



Designation: E 2375 – 04

Standard Practice for Ultrasonic Examination of Wrought Products^{1, 2}

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1. Scope

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

NOTE 1—This standard was adopted to replace MIL-STD-2154, 30 Sept. 1982. This standard 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.

1.2.1 *Wrought Aluminum Alloy Products*—Examination shall be in accordance with Practice B 594.

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, supercedes 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 brackets.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

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 Testing Procedures.

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² When accepted by DoD this standard is expected to replace MIL-STD-2154.

2. Referenced Documents

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

2.2 *ASTM Standards*:³

B 107 Specification for Magnesium-Alloy Extruded Bars, Rods, Shapes, Tubes, and Wire

B 221 Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

B 241 Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube

B 594 Practice for Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications

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

E 164 Practice for Ultrasonic Contact Examination of Weldments

E 213 Practice for Ultrasonic Examination of Metal Pipes and Tubing

E 317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Examination Instruments and Systems Without the Use of Electronic Measurement Instruments

E 428 Practice for Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Examination

E 543 Practice for Agencies Performing Nondestructive Testing

E 1065 Guide for Evaluating Characteristics of Ultrasonic Search Units

E 1158 Guide for Material Selection and Fabrication of Reference Blocks for the Pulsed Longitudinal Wave Ultrasonic Examination of Metal and Metal Alloy Production Material

E 1316 Terminology for Nondestructive Examinations

³ 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.

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	3/64 in. [0.794 mm] FB	1/64 in. [0.397 mm] FB	1/8 in. [3.175 mm] long 1/64 in. response [0.397 mm] FB	50	alarm level
AA ^H	3/64 in. [1.19 mm] FB	3/64 in. ^I [0.794 mm] FB	1/2 in. [12.7 mm] long 3/64 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	3/64 in. [3.18 mm] FB	5/64 [1.98 mm] FB	1 in. [25.4 mm] long 3/64 in. response [1.98 mm] FB	50	alarm level
C	3/64 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. 3, Fig. 4, or Fig. 5 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 equal to or greater than 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 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 American Society for Nondestructive Testing (ASNT) Standards:

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing⁴

ANSI/ASNT-CP-189 ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel⁴

2.4 Society for Automotive Engineers (SAE) Standards:

AMS 4928 Titanium Alloy, Bars, Wire, Forgings, and Rings 6Al-4V Annealed⁵

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 Tempered⁵

AMS 6415 Steel, Bars, Forgings, and Tubing, 0.80 Cr, 1.8 Ni, 0.25 Mo (0.38 - 0.43 C) (SAE 4340)⁵

AMS 6484 Steel, Bars, Forgings, and Tubing, 0.80 Cr, 1.8 Ni, 0.25 Mo (0.38 - 0.43 C) (SAE 4340) Normalized and Tempered⁵

2.5 Aerospace Industries Association Standard:

NAS 410 Certification and Qualification of Nondestructive Test Personnel⁶

2.6 Federal Specifications:

QQ-A-225/6 Aluminum Alloy Bar, Rod, and Wire, Rolled, Drawn, or Cold Finished, 2024⁶

QQ-A-225/9 Aluminum Alloy Bar, Rod, Wire, and Special Shapes, Rolled, Drawn, or Cold Finished, 7075⁶

2.7 Military Standards:⁷

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 E 1316, shall apply to the terms used in this standard.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *back surface resolution*—the minimum distance between the back surface and a discontinuity of known size that will result in a clear differentiation of the two signals as indicated by the trace recovering to 20 % or less of discontinuity or back surface amplitude (whichever is lower) between the indications at the sensitivity required for the specified examination.

3.2.2 *cognizant engineering organization*—the company, government agency, or other authority responsible for the design, or end use, of the system or component for which ultrasonic examination is required. This, in addition to design

⁴ Available from The American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518.

⁵ Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

⁶ Aerospace Industries Association of America, Inc., 1250 Eye Street NW, Washington, DC 20005.

⁷ 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.

personnel, may include personnel from engineering, material and process engineering, stress analysis, NDT or quality groups and others, as appropriate.

3.2.3 *contract document*—any document specified in the contract, including the purchase order, specification, drawing, or other written material.

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

3.2.5 *entry surface resolution*—the minimum distance between the entry surface and a discontinuity of known size that will result in a clear differentiation of the two signals as indicated by the trace recovering to 20 % or less of the discontinuity amplitude between the indications at the sensitivity required for the specified examination.

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

3.2.7 *horizontal limit*—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.

3.2.8 *immersion ultrasonic examination*—the use of a water medium to couple the search unit to the part surface. This technique includes immersion in a tank of water, the use of water columns, bubblers, or similar device.

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

3.2.10 *vertical linearity limit (upper and lower)*—values of the vertical amplitude at which a proportional relationship with the input signal deviates from or exceeds a prescribed amount.

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 Practice **E 543**.

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.

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 7.2.8), 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 E 317 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.

7.2.1.3 If automatic means are used for detection of loss-of-back reflection amplitude, it shall be demonstrated that the speed of response of such means is adequate to detect, at actual scanning speeds, at least a -6 dB reduction in back reflection signal from an area no larger than the theoretical area of search unit beam intersection on the near surface of the material. An alternate method such as a near zone FBH with only the back wall gated may be used if approved by the Level III of the cognizant engineering organization.

NOTE 3—This shall be demonstrated by one of the following techniques or a technique approved by the Level III of the cognizant engineering organization.

(1) Place on the surface of the material a temporary spot, consisting of a double layer of masking tape, or other absorptive material, nominally equal to the area of the beam intersection on the near surface. The spot shall be passed through the search unit beam at full scanning speed. When this is done the means used for loss-of-back signal shall indicate at least 50 % reduction in back signal amplitude.

(2) An alternate method is to use a near zone FBH with only the back wall gated.

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 to be 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 E 1065. 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 that the sensitivity profile along the major axis of the search unit does not vary more than ± 10 % of the vertical limit when the sensitivity is adjusted to provide a nominal 50 % response from a reference reflector (either a steel ball, wire, or flat-bottom hole) as shown in Fig. 1. The profile shall have been verified within a period not exceeding twelve months prior to the date of use of the search unit, unless masking is used to suppress the

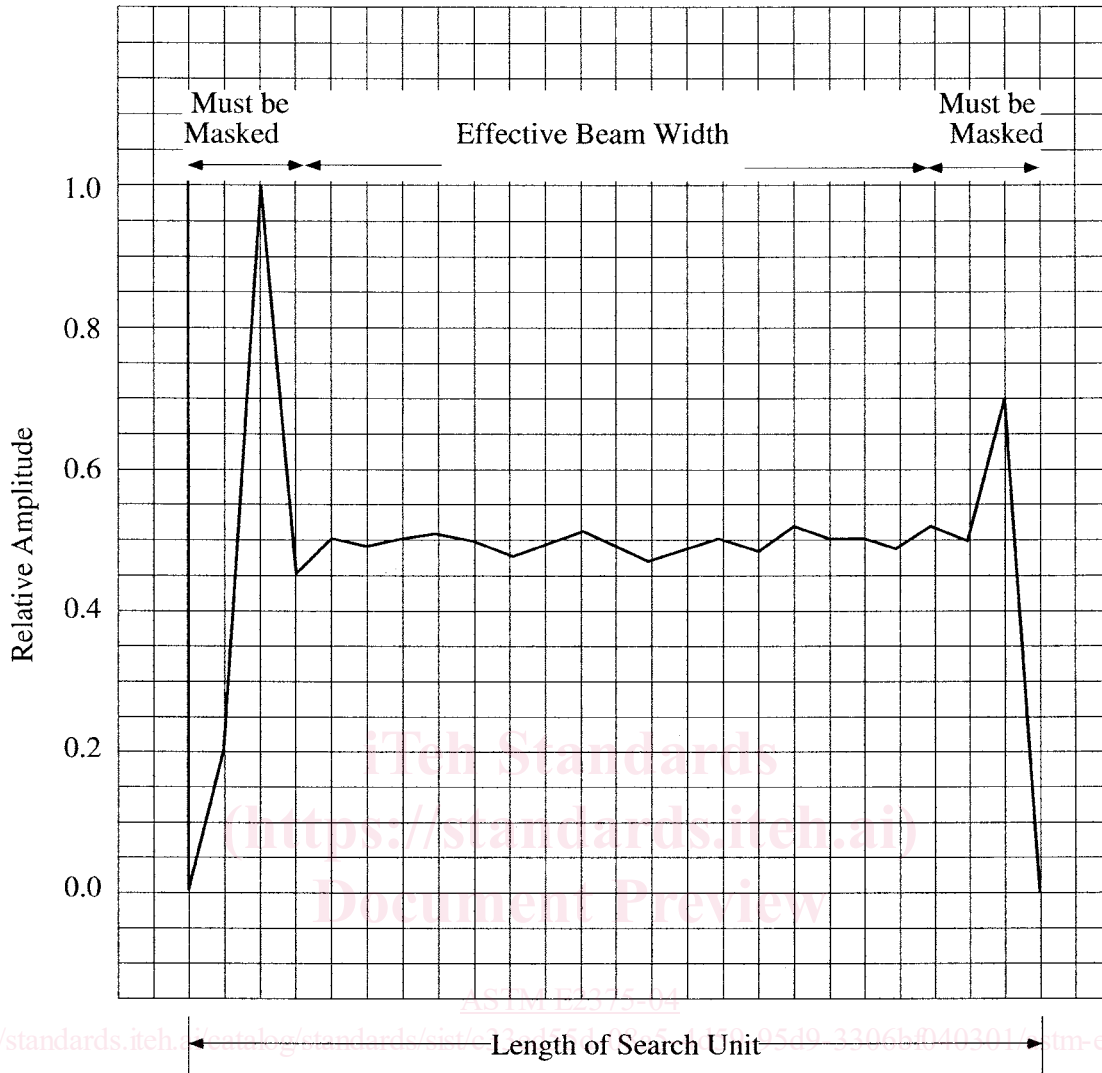


FIG. 1 Acceptable Sound Beam Profile of "Paintbrush" Search Unit

peaks. If masking is used, the search unit profile shall have been verified within a period not exceeding three months prior to the date of use.

7.2.5.2 A method shall 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). Variations from these requirements are acceptable for phased array search units.

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

7.2.8 *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.

7.2.8.1 *Attachments*—For special applications attachments may be used with the search unit to provide the required water path distances or coupling, see 3.2.8.

7.2.9 *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 E 127, E 428, E 1158, 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 working reference blocks provided the velocity and attenuation

TABLE 2 Recommended Reference Block Material

Material to be	Reference Material	Typical Specification
Aluminum	7075-T6	ASTM B 221 ASTM B 241 QQ-A225/9
	2024	ASTM B 221 ASTM B 241 QQ-A225/6
Magnesium	ZK60	ASTM B 107
Titanium	T1-6A1-4V annealed	AMS 4928
Low-Alloy Steels (4130, 4340);	4340 annealed	AMS 6484
High-Strength Low-Steels		AMS 6415
(such as NAX, T-300M);		AMS 6409
Straight Carbon and H-11 Tool		

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

difference between the reference block and the examination material are within the limits shown below:

7.3.1.1 The longitudinal wave velocity of the material for a reference standard for straight beam (normalized longitudinal wave) shall be within $\pm 10\%$ of the velocity of the examination material. Material for reference standards to be used for angle beam examination shall have a velocity, in the propagation mode to be employed, that is within $\pm 5\%$ of that of the examination material. This may be determined by comparing the sweep distance, on the ultrasonic instrument display, of back or end reflections from equal thicknesses of reference block and examination material.

7.3.1.2 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 per 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.

7.3.1.3 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 $3/64$. Gain extrapolation shall be restricted to hole diameters having ratios no greater than 2:1, requiring gain changes no greater than 12 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

TABLE 3 Surface Resolution Requirements

Examination Material	Required
Up to 2.50 in. [63.5 mm]	0.25 in. [6.35 mm]
Over 2.50 in. [63.5 mm]	$1/10$ thickness or $1/2$ in. [12.7 mm] whichever is less.
Solid Round Stock	
0.5 to 5.0 in. [12.7 to 127 mm]	0.25 in. [6.35 mm]
Over 5.0 in. [127 mm]	0.38 in.
Aluminum	
Up to 2.0 in. inclusive [50.8 mm]	0.12 in. [3.05 mm]
Over 2.0 to 10.0 in. [50.8 to 254 mm]	0.25 in. [6.35 mm]
Over 10.0 to 15.0 in. [254 to 381 mm]	0.38 in. [9.65 mm]
Over 15.0 in. [381 mm]	0.50 in. [12.7 mm]

NOTE—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]	±¼ [1.59]
0.250 [6.35] to 1.0 [25.4]	±⅓ [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

specified in 7.3.1 and shall be the stepped type shown in Fig. 2 (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 be fabricated from material of the same alloy, heat treatment and surface finish as the part to be examined, and have a radius of curvature within 5 % 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. 2. Flat-bottom holes, of the sizes required for the appropriate examination class per 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 use of reference standards with greater departure of radius from that of the test material than that listed above, may be permitted.

NOTE 4—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. 3 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 per Fig. 4 based on the applicable class of examination per 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 E 164 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 E 428. As an alternate, the holes may be verified in accordance with Practice E 127.

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 per Practice E 127, E 428, 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 E 127 or E 428, 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

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.

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. 6 and 7. 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 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.

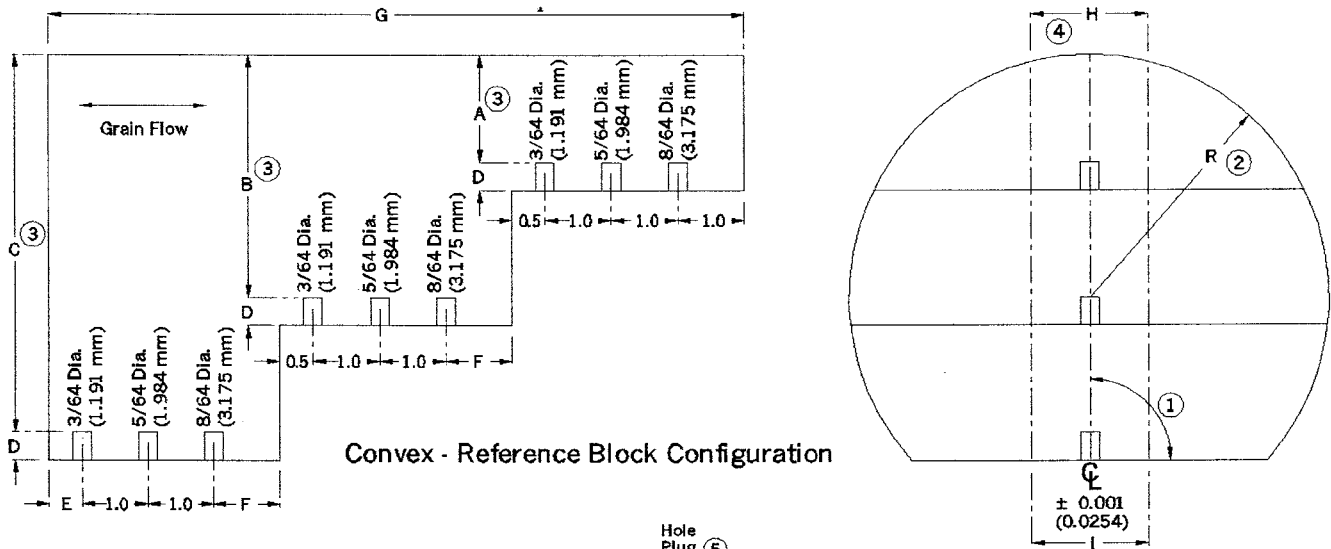
7.4.2.3 When the length of any of the examination dimensions (distance sound beam travels through the material) exceeds 18 in. [457 mm] supplementary examinations may be additionally required to locate discontinuities that are not detectable by straight beam examination. This is based on the

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



- ① 90° ± 30' Typical
- ② Tolerance: ± 0.025 inch (0.635 mm)
- ③ Tolerance: ± 0.010 inch (0.254 mm)
- ④ 100 R_a Maximum - Top Surface
- ⑤ Plug holes per ASTM E 428

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. 2 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. 2 apply except as follows:

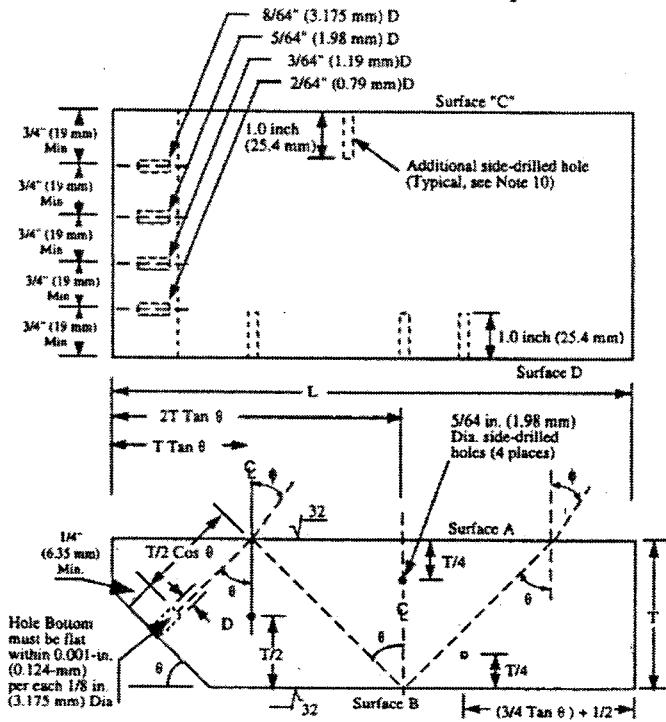
- (1) For each C block, the F dimension shall equal the listed E dimension.
- (2) For each B block, the F dimension and the sketched 0.5 in. [12.7 mm] dimension shall be 1.0 in. [25.4 mm].
- (3) For each A block, the sketched 0.5 in. [12.7 mm] dimension shall be 1.0 in. [25.4 mm].
- (4) The I thickness 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 7.3.1.2.

FIG. 2 Typical Convex Reference Block Configuration for Longitudinal Wave Examination

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.



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 3/4 in. [19.05 mm].

NOTE 3—A shorter block than shown may be used for thicker materials when only 1/2 or 1 vee-path examining distance is to be used. For shorter reference blocks the side-drilled holes shall be relocated along L so that each hole lies at least 3/4 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 = (1/2 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 1/4 in. [6.35 mm], 1/2 in. [12.7 mm], 1 in. [25.4 mm], 1-1/2 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 3/4 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. 3 Typical Reference Block for Angle Beam Examination

UT Class	Notch Size (Solid Bars)	Notch Size (Tubes)
	Depth ^A × Length, ^B in. [mm]	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	0.100 [2.54] × 0.500 [12.7]	10% of Wall ^E × 0.500 [12.7]
B	0.150 [3.81] × 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—Notch width to be as small as practical but shall not exceed twice the nominal notch depth.

FIG. 4 Rectangular Notch for Angular Beam Reference Reflectors