AEROSPACE MATERIAL SPECIFICATION

AMS-STD-2154™	REV. E

Issued 1998-03
Reaffirmed 2005-09
Revised 2021-07

Superseding AMS-STD-2154D

Inspection, Ultrasonic, Wrought Metals, Process for

RATIONALE

AMS-STD-2154D revises standard test block inspection (5.1.2.1), reference standards (5.3), distance-amplitude correction (5.4.10), evaluation of discontinuities (5.4.16), and Table 2, Note 4.

AMS-STD-2154E includes revision to transducer size (5.2.4), adds (5.4.15.1) exceptions to the transfer technique, allows a type 1 option (5.1.1.2), deletes noise note in Table 6, and adds notes of explanation for Figure 12. Because this revision clarifies changes from revision D, changes for both revisions are maintained.

NOTICE

The initial SAE publication of this document was taken directly from U.S. Military Standard MIL-STD-2154. This SAE Standard may retain the same part numbers established by the original military document.

Any requirements associated with Qualified Products Lists (QPLs) may continue to be mandatory for DoD contracts. Requirements relating to QPLs have not been adopted by the SAE for this standard and are not part of this SAE document.

FOREWORD

This document supersedes MIL-I-8950B and MIL-STD-2154, Inspection, Ultrasonic, Wrought Metals, Process. The purpose of AMS-STD-2154 is to standardize the process for applying ultrasonic inspection in the evaluation of wrought metals and wrought metal products.

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

For more information on this standard, visit
https://www.sae.org/standards/content/AMS-STD-2154E/

TABLE OF CONTENTS

1. SCOPE

1.1 Purpose

The purpose of this standard is to provide uniform methods for the ultrasonic inspection of wrought metals and wrought metal products.

1.2 Application

The methods for ultrasonic inspection in this standard are applicable in the detection of flaws in wrought metals and wrought metal products having a cross section thickness equal to 0.250 inch or greater. Round bar and billet may use AMS2628 techniques and equipment for billet over 4.5 inches using the acceptance criteria of Table 6 of AMS-STD-2154. Wrought metals include forging stock, forgings, rolled billet or plate, extruded or rolled bars, extruded or rolled shapes, and parts made from them. Application of the methods in this standard is not intended for non-metals, welds, castings, or sandwich structures.

1.2.1 Wrought Aluminum Alloy Products

Requirements for ultrasonic inspection of aluminum alloy wrought products, except as noted below, shall be in accordance with ASTM B594:

a. Ultrasonic inspection of machined aluminum alloy parts shall be in accordance with this standard.

1.3 Classification

The ultrasonic inspection methods in this standard shall be classified as follows:

1.3.1 Type

a. I - Immersion method

b. II - Contact method

1.3.2 Class

Five ultrasonic acceptance classes shall be as defined in Table 6.

2. APPLICABLE DOCUMENTS

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

2.1 SAE Publications

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

AMS2628	Enhanced Ultrasonic Immersion Inspection for Titanium Alloy and Other Metal Alloy Billets
AMS2632	Inspection, Ultrasonic, of Thin Materials 0.50 Inch (12.7 mm) and Under in Cross-Sectional Thickness
AMS4928	Titanium Alloy Bars, Wire, Forgings, Rings, and Drawn Shapes, 6Al - 4V Annealed
AMS-QQ-A-200/3	Aluminum Alloy 2024, Bar, Rod, Shapes, Tube, and Wire, Extruded

AMS-QQ-A-200/11	Aluminum Alloy 7075, Bar, Rod, Shapes, Tube, and Wire, Extruded
AMS-QQ-A-225	Aluminum and Aluminum Alloy, Bar, Rod, Wire, or Special Shapes; Rolled, Drawn, or Cold Finished; General Specification For
AMS-S-5000	Steel, Chrome-Nickel-Molybdenum (E4340) Bars and Reforging Stock

2.2 ASTM Publications

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

ASTM A36	Carbon Structural Steel
ASTM B107	Magnesium-Alloy Extruded Bars, Rods, Profiles, Tubes, and Wire
ASTM B221	Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B241/B241M	Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
ASTM B594	Ultrasonic Inspection of Aluminum-Alloy Wrought Products
ASTM E127	Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks
ASTM E317	Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems Without the Use of Electronic Measurement Instruments
ASTM E1316	Standard Terminology for Nondestructive Examinations

2.3 AIA Publications

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

NAS410	NAS Certification and Qualification of Nondestructive Test Personnel

3. DEFINITIONS

The following definitions and the definitions in ASTM E1316 shall apply to terms which are uncommon or have special meaning as used in this specification. Definitions of terms included herein are in addition to terms defined in referencing specifications and are associated primarily with ultrasonic inspection.

3.1 A-Scan Presentation

A method of data presentation on a display screen utilizing a horizontal base line that indicates distance, or time and vertical deflections from the base line which indicate pulse amplitudes.

3.2 Angle Beam Examination

Examination conducted using an ultrasonic beam traveling at an angle measured from the normal to the test surface.

3.3 Attenuation

Loss of energy per unit distance, commonly expressed in decibels per unit length.

3.4 Back Surface Resolution

The minimum distance between the back surface and a discontinuity of known size that will give an indication whose trailing edge will clearly be separated from the far surface indication down to at least 20% of full scale when the ultrasonic beam is perpendicular to the back surface.

3.5 C-Scan Presentation

A means of data presentation which provides a plan view of the part or material being tested. The location and sizes of areas containing discontinuities which give ultrasonic reflection above a pre-set amplitude are indicated on the C-scan presentation.

3.6 Decibel (dB)

Logarithmic expression of a ratio of two amplitudes.

$$db = 20 \log_{10} A_1/A_2 \qquad \text{(Eq. 1)}$$

where:

A_1 and A_2 = amplitudes or the area of reflectors

3.7 Distance-Amplitude Correction (DAC) (Swept Gain, Time Corrected Gain, and Time Variable Gain, etc.)

Electronic change of amplification to provide equal amplitude from equal reflectors at different depths.

3.8 Entry Surface Resolution

The minimum distance between the entry surface and a discontinuity of known size that will produce a first-echo indication whose leading edge will clearly be separated from the entry surface indication down to at least 20% of full scale when the ultrasonic beam is perpendicular to the entry surface.

3.9 Far Field

The region of sound beam travel beyond near field, in which intervals of high and low acoustic transmission intensity cease to occur. A reflector gives monotonically decreasing amplitude with increasing distance in this zone.

3.10 Horizontal Linearity Range

The range of horizontal deflection in which a constant relationship exists between the incremental horizontal displacement of vertical indications on the A-scan presentation and the incremental time required for reflected waves to pass through a known length in a uniform transmission medium.

3.11 Horizontal Limit

The maximum readable length of horizontal deflection that is determined either by an electrical or a physical limit in the A-scan presentation of an ultrasonic testing instrument. Horizontal limit is expressed as the maximum observed deflection in inches from the left side, or the start, of the horizontal line representing the time base.

3.12 Linear Array Probes

Probes made using a set of elements juxtaposed and aligned along a linear axis. They enable a beam to be rastered and focused along a single azimuthal plane (active axis) only.

3.13 Lower Linearity Limit

The level of vertical deflection defining the lower limit of an observed constant relationship between the amplitude of the indications on an A-scan screen and the corresponding magnitude of the reflected ultrasonic wave from reflectors of known size.

3.14 Near Field

The region immediately in front of a transducer in which the ultrasonic beam is subject to variation of intensity due to interference effects. The length of a region is governed primarily by frequency and probe diameter. The sound beam travel distance from the face of the transducer given by the equation:

$$N = D^2 f/4C \tag{Eq. 2}$$

where:

N = near field length, inches

D = major dimension of the transducer element, inches

for circles, D = diameter

for rectangles or squares, D = diagonal

F = ultrasonic frequency, Hertz

C = ultrasonic velocity, inches per second

3.15 Noise

A large number of unresolved signals at the baseline of the display which can be caused by nonhomogeneous structure, surface roughness, electrical interference, etc.

3.16 Primary Reference Response

The amplitude established from reference standards at metal travel distance where the least response is obtained.

3.17 Signal to Noise Ratio

The ratio of the amplitude of a given ultrasonic signal to the amplitude of the average background noise signal.

3.18 Straight Beam Examination

Examination conducted using an ultrasonic beam traveling normal to the test surface.

3.19 Transducer Element

The portion of a transducer which is made out of a piezoelectric material and used to transform electrical energy to ultrasonic energy and vice-versa.

3.20 Ultrasonic Sensitivity

The capacity of an ultrasonic testing system to detect a very small discontinuity. Ultrasonic sensitivity is expressed as the amplitude of the indication obtained from a small discontinuity of known size when the instrument gain setting is maximum.

3.21 Ultrasonic Penetration

A relative term denoting the ability of an ultrasonic testing system to inspect material exhibiting high absorption or scattering.

3.22 Upper Linearity Limit

The level of vertical deflection defining the upper limit of an observed constant relationship between the amplitude of the indications on an A-scan screen and the corresponding magnitude of the reflected ultrasonic wave from reflectors of known size.

3.23 Vee-Path

The angle-beam path in materials starting at the transducer examination surface, through the material to the reflecting surface, continuing to the examined surface in front of the search unit, and the reflection back along the same path to the transducer. The path is usually shaped like the letter V.

3.24 Vertical Limit

The maximum readable level of vertical indications that is determined either by an electrical or a physical limit in the A-scan presentation of an ultrasonic testing instrument. For purposes of definition, vertical limit is expressed as the maximum observed deflection in inches from the horizontal line representing the time base.

3.25 Virtual Probe

A group of individual array elements pulsed simultaneously or at phasing intervals to generate a larger acoustic aperture.

4. GENERAL REQUIREMENTS

4.1 Specifying

When ultrasonic inspection is specified in accordance with this standard, orders, contracts, or referencing specifications shall specify the ultrasonic type and class or classes (see Table 6). Engineering drawings shall be zoned to indicate different quality level acceptance classes based on the criticality of each zone. Directions of maximum stressing shall be indicated on engineering drawings to indicate the requirements for performing ultrasonic inspection to locate discontinuities oriented perpendicular to the directions of maximum stressing.

4.2 Personnel Qualification

Personnel making accept-reject decisions described in this standard shall be qualified in accordance with NAS410.

4.3 Written Procedure

A detailed NDT procedure shall be prepared for each part and type of inspection to be performed. The procedure shall meet the requirements of this standard and shall provide consistency for producing the desired results and quality level. The procedure shall cover all of the specific information required to set-up and perform the test, such as the following:

a. Name and address of testing facility.

b. Number of the procedure including latest revision letter, if applicable, and date.

c. Personnel requirements.

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

e. Inspection method type and acceptance class or classes to be applied.

f. Inspection mode (shear longitudinal, etc.).

g. Inspection zones, if applicable.

h. Specific part number and configuration to be tested.

i. Specific material and form for which the procedure is being prepared.

j. Manufacturer and model numbers of any instrumentation to be used in the test. Include any recording equipment, alarm equipment, and electronic distance-amplitude correction equipment.

k. Type and size of transducer. Include frequency, sound beam angle and description of any wedges, shoes, saddles, stand-off attachments, bubblers, or squirters.

l. Description of manipulating and scanning equipment.

m. Surface condition requirements.

n. Special material handling and processing of parts defined when needed.

o. Couplant.

p. Scanning plan. Describe the surfaces from which the tests will be performed and the ultrasonic beam paths to be used.

q. Method of applying transfer, if utilized.

r. Test blocks, water path, and methods of standardization and index determination.

s. Scanning speed and index.

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

u. Limits on reject, noise level, gate levels.

v. Discontinuity evaluation procedure.

w. Complete post inspection cleaning instructions, or reference to procedures containing such instructions.

x. Marking instructions that ensure compliance to 5.6.1.

y. Any other pertinent data.

4.4 General Procedures

General procedures are acceptable for common product forms such as plate, bar stock extrusions and forgings. The general procedure shall cover applicable items of 4.3.

5. DETAIL REQUIREMENTS

5.1 Materials

5.1.1 Couplants

5.1.1.1 Immersion Method (Type I)

For the immersion method (Type I), water shall be used, either in an immersion tank or as a water column. The water shall be free of visible air bubbles and other foreign material which could interfere with ultrasonic tests. A suitable corrosion inhibiting agent and a wetting agent shall be added to the water, if necessary, to inhibit corrosion and to reduce the formation of air bubbles on the material and the transducer. The specific inhibiting and wetting agents shall have been previously determined to be suitable for the materials to be inspected.

5.1.1.2 Contact Method (Type II)

For the contact method (Type II), a liquid or semi-liquid which forms a thin film between the transducer and the test part is required. The couplant material used shall not be injurious to the material to be inspected. Typical couplant materials for contact inspections include: water, oil, grease, penetrant emulsifier, and water soluble gels. Viscosity and surface wetting of the couplant must be sufficient to maintain good ultrasonic energy transmission into the part. Type I immersion method may be substituted for Type II contact method unless specifically prohibited by contract.

5.1.2 Standard Test Block Materials

Standard test block recommendations are listed in Table 1. For inspection of materials not listed in Table 1, the test block material shall be made from the same base alloy as the part to be tested or as specified in the contract or order. These standards shall be free of manufacturing and material related conditions that might result in spurious indications not representative of the material under test or which might otherwise interfere with the inspection process.

5.1.2.1 Standard Test Block Material Inspection

The candidate reference standard material shall be ultrasonically inspected and found to be acceptable in accordance with ASTM E127 prior to being accepted for use as a reference standard.

5.2 Equipment

5.2.1 Electronic Equipment

The electronic equipment when used with appropriate transducers shall be capable of producing ultrasonic test frequencies in the range of at least 2.25 to 10 MHz and shall be capable of meeting or exceeding the minimum requirements of Table 2 as determined by the procedures defined in ASTM E317, or shall be capable of meeting the original manufacturer's requirements. The electronic equipment shall be checked after any repair or part/component replacement which could affect its response characteristics, or once each year, whichever occurs first, and shall meet the minimum requirements of Table 2. Records of the current ASTM E317 evaluation shall be retained.

5.2.2 Alarm

When inspecting parts or material with regular shape and parallel surfaces such as plate, bar stock, and forged billets, an audible alarm shall be used. (Not required with C-scan recording.) Triggering of the alarm shall be controlled by received ultrasonic signals over an adjustable time interval. The amplitude of ultrasonic signal required to trigger the alarm shall be adjustable. During operation, the sound level produced by the alarm shall be sufficiently above ambient to ensure that it is easily detected by the operator. When immersion straight beam testing, the gate used to trigger the alarm shall be set to follow the front surface response of the part (first echo synchronization). This is not applicable to the reflector plate technique.

5.2.3 Voltage Regulator

If fluctuations in line voltage cause variations exceeding ±2.5% of the vertical limit in a signal with an amplitude of one half the vertical limit, a voltage regulator shall be required on the power source. Battery powered units are excepted.

5.2.4 Transducers

For immersion methods (Type I), transducers with active element diameters between 3/8 inch and 1 inch inclusive, or rectangular flat or cylindrically focused transducers with active element area of 1 square inch or less, shall be used. (Exceptions allowing the use of "paintbrush" transducers for plate inspection are covered in 5.2.5.) Transducers with active element diameters less than 3/8 inch or exceeding 1 inch may be used, provided it can be demonstrated that the search unit and instrument meet or exceed the minimum requirements of Table 2. For contact method (Type II) only, transducers with active element dimensions (diameter for circular elements, length, for rectangular elements) between 1/4 inch and 1 inch, inclusive, shall be used. All transducers shall be serialized, and records of evaluation shall be maintained.

5.2.4.1 Phased Array Transducers

Linear phased array probes may be used for scanning and evaluation of wrought metals.

The written procedures (see 4.3) shall include at least the following additional controls for phased array usage:

- Virtual probes within the array shall meet the requirements for minimum effective beam width of 5.4.12 in both the scan and index directions.

- Each virtual probe in the array shall meet the applicable requirements of a conventional probe as defined in 5.2.4.

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

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

5.2.5 Rectangular “Paintbrush” Transducers

Rectangular “paintbrush” transducers shall be allowed for straight beam, immersion initial scanning inspection of plate if it is demonstrated that the transducer provides the required inspection results. The written procedures (see 4.3) shall include at least the additional items specified in 5.2.5.1 through 5.2.5.5.

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

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

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

5.2.5.4 Procedures for evaluation of indications detected during scan shall be made using transducers that meet the requirements of 5.2.4, including attenuation comparisons.

5.2.5.5 A procedure for determining effective beam width (major dimensions of the transducer). The scan index established in accordance with 5.4.12 shall be based on the beam width so determined.

5.2.6 Transducer Attachments

For special applications, when immersion (Type I) inspection cannot be performed, “bubbler” or “squirter” attachments shall be used with the transducers to provide the required water path distances.

5.2.7 Tank

A tank is required for the immersion method. The tank shall be of sufficient size to permit submersion of the part of material to be inspected with proper placement of the transducer.

5.2.8 Manipulating Equipment

For immersion (Type I) inspection, manipulating equipment shall adequately support a tube containing a transducer and shall provide angular adjustment within 1 degree in two mutually perpendicular, vertical planes. The bridge shall be of sufficient strength to provide rigid support for the manipulator and shall allow smooth, accurate positioning of the transducer. The scanning apparatus shall permit measurement of both the scan and index distances within ±0.1 inch. Water travel distance shall be adjustable. When part size and/or geometry prevent the use of manipulating equipment, transducer 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 do not exceed limits which will degrade the test.

5.3 Reference Standards

5.3.1 Reference Standards for Straight Beam Inspection

Standards for straight beam inspection shall conform to the quality and dimensional requirement specified herein.

5.3.1.1 Flat Surface Reference Standards

Blocks used for test set-up and for evaluation of discontinuity size and metal travel shall be fabricated and checked in accordance with ASTM E127. Test blocks used as standards for defect evaluation shall contain flat-bottom holes of standard diameters (2/64 inch, 3/64 inch, 5/64 inch, and 8/64 inch). Metal travel tolerances shall be in accordance with Table 4.

5.3.1.2 Curved Surface Reference Standards

When performing straight beam inspection of curved entry surfaces on cylindrical or irregularly shaped products, special ultrasonic test blocks, containing specified radii of curvature and flat-bottom holes of standard diameter shall be used. For inspecting parts with convex radii up to 4 inches (8 inch diameter), blocks conforming to Figure 3 may be used. Alternative block configurations may be used. For round bar and billet, the reference standard configuration of Table 7 is recommended. For parts with convex radii over 4 inches, standard flat face blocks may be used. Correction factors for setting up on flat blocks to inspect curved surfaces up to 4 inches in radius (8 inch diameter) shall be used only when supported by test data acceptable to the purchaser. The curvature of the entry surface of alternative block configurations and the production material shall be within ±10%.

5.3.1.3 Other Complex Shape Reference Standards

Occasionally, reference standards may be needed that cannot be easily made to conform to the requirements of ASTM E127. In this instance, the supplier and purchaser shall agree on the design and acceptance criteria for complex reference standards and their permissible use.

5.3.2 Reference Standards for Angle Beam Inspection

Standards for angle beam inspection shall conform to the quality and dimensional requirement specified herein.

5.3.2.1 Rectangular Angle Beam

Figure 4 is the configuration for the rectangular angle beam standards using flat bottom holes.

5.3.2.2 Hollow Cylindrical Standards

Standards for inspection of hollow cylindrical parts or sections shall be fabricated in accordance with Figures 5 and 6. Standards shall have a thickness equal to ±25% of the part thickness. The outer diameter shall be within ±10% of the outer diameter of the part or section being evaluated. Standards shall have flat-bottom holes of the size specified for the applicable class (see Table 6). Other reflecting surfaces that meet the requirements of 5.3 shall be permitted. A set of reference holes for normal inspection consists of three with the maximum acceptable hole diameter for the class located in the center. (Class A is illustrated in Figure 5 with 3/64 inch, 5/64 inch, and 8/64 inch diameter flat bottom holes.)

5.3.2.3 International Institute of Welding (IIW) Block

An IIW block, as shown in Figure 7, shall be used for evaluation of contact angle beam transducers as an aid in determining proper positioning for contact angle beam inspection, and to determine beam exit point from the transducers and angle of the sound beam.

5.3.2.4 Angle Beam Standards Fabrication

5.3.2.4.1 The reference holes or notches shall be introduced into the standard material as indicated by the drawing for the standard. Hole bottoms and notch faces shall be checked for flatness in accordance with ASTM E127. The angular position of the holes shall be checked and shall be within ±2 degrees of the indicated orientation. After verification, all holes shall be plugged using methods which will provide an air-interface at the bottom of the hole and to prevent corrosion of the hole face.

5.3.2.4.2 All standards shall be clearly identified so that the material type, hole or notch size, angle, and depth of the holes are readily discerned on the standard or drawing of the standard.

5.3.2.4.3 Using standard test conditions, i.e., instrument, transducer frequency, etc., the standard reflectors shall be checked ultrasonically. The ratio of the reflected signal amplitude to the area of the reflector shall be proportional within ±25%, as shown in Figure 8.

5.3.2.4.4 Standards shall be dried or cleaned of couplant after use. They shall be protected from damage and corrosion when not being used.

5.3.3 Verification

The following information, to verify correctness of reference standard fabrication, shall be made available by the NDT facility for review by the Customer Representative.

5.3.3.1 Dimensional or lay-up inspection data and/or radiograph data verifying that holes are in proper alignment.

5.3.3.2 If the reference standard configuration shown in Figures 3, 4, or 5 is used, comparison amplitude plot of all holes or notches showing amplitude linearity to class size. Make the test using the gain setting that will display the largest class at 100% (upper linearity limit), as shown in Figure 8. Indicate if the pulser/receiver display has a linear amplifier or a linear dB presentation (see Figure 9).

5.3.3.3 For hollow round cylindrical standards, listing of the angle of incidence or offset distance “d” (see Figure 10) for maximum amplitude response for all grades.

5.3.3.4 Measured surface finish (RMS, AA, or RHR) of standards fabricated, per Figure 3.

5.3.3.5 Certification that the standard material is free from discontinuities detrimental to reliable response from the reference standard.

5.3.3.6 Chart with dimensions showing location of reference holes or notches.

5.3.3.7 Alloy type and heat treat condition.

5.3.4 Alternate Reference Reflectors

Other types of reference reflectors (machined electrodischarge slots, side drilled holes, etc.) may be used, unless otherwise specified in the contract or order.

5.4 Inspection Procedures

5.4.1 General

Prior to ultrasonic inspection, it shall be determined that the surface roughness and the part geometry are compatible with good ultrasonic practice and that an adequate inspection can be performed. Surfaces shall be sufficiently free from waviness to permit a uniform test over the required area. When inadequate sound transmission is experienced, the test surface or reflecting surface shall be considered suspect until determined otherwise. When it is determined that surface roughness precludes adequate disclosure and evaluation of subsurface discontinuities, those areas of surface roughness must be smoothed by machining or other permissible means before acceptance of any parts in accordance with this specification.

5.4.2 Coverage

The minimum acceptable inspection coverage of wrought materials consists of scanning with the sound beam normal to those surfaces which are parallel to the predominant grain flow. Angular manipulation shall be used to obtain maximum response from individual discontinuities. In addition, when directions of maximum stressing are indicated by referencing specifications or engineering drawings, scanning shall be performed to locate discontinuities that are oriented in specified directions.

5.4.2.1 When entry surface resolution, based on a 2 to 1 or greater signal-to-noise ratio, is not sufficient to resolve discontinuities near the test surfaces (see Figure 11 for aluminum forgings and Table 5 for material other than aluminum forgings), additional tests shall be performed from the opposite side, or to established zoning requirements. Also, for each inspection direction, tests 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 tests applied from only one side.

5.4.2.2 When the cross sectional thickness in any of the inspection directions exceeds 18 inches, additional inspections may be required, and the ultrasonic scanning requirements shall be established by mutual agreement between the NDT facility and the purchaser.

5.4.3 Scanning Speed

The scanning speed shall not exceed the maximum scanning speed which provides for detection of all discontinuities in the reference standards used to set up the test.

5.4.4 Ultrasonic Frequency

Standardization and testing shall be performed at the ultrasonic frequency which will provide the penetration, sensitivity, and resolution required for the production material. When both angle and straight beam methods are used on a single part, the frequency used for the angle beam inspection shall be determined by penetration and resolution requirements. Inspection performed with transmitting and receiving transducers of different frequencies shall be considered to be performed at the frequency of the transmitting transducer for broadband systems. For tuned systems, the operating system frequency is established by the frequency of the receiving system.

5.4.5 Water Travel Path for Immersion Method (Type I)

The distance from the face of the transducer to the front surface of a part shall be such that the second front reflection from the test material does not appear between the first front and first back reflections. This distance (water travel) must be the same within ±1/4 inch for standardization, initial scanning, and final evaluation.

5.4.6 Surface Preparation

The sound entry surface and reflecting surface shall be free from loose, heavy, or uneven scale, machining or grinding particles, or other loose foreign matter. The surface texture shall be as required to meet near surface resolution requirement and not rougher than 250 microinches. As required, clean parts before ultrasonic inspection. In addition, there shall not be any local grinding depressions present that interfere with the inspection.

5.4.7 Visual Inspection

Visually inspect the part or material for cracks, burrs, nicks, gouges, raised areas, irregular machining, and tool tears prior to ultrasonic inspection. Any surface defects that will impair ultrasonic inspection shall be removed prior to inspection only if the requirements of 5.4.6 can be met. If removal is not possible or not practicable, mark such discrepancies on the part for later use during evaluation of ultrasonic indications.

5.4.8 Reference Standards

Select reference standards (see 5.3) with hole diameters for the applicable class (see 5.5.4). Metal travel distances shall be comparable to the work piece thickness and as specified by the acquisitioner for near surface resolution. In the event the hole diameter for the applicable class is not available, adjustments may be made to the sensitivity settings in decibels in accordance with Figure 8.

5.4.9 Preparation for Standardization (Type I)

For the immersion method, immerse the reference standards and transducer in the water bath. Adjust the water travel in accordance with 5.4.5.

5.4.9.1 Straight Beam Inspection

For Type I immersion inspection, normalize the transducer to maximize the reflected signal from the water-metal interface by manipulating the transducer about each of the two axes at 90 degrees with one another to obtain maximum response from the reference standard. For Type II contact inspection, couple the transducer to the surface of the reference standard (see 5.1.1.2) and obtain maximum response from the reference standard. For both Type I immersion and Type II contact inspection, adjust the instrument gain to provide 80% amplitude signal from whichever reference standard selected from 5.4.8 that exhibits the least response. This is the primary reference response.

5.4.9.2 Angle Beam Inspection

Maximize the reflected signal response from the reference reflector by initially angling the transducer approximately 23 degrees ± 4 degrees and obtain a response from the reference reflector. The transducer will be tilted approximately 19 to 27 degrees from the normal to the test surface to obtain a shear wave with an angle from 45 to 70 degrees, respectively, in aluminum, steel, and titanium. Adjust the instrument gain to provide 80% amplitude signal from whichever reference standard exhibits the least response. This is the primary reference response.

5.4.10 Distance-Amplitude Correction Curve

If a distance-amplitude correction (DAC) is to be used, establish the curve in accordance with ASTM E127. An electronic DAC curve, or time corrected gain (TCG), may also be constructed by collecting and correcting all the responses electronically to a minimum of 80% of the vertical limit utilizing the established instrument gain setting. Direct comparison method may be used with an alternate amplitude besides 80% for the reject limit provided that the full reference signal is visible on the screen and the reference signal is large enough to determine its amplitude.

5.4.10.1 Electronic Distance-Amplitude Correction Curve

Establish the curve by adjusting the instrument gain such that the reference reflector which produces the largest response is at 80% of the vertical limit. This is the primary reference response. At this instrument gain setting, record all other reference block responses over the desired metal path range. The DAC curve is constructed by joining the peak responses from each reference block with a smooth curve. An electronic DAC curve, or time corrected gain (TCG), may also be constructed by collecting and correcting all the responses electronically to a minimum of 80% of the vertical limit utilizing the established instrument gain setting.

5.4.11 Part Thickness Increases

When increases in part thickness occur which cause the reference standard metal travel to become less than 75% of the thickness of the test material, the distance-amplitude curve must be extended, or the sensitivity must be re-established.

5.4.12 Scanning Index-Determination (Type I)

Use the reference standards selected in 5.4.8 to determine the maximum scan index as follows: Using the same gain selected in 5.4.9.1, determine the total traversing distance across the test blocks through which no less than 50% of the primary reference response is obtained. One-half to 80% of the least of the distances determined (effective beam width or EBW) shall be used as the maximum scanning index. This index distance must be established for each individual transducer and re-established whenever there is a metal travel distance change or equipment change or alteration. Wider scan indexing than specified above shall be permitted if the instrument gain is increased to compensate for the wider indexing. Determination of indexing parameters shall be documented. Documentation shall show that the scan speed and repetition rate are selected and controlled to ensure there are no gaps in coverage (see 6.3).

5.4.13 Establishment of Scanning Gain (Type I)

Position the transducer over the part to be inspected using the same transducer-to-part distance, angular relationship, and gain as was used in setting up on the reference standards.

5.4.13.1 Dynamic Check

Whenever possible, a dynamic check shall be made to determine the operational scanning speeds, pulse repetition rates, and index increments, and to ensure that the alarm system or data acquisition is capable of detecting all rejectable defects at these operating conditions.

5.4.14 Scanning

Scan the part at the scanning gain established in 5.4.13 and at a speed selected in accordance with 5.4.3. Set the minimum level in accordance with the acceptance requirements. Note all indications which produce signal amplitudes equal or greater than the above level at scanning gain after ascertaining that the signal is not produced by surface conditions.

5.4.14.1 Discontinuities

Note and evaluate in accordance with 5.4.16 all discontinuities found at scanning gain which have amplitudes greater than the alarm set level.

5.4.14.2 Back Reflection

For straight beam inspections, where geometry permits, compare the back reflections from normal sound material on the same part or like part with the back reflections from all areas exhibiting any signal or signals which exceed twice the normal background noise level at scanning gain. The back reflection amplitudes shall be measured by lowering the gain so that the first back reflection amplitudes are below the vertical limit. Any loss of back reflection exceeding 50% shall be cause for rejection unless it can be shown that the loss of back reflection is due to a non-parallel back surface or back surface roughness. If back surface roughness is found to be the cause of the back reflection loss, the entire test item shall be reviewed for conformance to 5.4.6. When the back reflection amplitude is continuously monitored, the reference back reflection amplitude shall be set in the same location used for the transfer technique of 5.4.15.

5.4.15 Transfer Technique

The transfer technique shall be used to compensate for differences in sound transmission characteristics that may exist between the reference standards and each part or piece of material to be tested. Transfer shall be accomplished by noting the dB or gain difference in the responses received from reflectors in the reference standard and the part or piece of material to be inspected. These reflectors may be the back surfaces for straight beam inspections, “V” notches for angle beam inspections, or any other reflectors which will aid in accomplishing transfer. If possible, a minimum of four reflections from different locations in the part or piece of material to be tested shall be noted and the lowest response shall be used for comparison with the response from the reference standard. For bar and billet stock, the four areas may be on one representative piece from each heat or lot when back reflection is continuously monitored. The instrument response shall be corrected by first calibrating on the applicable reference standards and then changing the gain or dB of the instrument by the difference in gain or dB noted above. This correction may be applied in dB per inch for instruments with that capability using the formula of dB correction divided by the sound path to the reflector. Negative attenuation shall only be applied using the dB per inch technique.

5.4.15.1 Exception

Acoustic compatibility between the reference standard material and the material to be tested shall be within 12 dB. If the acoustic compatibility is within 2.5 dB, no gain compensation is required for inspection. If the acoustic compatibility differences are greater than 2.5 dB but less than 12 dB, the instrument sensitivity shall be increased to compensate for the differences in acoustic compatibility. If the acoustic compatibility differences are greater than 12 dB, a different reference standard shall be used.

5.4.16 Evaluation of Discontinuities

Evaluate discontinuities by first resetting the sensitivity to 80% (or the reject response from 5.4.10, 5.4.10.1) vertical limit amplitude on a test block with hole diameter equal to the smallest acceptable for the applicable class (see 5.5.4). Use a test block with metal travel distance equal to the discontinuity depth in the part within the tolerance specified in Table 4 or use the applicable distance-amplitude curve established in 5.4.10. Ensure that signal amplitude from discontinuity is maximized. Immersion inspections using longitudinal waves may have to angulate the beam slightly to maximize the signal. Apply the transfer technique, if required.

5.4.16.1 Multiple Discontinuities

Determine the distance apart of multiple discontinuities by positioning the transducer over the center of each discontinuity where the signal is a maximum. Reject any part or material where the distance between the centers of any two discontinuities is closer than the minimum allowed in the applicable class (see Table 6).

5.4.16.2 Linear Discontinuities

Estimate the length of linear discontinuities having signal amplitudes, corrected by the transfer technique, which are greater than 30% of the primary reference response or 50% of the distance-amplitude curve. Position the transducer over one extremity of the discontinuity where signal amplitude is reduced to 50% of the primary reference response or distance-amplitude curve. Move the transducer toward the opposite extremity of the discontinuity until the signal amplitude is again reduced to 50%. The distance between these two positions indicate the linear discontinuity length. Reject any material or part with linear discontinuities longer than the maximum allowed in the applicable class (see 5.5.4). Systems using automated position recording may deduct the beam width of the evaluation transducer at the depth of the discontinuity from the overall length.

5.4.17 Corrosion Protection

Parts shall not be held in immersion tanks beyond the time required for inspection. After completion of ultrasonic inspections, all parts shall be dried and coated with a corrosion protective material, as necessary, before they are stacked, nested, or placed in contact with one another in any way.

5.5 Quality Assurance Provisions

5.5.1 Responsibility for Inspection

Unless otherwise specified, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the purchaser. The purchaser reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

5.5.2 System Performance

In order to check test system performance characteristics, standardization of systems with respect to sensitivity shall be performed prior to and immediately after each inspection and after any changes in instrument settings, or instrument modules, and at 2 hour intervals during continuous operation. The 2 hour interval may be extended up to 8 hours with documented stability of the system performance. If the sensitivity has increased, only those indications found during the interim need to be re-examined. If the sensitivity is found to have decreased more than 10% from one calibration check to the next standardization check, the test items examined during the interim shall be re-examined at the correct sensitivity. In addition, when distance-amplitude curves are being used for inspection of parts, the transducer and test instruments shall be checked daily for the thickness range of material being inspected.

5.5.3 Data Records

Data records of all tests shall be kept on file in accordance with the contract or order. For any rejectable item, the location and general shape of the rejectable discontinuities within the material tested shall be recorded.

5.5.4 Acceptance Classes

Five ultrasonic classes are defined in Table 6 for governing the acceptability of parts and materials. Engineering drawings, contracts, or orders shall specify the class as defined in this document. When a part requires multiple classes, the drawing shall be zoned to indicate the areas to which each class is applicable. Any other classes not covered by this standard shall be specified in the contract or order.

5.5.4.1 Acceptance Criteria for Parts to be Machined

Discontinuity indications in excess of the specified ultrasonic class shall be permitted if it is established that such discontinuities will be removed by subsequent machining operations. In such cases, a record of the ultrasonic inspection results shall be provided on a grid map or C-scan showing the location and size of indications by discontinuity grade with respect to a “bench mark” on one corner of the surface from which the material is scanned.

5.5.5 Rejection

Items containing discontinuities or defects exceeding the limits of the written procedure (see 4.3), subject to the provisions of 5.5.4, shall be rejected. The location and estimated size of each indication exceeding the specified limits shall be reported.

5.6 Packaging

5.6.1 Marking

5.6.1.1 Wrought Metal - Raw Stock

Acceptable methods include the following:

5.6.1.1.1 Each item of raw material which has been ultrasonically inspected and found to conform to the requirements of this specification and the acceptance requirements of the contract or order shall be marked with a symbol containing a “U” and an additional mark indicating the type and class of inspection (see 1.3). The acceptance stamp shall provide identification of the inspector and the inspection facility. Marking shall be applied in such a manner and location as to be harmless to the item and to preclude removal, smearing, or obliteration by subsequent handling.

5.6.1.1.2 Alternate methods to 5.6.1.1.1 are acceptable. These methods must identify the method for ensuring direct traceability to an inspection report that describes the type, class, inspector, and inspection facility.

5.6.1.2 Parts Machined from Wrought Metal

Parts in process which have been ultrasonically inspected and found to be acceptable shall be identified by stamping the accompanying paperwork. When practical, the completed parts or raw materials shall be identified with a final acceptance stamp which indicates that all required operations have been completed and accepted. This stamp shall identify the final acceptance inspector and the inspection facility.

5.6.1.3 Other Identification

Other means of identification, such as dyeing or tagging, shall be applied when the construction, finish, or functional requirements preclude the use of stamping.

6. NOTES

6.1 Revision Indicator

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

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

6.3 Commentary on Scan Coverage

6.3.1 Figure 12 is a coverage diagram for spherically focused transducers showing unacceptable gaps of under-inspection and acceptable coverage with no gaps.

6.3.2 For cylindrical focus and paintbrush transducers, the different beam profiles shall be taken into account.

6.3.3 For inspections where beam width measurement in the scan direction cannot be performed, the dynamic check of 5.4.13.1 shall be used to verify adequate scan direction coverage. An example would be some helical bar testing systems where beam width can be measured for the index direction but the beam width in the circumferential direction is not encoded and cannot be measured.

Table 1 - Recommended standard test block materials

Material to be Inspected	Test Block Material Alloy Designation	Typical Specification
Aluminum alloys	7075-T6	QQ-A-200/11 QQ-A-225/9
	2024	QQ-A-200/3 QQ-A-225/6
Magnesium alloys	ZK60A	ASTM B107
Titanium alloys	Ti-6Al-4V annealed	AMS4928
Low alloy steels (4130, 4330, 4340; low alloy high strength steels, such as NAX, T-1, 300M; straight carbon steels and H-11 tool steels)	4340 annealed	AMS-S-5000

Table 2 - Electronic equipment requirements

Instrument Characteristics Minimum	Ultrasonic Test Frequency (MHz) 6/				
	1 4/	2-1/4	5	10	15 4/
Vertical limit, deflection in inches from baseline 7/	2.5				
Upper linearity limit, % of full scale 7/	≥95				
Lower linearity limit, % of full scale 7/	≤10				
Ultrasonic sensitivity %	100 1/	50 3/	100 3/	100 3/	100 3/
Signal-to-noise ratio	10:1 1/	10:1 1/	10:1 1/	10:1 1/	10:1 1/
Entry surface resolution, in aluminum, inches	1.5 2/	0.7 3/	0.5 3/	0.3 3/	0.2 3/, 5/
Back surface resolution in aluminum, inches	0.75 1/	0.3 3/	0.2 3/	0.1 3/	0.1 3/, 5/
Horizontal limit 7/	Full scale				
Horizontal linearity range, % of horizontal limit 7/	≥85				
Gain or attenuator accuracy 7/	±2 dB per 20 dB of control range				

1/ ASTM reference block 2-0300 (refer to ASTM E127).
2/ ASTM reference block 3-0150 (refer to ASTM E127).
3/ ASTM reference block 1-0300 (refer to ASTM E127). Note: Due to problems with manufacture of the 1-0300 block, alternate blocks and gain offsets may be used.

4/ The 1 MHz and 15 MHz requirements are applicable only when these frequencies are to be used and are not specific requirements for all instruments.
5/ The resolution shall be accomplished if the intercept of the response separating the flaw from the surface is within 40% (of total screen height) from the baseline.
6/ Higher frequency pulser/receivers may be used for entry surface resolution applications for sound metal travels less than 0.2 inch without satisfying the other instrument characteristics.
7/ This shall be performed once at any frequency.

Table 3 - Deleted

Table 4 - Flat surface reference standard metal travel

Depth of Discontinuity (Inches)	Reference Standard Metal Travel Distance Tolerance (Inches)
Up to 1/4	±1/16
1/4 to 1	±1/8
1 to 3	±1/4
3 to 6	±1/2
Over 6	±10% of metal travel

Table 5 - Surface resolution requirements (except for aluminum forgings)

	Resolution Requirements	
Material Thickness (t)	Forgings/Re-Forgings	Other Materials
Up to 1.25 inches	1/4 inch	1/8 inch
1.25 inches and over	1/4 inch	1/10 t
2.5 inches and over	1/10 t or 1/2 inch, whichever is less	

Table 6 - Ultrasonic classes

Class	Single Discontinuity Response 1/, 6/	Multiple Discontinuities 2/, 5/, 7/	Linear Discontinuity - Length and Response 3/, 7/	Loss of Back Reflection - Percent 4/	Noise
AAA	25% of 3/64	10% of 3/64	1/8 inch-10% of 3/64 response	50	Alarm level
AA	3/64	2/64	1/2 inch-2/64 response	50	Alarm level
A	5/64	3/64	1 inch-3/64 response	50	Alarm level
B	8/64	5/64	1 inch-5/64 response	50	Alarm level
C	8/64	Not applicable	Not applicable	50	Alarm level

1/ Any discontinuity with an indication greater than the response from a reference flat-bottom hole or equivalent notch at the estimated discontinuity depth of the size given (inches diameter) is not acceptable.
2/ Multiple discontinuities with indications greater than the response from a reference flat-bottom hole or equivalent notch at the estimated discontinuity depth of the size given (inches diameter) are not acceptable if the centers of any two of these discontinuities are less than 1 inch apart. Not applicable to class C.
3/ Any discontinuity longer than the length given with indications greater than the response given (flat-bottom hole or equivalent notch response) is not acceptable. Not applicable to class C.
4/ Loss of back reflection greater than the percent given, when compared to non-defective material in a similar or like part, is not acceptable when this loss of back reflection is accompanied by an increase or decrease in noise signal (at least double the normal background noise signal) between the front and back surface. Applicable only to straight beam tests.
5/ When inspecting titanium to class AA, the multiple discontinuity separation shall be 1/4 inch.
6/ For class AAA single discontinuity, 50% of 2/64 = 25% of 3/64.
7/ For class AAA linear and multiple discontinuities, 1/64 or 25% of 2/64 = 10% of 3/64.

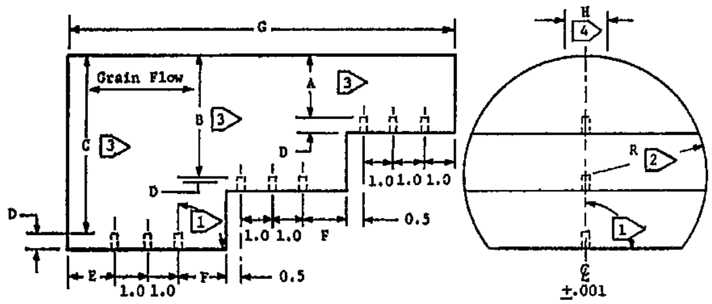
Table 7 - Round bar and billet reference standard configuration for longitudinal wave inspection

Round Bar/Billet Diameter (T)	Required Test Metal Distance (TMD) for Flat Bottom Hole (FBH) Reflectors	Alternate Zone Inspection from Mid-Thickness TMD to Full Thickness
0.25 inch to less than 0.5 inch	0.125 inch, T-0.125 inch	Not applicable
0.5 inch to less than 1.25 inches	0.125 inch, T/4, and T/2	T/2 and T-0.125 inch
1.25 inches to less than 5.0 inches	T/10, T/4, and T/2	T/2, 3/4T, and T-T/10
5.0 inches and up	0.5 inch, T/8, T/4, and T/2	Not applicable

NOTE: The reference standard configuration must permit the dynamic check of 5.4.3. Alternate test metal distances are allowed, provided they encompass the minimum TMD range stated.

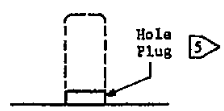
Figure 1 - Deleted

Figure 2 - Deleted



CONVEX SURFACE REFERENCE BLOCK CONFIGURATION

1 90° ± 30' Typical.
2 Tolerance: ± 0.025 inch.
3 Tolerance: ± 0.010 inch.
4 100 RHR Top Surface.
5 See 5.3.2.4.1.



CONVEX - SURFACE REFERENCE BLOCK DIMENSIONS

R	A	B	C	D	E	F	G	H
4.0	2.0	4.0	6.0	0.425	1.5	1.5	12.5	2.0
3.5	1.75	3.5	5.25	0.425	1.5	1.5	12.5	2.0
3.0	1.5	3.0	4.5	0.425	1.0	1.5	12.0	2.0
2.5	1.25	2.5	3.75	0.425	1.0	1.5	12.0	2.0
2.0	1.0	2.0	3.0	0.425	1.0	1.5	12.0	2.0
1.5	0.75	1.5	2.25	0.425	1.0	1.5	12.0	2.0
1.25	0.625	1.25	1.875	0.425	1.0	1.5	12.0	1.5
1.0	0.5	1.0	1.5	0.425	1.0	1.5	12.0	1.5
0.75	0.375	0.75	1.125	0.3	1.0	1.0	11.0	1.5
0.5	0.25	0.5	0.75	0.2	1.0	1.0	11.0	1.0

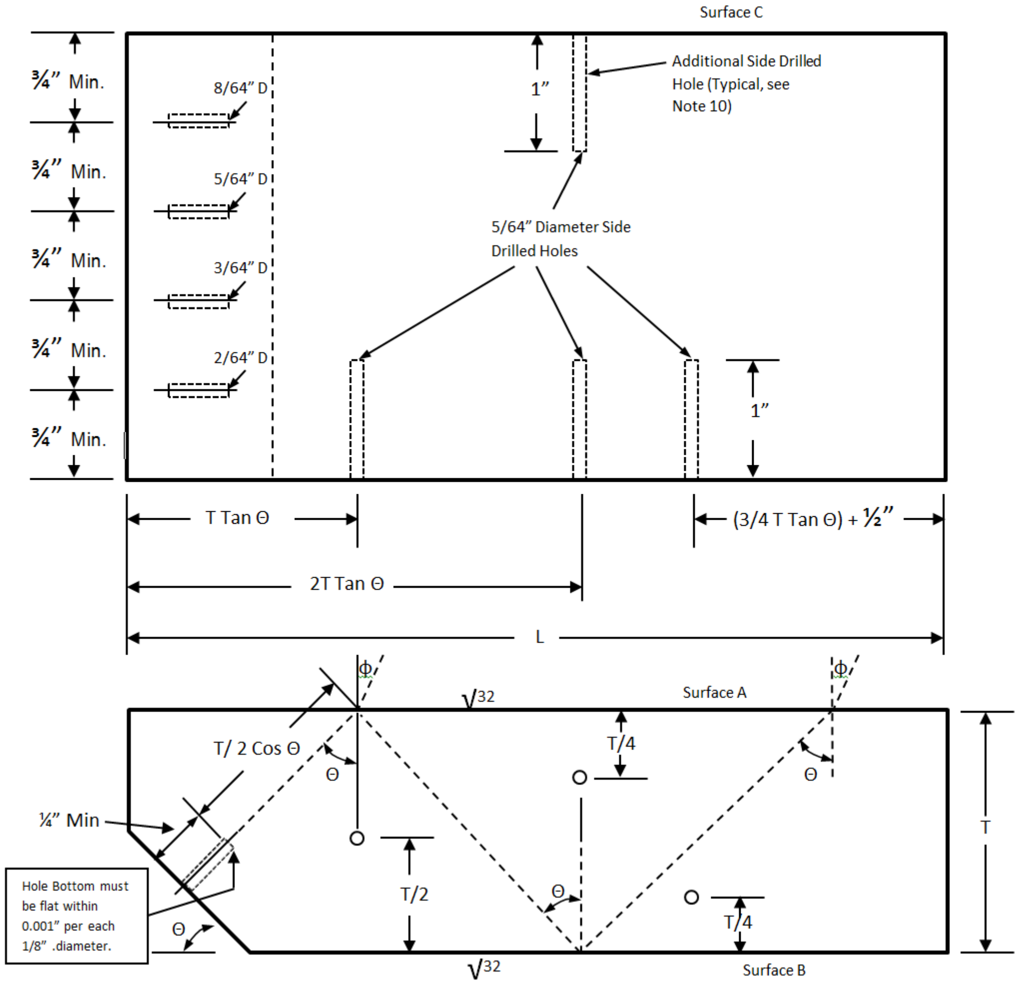
Notes: An approved alternate configuration to that of Figure 3 is to divide and construct each of the ten reference standards as three separate blocks; one containing the C dimension, one containing the B dimension, and one containing the A dimension. For this alternate construction, all dimensions of Figure 3 and Table IV 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 dimension shall be 1.0.

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

Figure 3 - Convex surface reference standard configuration for longitudinal wave inspection of parts



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

NOTES:

1. A block fabricated with flat bottomed holes (FBHs) with diameters as shown will cover all classes in this specification. A narrower block with fewer holes may be used if the block is to be used for fewer classes.
2. Side drilled holes (SDHs) shall not be used for T less than 3/4 inch.
3. A shorter block than shown may be used for thicker materials when only 1/2 or 1 vee-path testing distance is to be used for thicker materials when only 1/2 or 1 vee-path testing distance is to be used. For shorter test blocks, the SDHs shall be re-located along L so that each hole lies at least 3/4 inch from all sound beam paths used for the other holes.
4. D = hole diameter for applicable class.
5. Θ is the nominal angle ±2 degrees of sound beam in the part with respect to normal to the sound entry surface. Θ = 60 degrees for T = (1/2 to 1 inch) and θ = 45 degrees for T = (over 1 inch).
6. Φ is the angle of the entering sound beam with respect to normal to the sound entry surface.
7. All dimensions are in inches.
8. All dimensions ±0.03 inch except for hole diameters, which are ±3% of diameter specified.
9. Surface A and Surface B must be flat and parallel within 0.001 per inch.
10. For blocks thicker than 1 inch, additional 5/64 inch diameter SDHs shall be drilled in from surface C with the axes of these holes located at 1/4 inch, 1/2 inch, 1 inch, 1-1/2 inches, 2 inches, etc., from Surface A until the T/4 distance is reached. No specific location along L is required for these holes except they shall be located at least 3/4 inch from the sound beam paths used for other SDHs.
11. All holes shall be permanently plugged in a manner to ensure that they are water tight and that an air-metal interface is preserved.

Figure 4 - Standard ultrasonic test block for angle beam examination

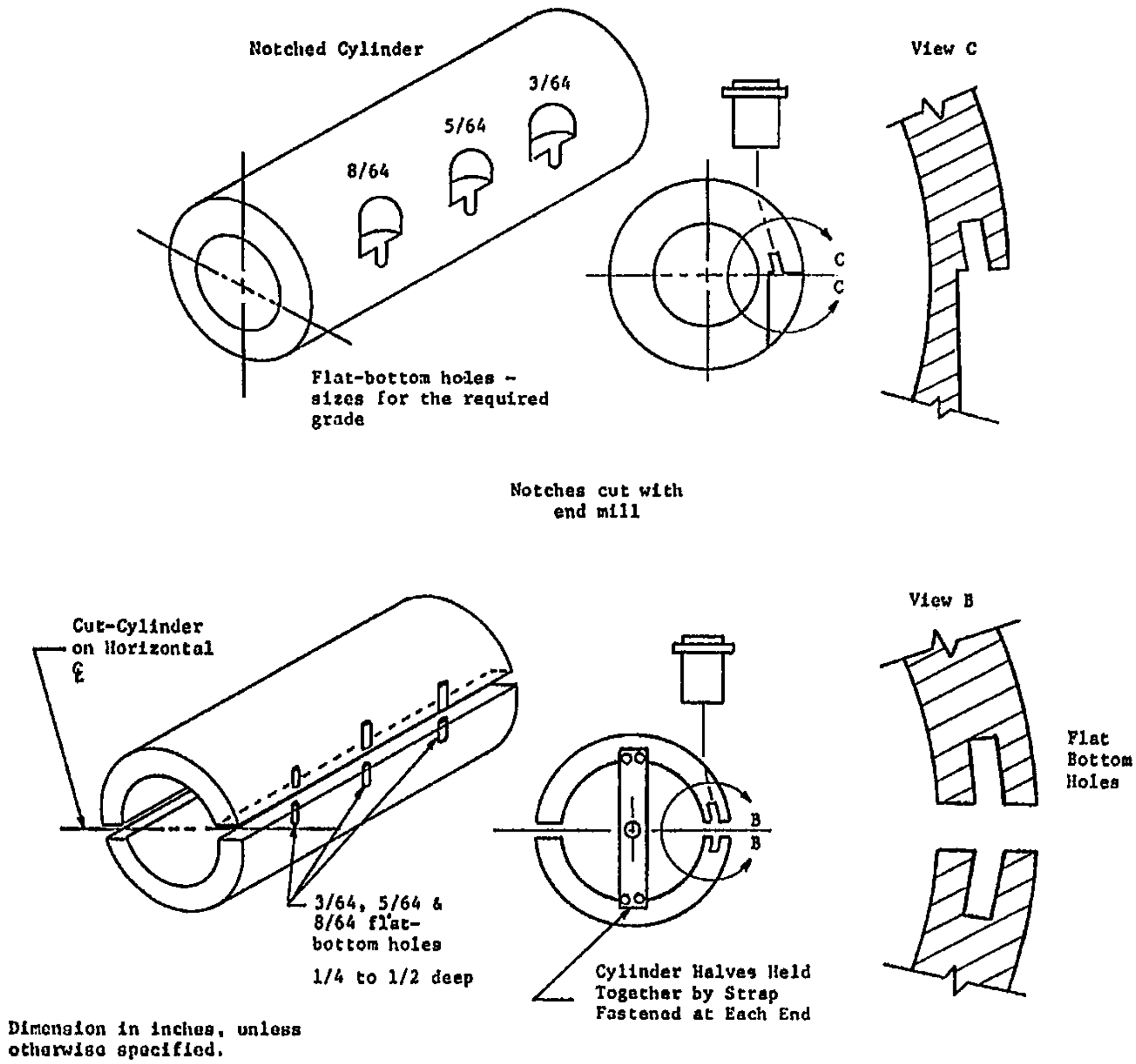
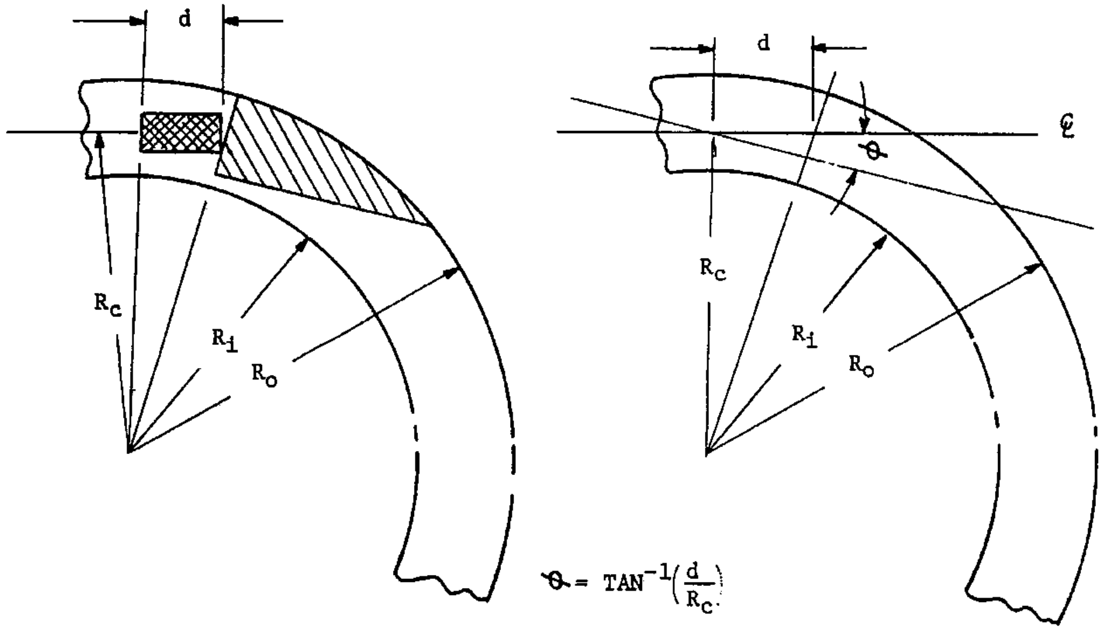
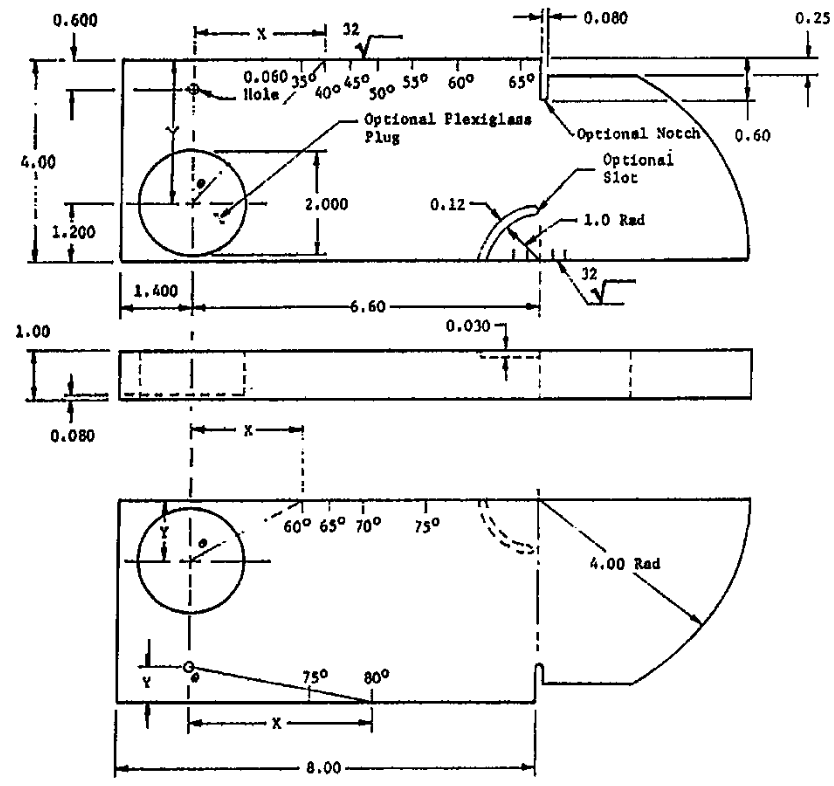


Figure 5 - Hollow cylindrical standards



NOTES:
1. Hole Depth, d = 0.375 ± 0.125 inch.
2. Hole centerline and wall thickness centerline shall be within ± 2%.
3. Bottom of hole or reflecting surface (see 5.3.2.2) shall be parallel to radius.

Figure 6 - Geometry of flat-bottom holes in hollow cylindrical standards

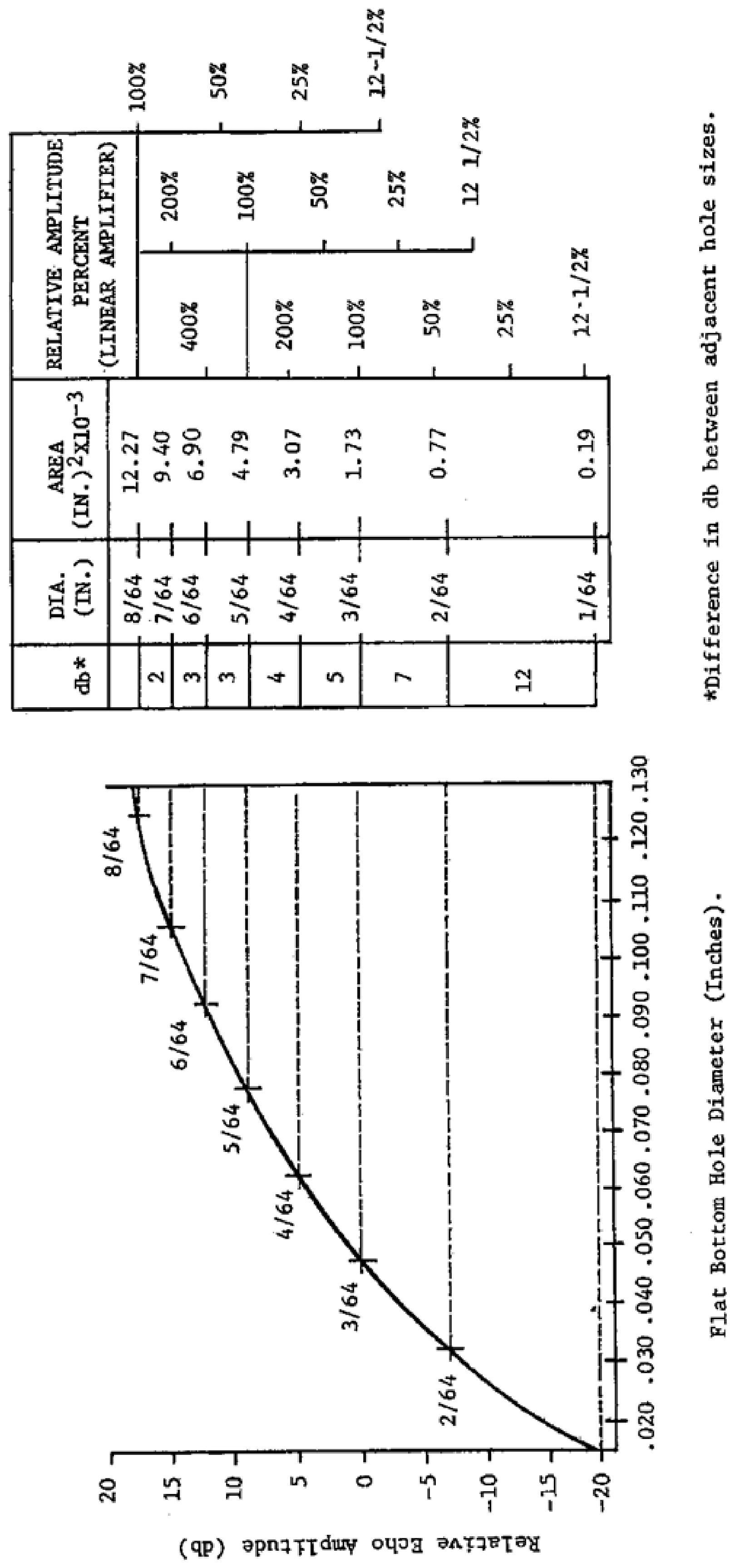


Notes:

1. Other IIW approved reference blocks with slightly different dimensions or distance calibration slot features are permissible.
2. Material: ASTM A 36 steel or equivalent.
3. Acoustic Velocity: 2.32×10^5 in./sec or 5.90×10^3 m/sec longitudinal mode.
   1.27×10^5 in./sec or 3.23×10^3 m/sec shear mode.
4. The positions of the angular indication lines are determined from the following relationship:

   x = y Tan θ where x = distance along the block surface from the intersection of the centerline of the applicable hole and the block surface
   θ = the indicated angle y = distance from the surface of the block to the center of the applicable hole.
5. Limits:
   .X = ±0.1
   .XX = ±0.03
   .XXX = ±0.010

Figure 7 - International institute of welding (IIW) ultrasonic reference block



NOTES: 1. There is a 6 db gap between targets with areas in the ratio 2:1.

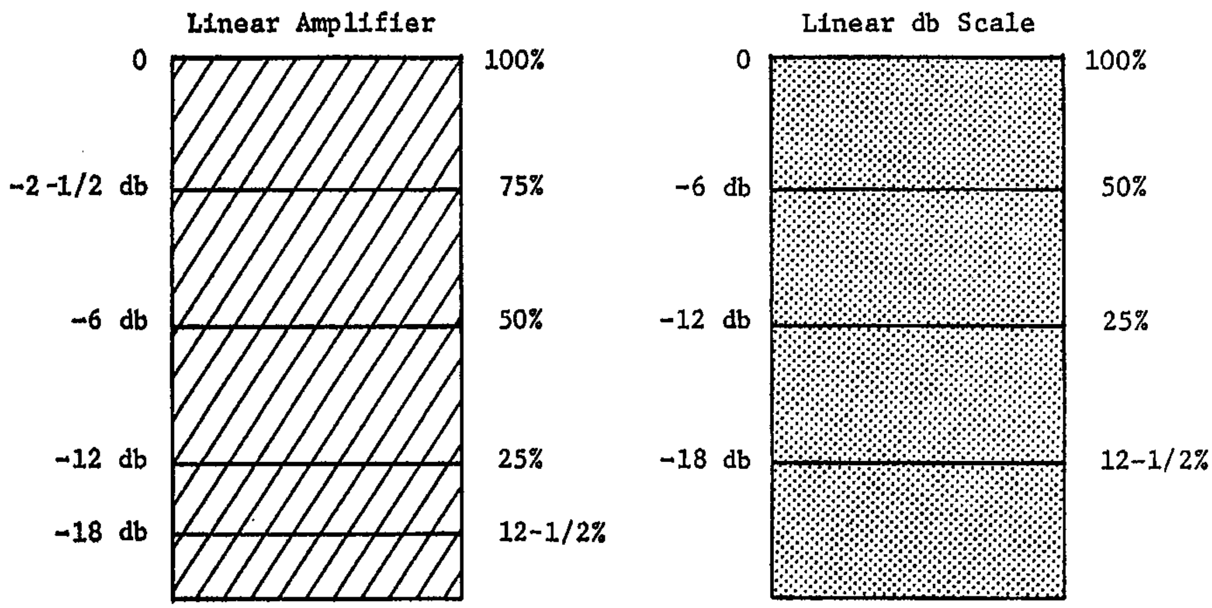
2. There is a 12 db gap between targets with linear dimensions in the ratio 2:1.

Figure 8A - Relevant amplitude versus hole size

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

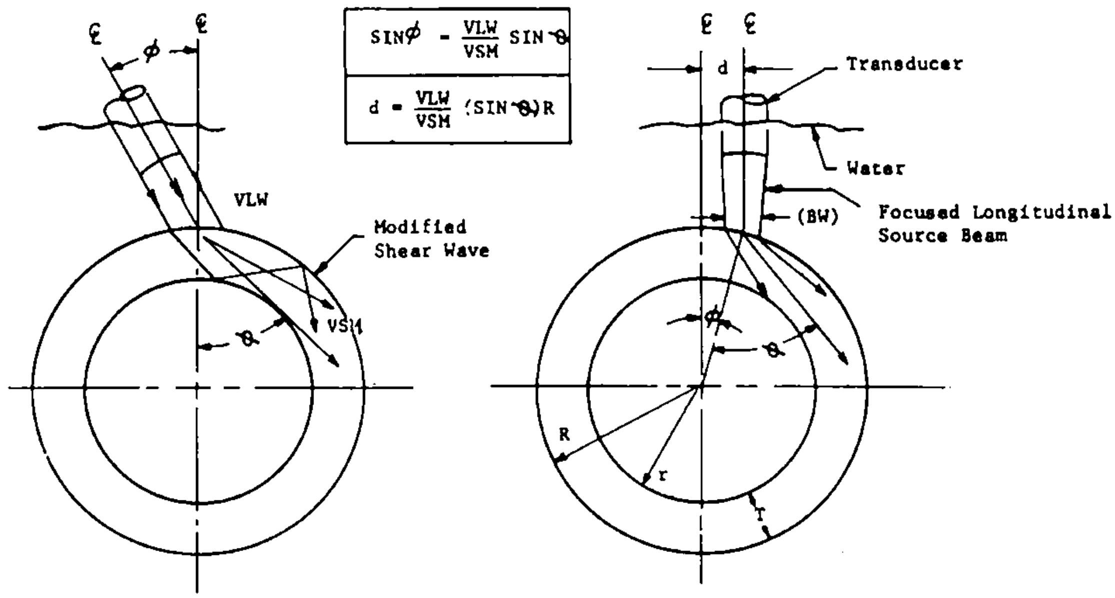
dB change - dB = 20*log(A1/A2) where A1 and A2 are the areas of the respective FBHs.

Figure 8B - dB conversion for FBH size



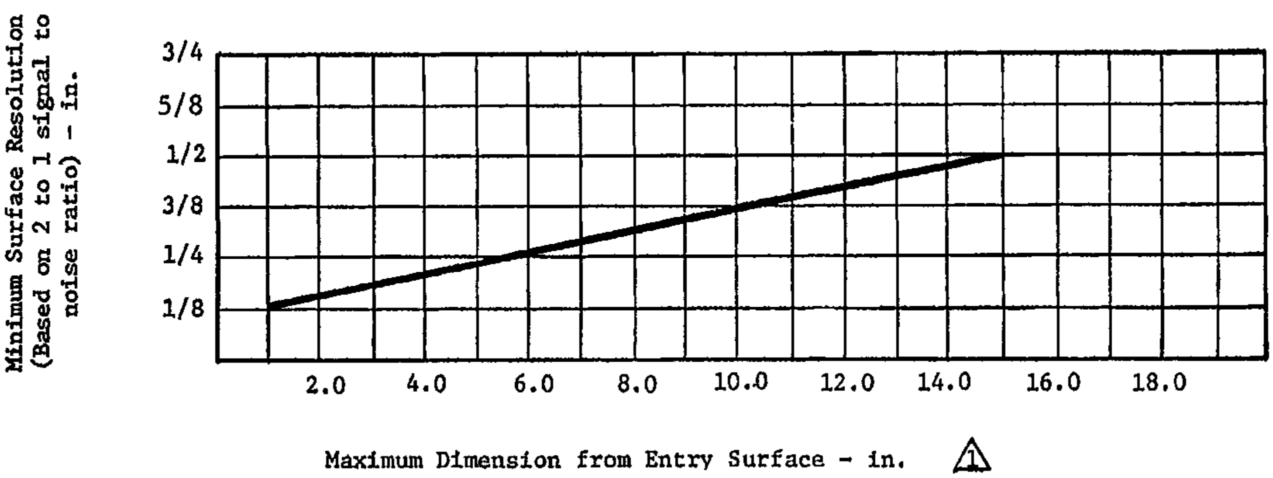
NOTE: The same 6 db difference is found for all echoes with a relative amplitude ratio of 2:1.

Figure 9 - Relation of dB scales and the commonly used percentage scale



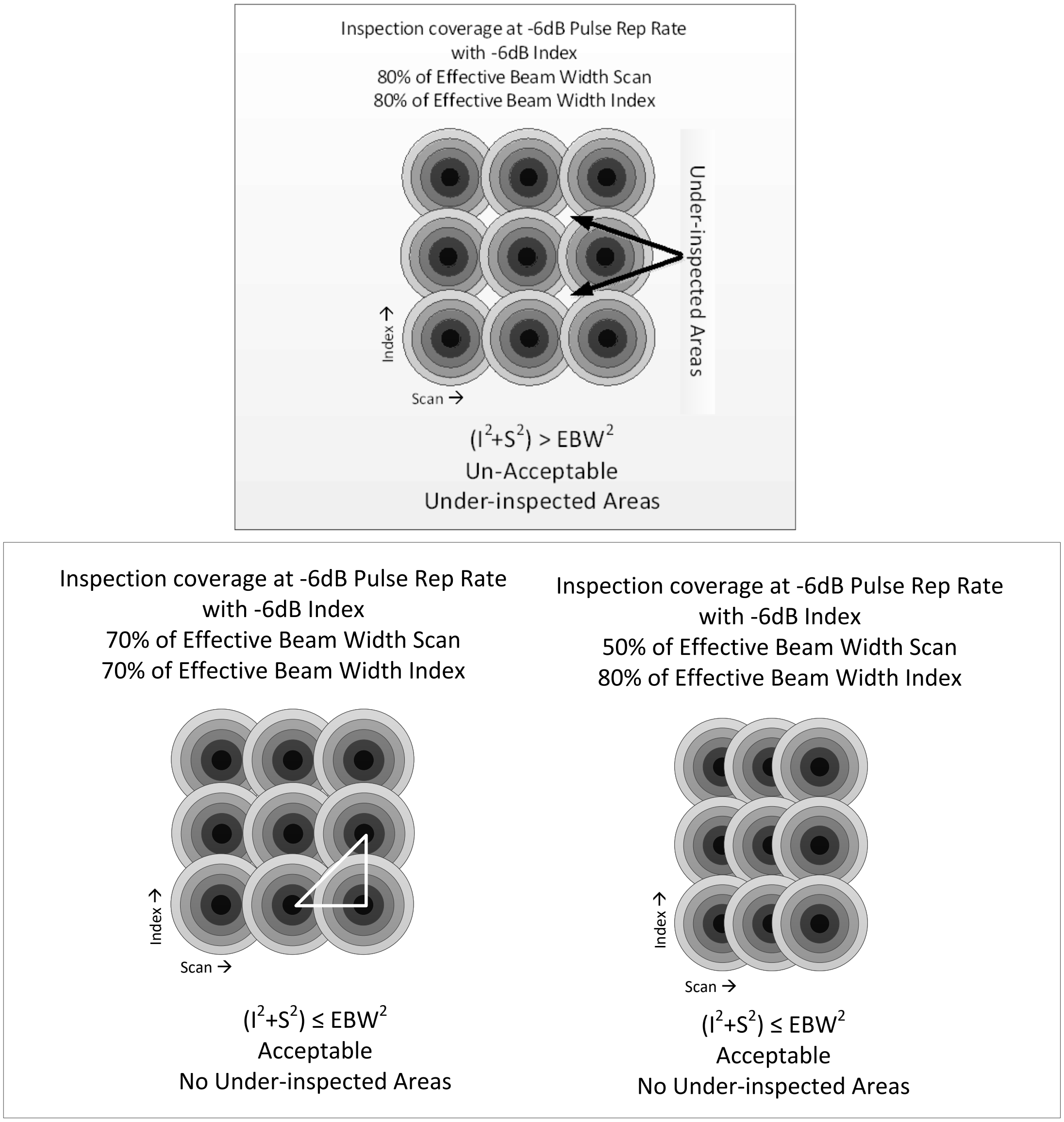
NOTES: 1. φ = angle of incident sound beam
2. θ = angle of refracted sound beam
3. VLW = velocity of longitudinal waves in water
4. VSM = velocity of shear waves in metal
5. d = distance of transducer centerline off-set from normal to cylinder outside diameter

Figure 10 - Angle of refraction and beam off-set for cylindrical standards



NOTES: 1 Applies to forging when a single finished part is produced from one forging. Applies to finished part when multiple parts are produced from one forging.
2 If above surface resolution requirements cannot be met, additional tests must be performed from opposite sides.

Figure 11 - Surface resolution requirements for ultrasonic inspection of aluminum forgings



where:

I = movement in the Index direction

S = movement in the Scan direction

Figure 12 - Coverage diagram for spherically focused transducers showing unacceptable and acceptable areas of coverage

Note: Figure 12 top image is applicable to ultrasonic units using pulse on position scanning. “Free running” instruments with properly set PRF for the material thickness being scanned will not exhibit scan gaps even when using cylindrically focused transducers with 80% EBW used for scanning index.

PREPARED BY AMS COMMITTEE “K”