practical, mark such discrepancies on the part for later analysis during evaluation of ultrasonic indications.

7.4.2 *Coverage*—The sound beam direction required for examination of various wrought shapes shall be in accordance with Figs. 5 and 6. Additional coverage requirements shall be as specified below:

7.4.2.1 When directions of maximum stressing are indicated on contract documents, scanning shall be performed to locate discontinuities that are oriented perpendicular to the specified directions (see 6.1).

7.4.2.2 When entry surface resolution is not sufficient to resolve discontinuities near the part surface, as required by Table 3, while achieving at least a 2:1 or greater signal-to-noise ratio, additional examinations shall be performed from the opposite side, or, different examination zone depths shall be

TABLE 5 Appropriate dB Gain Changes between Flat-Bottom Hole (FBH) Sizes

Acceptable Flat-Bottom Hole Diameter, 1/64 in. (mm)	Reference Flat-Bottom Hole Diameter, 1/64 in. (mm)							
	1 (0.4)	2 (0.8)	3 (1.2)	4 (1.6)	5 (2.0)	6 (2.4)	7 (2.8)	8 (3.2)
1 (0.4)	0 dB	+12 dB						
2 (0.8)	−12 dB	0 dB	+7 dB	+12 dB				
3 (1.2)		−7 dB	0 dB	+5 dB	+9 dB	+12 dB		
4 (1.6)		−12 dB	−5 dB	0 dB	+4 dB	+7 dB	+10 dB	+12 dB
5 (2.0)			−9 dB	−4 dB	0 dB	+3 dB	+6 dB	+8 dB
6 (2.4)			−12 dB	−7 dB	−3 dB	0 dB	+3 dB	+5 dB
7 (2.8)				−10 dB	−6 dB	−3 dB	0 dB	+2 dB
8 (3.2)				−12 dB	−8 dB	−5 dB	−2 dB	0 dB

NOTE 1—Blank areas contain absolute values of gain changes greater than ±12 dB and are not applicable, see 7.3.1.1.

NOTE 2—Reference FBH diameter refers to the size of the FBH in the reference blocks. Acceptance FBH diameter refers to the extrapolated FBH. Table entries are calculated as follows:

$$40 \log_{10}\left(\frac{\text{reference FBH diameter}}{\text{acceptance FBH diameter}}\right) = \text{dB}$$

NOTE 3—+dB = instrument gain increase; −dB = instrument gain decrease.

NOTE 4—If the dB control has a minimum incremental change of 2 dB and the extrapolation requires an uneven dB change, the dB control shall be adjusted for 1 dB more gain than required. For instance, in this case note the dB control in Note 5 would be increased by +10 dB instead of +9 dB.

NOTE 5—Explanation of Extrapolation: With a reference FBH of 5/64 in. (1.98 mm) and an acceptance FBH of 3/64 in. (1.191 mm), the difference is +9 dB. Since the acceptance FBH is smaller than the reference FBH, the gain must be increased by 9 dB from the reference FBH setting.

NOTE 6—This table assumes a linear relationship between the amplitude of the response of an instrument and the area of a flat-bottom hole target. This assumption is approximately valid only for certain material configurations and combinations of search units and instrument parameters.

established, or the examination frequency may be changed as long as all other requirements are met. Also, for each examination direction, examinations from opposite sides are required when the maximum metal travel distance is such that the minimum size discontinuity of the applicable class cannot be detected by examination from only one side.

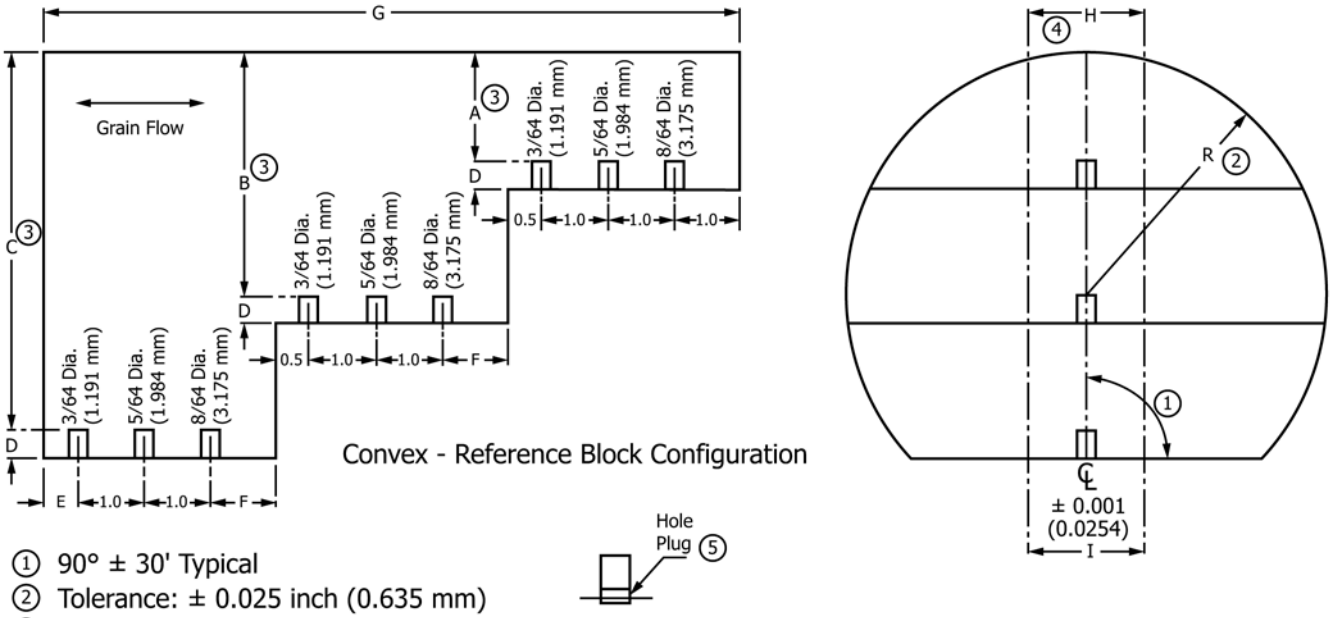
7.4.2.3 When the length of any of the examination dimensions (distance sound beam travels through the material) exceeds 18 in. (457 mm) supplementary examinations may be additionally required to locate discontinuities that are not detectable by straight beam examination. This is based on the fact that it would be very difficult to detect discontinuities greater than 9 in. (228 mm) in depth for a Class A, or higher, examination. It shall be verified that the side walls do not give erroneous examination results.

7.4.3 *Scanning Speed*—The scanning speed shall not exceed the maximum scanning speed which provides for detection of the reference reflectors in the reference standards used to set up the examination.

7.4.4 *Ultrasonic Frequency*—Standardization and examination shall be performed at the ultrasonic frequency which will provide the penetration and resolution required for valid examination of the production material. Examination performed with transmitting and receiving search units of different frequencies shall be considered to be performed at the frequency of the transmitting search unit for broadband systems. For tuned systems, the operating system frequency is established by either the transmitting or receiving system whichever is tuned.

7.4.5 *Water Travel Path for Immersion Method*—The distance from the face of the search unit to the front surface of a part shall be such that the second front reflection from the examination material does not appear between the first front and first back reflections. This distance (water travel) must be the same within ±0.25 in. (±6.35 mm) for standardization, initial scanning and final evaluation. When possible, examination shall be performed using water paths that result in examinations being performed in the far field of the search unit, or in the depth of field of a focused search unit approved by the cognizant engineering organization. When focused search units are used, the distance shall be such that the search unit focus is within the material at the depth required to meet front surface resolution requirements. For angle beam examination of curved or cylindrical parts the water path distance must be maintained at a length which does not vary during material examination or between standardization and examination by more than ±0.02 times the radius of curvature of the material.

7.4.6 *Lateral Position Stability for Examination of Cylindrical Parts*—During dynamic scanning, variation in position of the vertical centerline of a flat or focused search unit beam with



R	A	B	C	D	E	F	G	H
4.0 (101.6)	2.0 (50.8)	4.0 (101.6)	6.0 (152.4)	0.425 (10.8)	1.5 (38.1)	1.5 (38.1)	12.5 (317.5)	2.0 (50.8)
3.5 (88.9)	1.75 (44.5)	3.5 (88.9)	5.25 (133.4)	0.425 (10.8)	1.5 (38.1)	1.5 (38.1)	12.5 (317.5)	2.0 (50.8)
3.0 (76.2)	1.5 (38.1)	3.0 (76.2)	4.5 (114.3)	0.425 (10.8)	1.0 (25.4)	1.5 (38.1)	12.0 (304.8)	2.0 (50.8)
2.5 (63.5)	1.25 (31.8)	2.5 (63.5)	3.75 (95.3)	0.425 (10.8)	1.0 (25.4)	1.5 (38.1)	12.0 (304.8)	2.0 (50.8)
2.0 (50.8)	1.0 (25.4)	2.0 (50.8)	3.0 (76.2)	0.425 (10.8)	1.0 (25.4)	1.5 (38.1)	12.0 (304.8)	2.0 (50.8)
1.5 (38.1)	0.75 (19.1)	1.5 (38.1)	2.25 (57.2)	0.425 (10.8)	1.0 (25.4)	1.5 (38.1)	12.0 (304.8)	2.0 (50.8)
1.25 (31.8)	0.625 (15.9)	1.25 (31.8)	1.875 (47.6)	0.425 (10.8)	1.0 (25.4)	1.5 (38.1)	12.0 (304.8)	1.5 (38.1)
1.0 (25.4)	0.5 (12.7)	1.0 (25.4)	1.5 (38.1)	0.425 (10.8)	1.0 (25.4)	1.5 (38.1)	12.0 (304.8)	1.5 (38.1)
0.75 (19.1)	0.375 (9.53)	0.75 (19.1)	1.125 (28.6)	0.3 (7.62)	1.0 (25.4)	1.0 (25.4)	11.0 (279.4)	1.5 (38.1)
0.5 (12.7)	0.25 (6.35)	0.5 (12.7)	0.75 (19.1)	0.2 (5.08)	1.0 (25.4)	1.0 (25.4)	11.0 (279.4)	1.0 (25.4)

NOTE 1—Primary units are inches, ( ) are millimetres.

NOTE 2—An approved alternate configuration to that of Fig. 1 is to divide and construct each of the ten reference blocks as three separate blocks; one containing the "C" dimensions, one containing the "B" dimensions, and one containing the "A" dimensions. For this alternate construction, all dimensions of Fig. 1 apply except as follows:

(1) For each C block, the F dimension shall equal the listed E dimension.

(2) For each B block, the F dimension and the sketched 0.5 in. (12.7 mm) dimension shall be 1.0 in. (25.4 mm).

(3) For each A block, the sketched 0.5 in. (12.7 mm) dimension shall be 1.0 in. (25.4 mm).

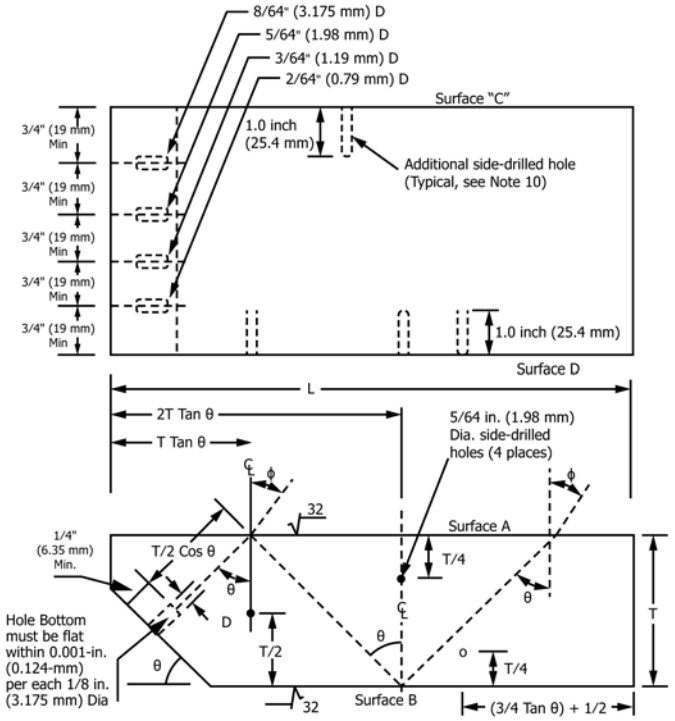
(4) The I thickness shows an alternate design based on the H dimension.

NOTE 3—Alternate forms and dimensions of reference standards may be used in accordance with 7.3.3 that contain only the flat-bottom hole diameter(s) necessary to meet Table 1 requirements for the specified examination class and which contain metal travel distances to meet 7.4.7.1 and that have radii of curvature to meet 7.3.1.1.

FIG. 1 Typical Convex Reference Block Configuration for Longitudinal Wave Examination

respect to a radius perpendicular to that centerline shall not exceed ±0.02 times the radius of curvature.

7.4.7 *Reference Blocks*—Select reference blocks that have been prepared in accordance with 7.3 with flat-bottom-hole (FBH) diameters or reference reflectors for the applicable class (Table 1). Diameters other than specified may be used provided the diameters are within a factor of two and, after the response from the reflector is set to be not less than 80 % FSD, or other amplitude approved by the cognizant engineering organization, and the gain is adjusted by an amount equal to the ratio of the



Thickness (t), of Part of Material to be Examined	T	L (Min. Inch)
Up to and Including 1 in. (25.4 mm)	3/4 in. or t (19.05 mm)	(3T Tan θ+ 1)
Over 1 in. to 2 in. (25.4 including 50.8 mm)	1-1/2 in. or t (38.1 mm)	
Over 2 in. to 4 in. (50.8 including 101.6 mm)	3 in. or t (76.2 mm)	
Over 4 in. to 6 in. (101.6 including 152.4 mm)	5 in. or t (127 mm)	
Over 6 in. (Over 152.4 mm)	t ± 1 in. (25.4 mm)	

All surfaces shall be equal to or smoother than 32 rms or equivalent.

"NOT TO SCALE"

NOTE 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.

NOTE 2—Side-drilled holes shall not be used for T less than ¾ in. (19.05 mm).

NOTE 3—A shorter block than shown may be used for thicker materials when only ½ or 1 vee-path examining distance is to be used. For shorter reference blocks the side-drilled holes shall be relocated along L so that each hole lies at least ¾ in. from all sound beam paths used for the other holes.

NOTE 4—D = hole diameter for applicable class.

NOTE 5—θ is the nominal angle of the sound beam in the part with respect to the normal to the sound entry surface. Typical examples: θ = 60° for T = (½ in. (12.7 mm) to 1 in. (25.4 mm)) and θ = 45° for T = (Over 1 in.).

NOTE 6—φ is the angle of the entering sound beam with respect to the normal to the sound entry surface.

NOTE 7—Primary dimensions are in inches, metric (XX mm).

NOTE 8—All dimensions ± 0.03 in. (0.762 mm) except for hole diameters which are ±3 % of diameter specified.

NOTE 9—Surface A and Surface B must be flat and within 0.001 in. per in. (0.025 mm per mm).

NOTE 10—For blocks thicker than one inch, additional 5⁄64 in. (1.98 mm) diameter side-drilled holes shall be drilled from Surface C with the axes of the holes located ¼ in. (6.35 mm), ½ in. (12.7 mm), 1 in. (25.4 mm), 1-½ in. (38.1 mm) and so forth, 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 ¾ in. (19.05 mm) from the sound beam paths used for other side-drilled holes.

NOTE 11—All holes should be permanently plugged in a manner to ensure that they are water-tight and that an air-metal interface is preserved.

FIG. 2 Typical Reference Block for Angle Beam Examination

UT Class	Notch Size (Solid Bars) Depth[A] × Length,[B] in. (mm)	Notch Size (Tubes) Depth[A] × Length,[B] in. (mm)
AAA	0.004 (0.10) × 0.188 (4.76)	3 % of Wall[C] × 0.063 ± 0.005 (1.60 ± 0.13)
AA	0.005 (0.13) × 0.250 (6.35)	5 % of Wall[D] × 0.250 (6.35)
A	0.010 (0.25) × 0.500 (12.7)	10 % of Wall[E] × 0.500 (12.7)
B	0.015 (0.38) × 1.000 (25.4)	12.5 % of Wall[F] × 1.000 (25.4)
C	Not Applicable	Not Applicable

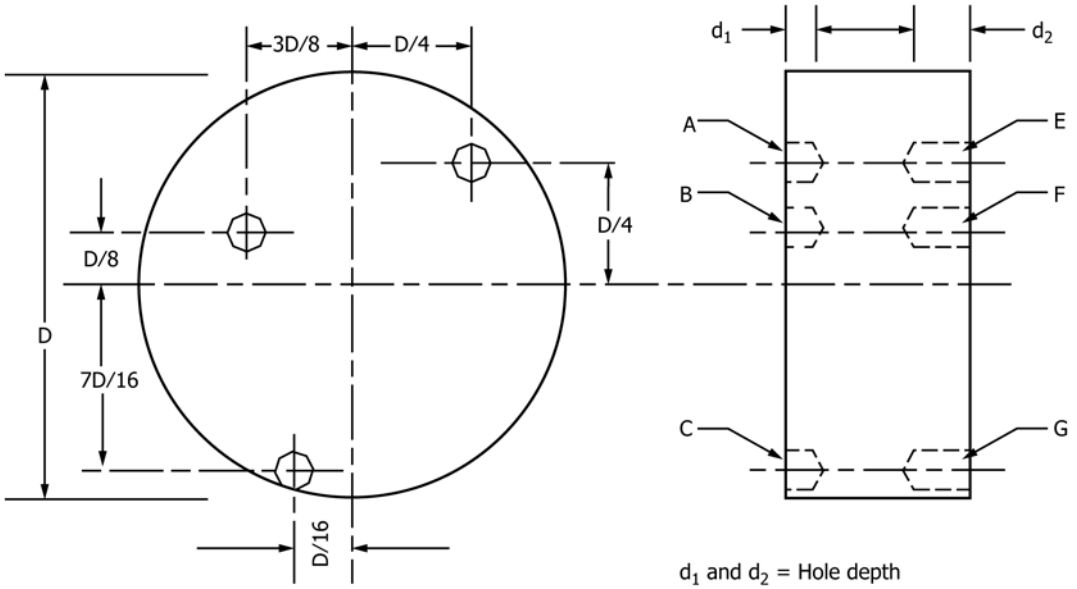
[A] Depth tolerance = ±0.0005 in. (± 0.013 mm) for notches 0.005 in. (0.13 mm) or less in depth, and = +10 %, −15 % for notches over 0.005 in. (0.13 mm) depth, except as noted.
[B] Length tolerance = ± 0.010 in. (± 0.254 mm) except as noted.
[C] 3 % of wall or 0.003 in. (0.076 mm) whichever is greater.
[D] 5 % of wall or 0.004 in. (0.102 mm) whichever is greater.
[E] 10 % of wall or 0.004 in. (0.102 mm) whichever is greater.
[F] 12.5 % of wall or 0.004 in. (0.102 mm) whichever is greater.

NOTE 1—Notch width to be as small as practical but shall not exceed twice the nominal notch depth.

FIG. 3 Rectangular Notch for Angular Beam Reference Reflectors

areas of the two reflectors. The examination shall be performed at the equivalent gain level for the specified hole.

7.4.7.1 *Reference Block Metal Path Increments*—Select reference block(s) containing at least three of the following metal



UT Class	Hole Diameter / Depth, in. (mm)	
	Multiple	Single
A	0.020 (0.508) diameter / 0.25 (6.35) depth	0.020 (0.508) diameter / 0.50 (12.70) depth
B	0.020 (0.508) diameter / 0.50 (12.70) depth	0.047 (1.19) diameter / 1.00 (25.4) depth
C	Not Applicable	0.047 (1.19) diameter / 1.00 (25.4) depth

NOTE 1—Tolerance for location of side-drilled holes is ±0.010 in. (0.254 mm).
NOTE 2—All surfaces Roughness = 125 Ra.
NOTE 3—Multiple and single discontinuity size and spacing requirements are defined in Table 1.
NOTE 4—Since reflections are from the hole side, hole bottoms need not be flat.

Diameter of FBH for which Side-Drilled Hole is to be Substituted, in. (mm)	Side-Drilled Hole (A, B, C, E, F, and G)	
	Diameter ± 0.001 in. (± 0.025 mm)	Depth ± 0.020 in. (± 0.503 mm)
3/64 (1.190)	0.020 (0.508)	0.25 (6.35)
5/64 (1.980)	0.020 (0.508)	0.50 (12.7)
8/64 (3.175)	0.047 (1.190)	1.00 (25.4)

NOTE 5—Side-drilled holes may be used when specified, but are not necessarily equivalent. Holes should be plugged to keep out dirt and water.

FIG. 4 Side-Drilled-Hole Reference Block

paths distances, unless an alternate plan demonstrates, and is approved by the cognizant engineering organization, that only the extremes of the examination depth of interest are necessary:

(1) A metal path equal to or less than the front surface resolution. When examination is performed from both surfaces of a part, or if solid cylindricals are rotated during examination, examination of only the center-to-far-wall region of the part may be used if defect detection is demonstrated.

(2) A metal path equal to half of the examination piece or zone thickness ±0.125 in. (3.2 mm).

(3) A metal path equal to or greater than the thickness of the part or zone to be examined.

(4) When examining parts greater than 2 in. (50.8 mm) thickness or diameter, reference reflectors shall be provided with metal paths throughout the examination zone at intervals sufficient to establish total gain requirements and amplitude interpolation.

7.4.8 *Preparation for Standardization:*

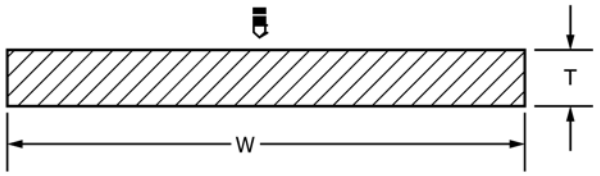
7.4.8.1 *Immersion*—Using the reference blocks selected in accordance with 7.3, immerse the reference standards and search unit in the water bath. Normalize the search unit to maximize the reflected signal from the water-metal interface by manipulating the search unit.

7.4.8.2 *Contact*—Using the reference standards selected in 7.3, apply the couplant selected in accordance with 7.1.2.

7.4.9 *Use of Reference Curve and Direct Comparison Methods for Standardization*—Standardization of the examination shall be accomplished by determining the distance-amplitude relationship for the reference blocks selected in 7.4.7. Compensation for the variation of detection sensitivity with distance from the entry surface shall be accomplished by using either the reference curve method of 7.4.9.1, the direct comparison method of 7.4.9.2, or electronic distance-amplitude correction (EDAC) as described in 7.4.10.2 and 7.4.10.3.

7.4.9.1 *Reference Curve Method*—Position the search unit on each reference block and maximize the signal amplitude. Set the instrument to achieve the required resolution (for example, pulse length and tuning). Select the reference standard that provides the largest amplitude and adjust the gain to obtain an indication that is not less than 80 % FSD or other approved amplitude. Mark the amplitude of the maximized indication from each reference standard on the display and

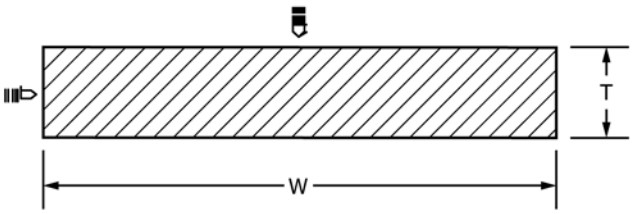
Plate and Flat Bar



Cross Section
T = Thickness
W = Width

Notes:
1. If W/T > 5, scan with a straight beam with the beam directed as shown
2. If W or T > 9 inches (228.6 mm), surface resolution requirements may require scanning from opposite side.

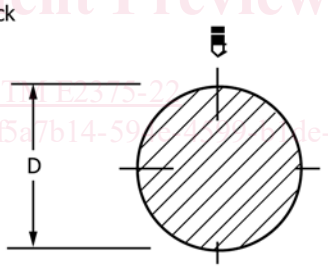
Rectangular Bar, Bloom, and Billets



Cross Section
T = Thickness
W = Width

Notes:
1. If W/T < 5, scan with a straight beam from two adjacent sides with the sound beam directed as shown
2. If T or W > 9 inches (228.6 mm), surface resolution requirements may require scanning from opposite sides.

Round Bars and Round Forging Stock



Cross Section
D = Diameter

Notes:
1. Examine by straight beam with sound beam directed towards the center of the bar as shown while bar is rotating to locate discontinuities at or near the center of the bar.
2. When specified in the contract documents purchase order, or engineering drawing scan with a circumferential angle beam technique per appendix A

FIG. 5 Sound Beam Direction for Various Shapes

connect the points with a smooth curve. When material thickness and attenuation do not permit the above, zoning and multiple curves or examination from the opposite side may be required. Once this is done, display time based controls (for example, sweep delay and length) shall not be changed.

7.4.9.2 *Direct Comparison Method*—Use block(s) with the proper hole sizes at sufficient metal travel depth to establish the gain relation of the beam profile throughout the full examination depth.

7.4.10 *Establishment of Scanning Gain, Index, and Alarm Level for Standardization*—Determine the gain setting for initial scanning with or without electronic distance-amplitude correction (EDAC). For the applicable class, the multiple discontinuity hole size of Table 1 shall be used to establish the scanning gain, index, and alarm level, except for Class C, where the single discontinuity hole size shall be used.

7.4.10.1 *Scanning Gain without EDAC*—Set the initial scanning gain by selecting the reference standard that provides the lowest echo amplitude on the distance-amplitude curve as determined by either method of 7.4.9. Maximize the amplitude from the reference reflector in this reference block, and adjust the instrument gain to obtain an amplitude not less than 80 %,