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Inspection, Ultrasonic, Wrought Metals, Process For

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FOREWORD

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

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1. SCOPE:

1.1 Purpose:

The purpose of this military 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. 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 B 594:

a. When ultrasonic quality level class AA is required, the discontinuity acceptance criteria shall be as defined in table VI.

b. 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:

I - Immersion method.
II - Contact method.

1.3.2 Class: Five ultrasonic acceptance classes shall be as defined in table VI.

2. APPLICABLE DOCUMENTS:

The following publications, of the issues in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111 -5094.

MIL-S-5000	Steel, Chrome-Nickel-Molybdenum (E4340) Bars and Reforging Stock.
MIL-STD-410	Nondestructive Testing Personnel Qualification and Certification (Eddy Current, Liquid Penetrant, Magnetic Particle, Radiographic and Ultrasonic).
QQ-A-200/3	Aluminum Alloy Bar, Rod, Shapes, Tube, and Wire, Extruded, 2024.
QQ-A-200/11	Aluminum Alloy Bar, Rod, Shapes, Tube, and Wire, Extruded 7075.
QQ-A-225/6	Aluminum Alloy Bar, Rod, and Wire, Rolled, Drawn, or Cold Finished, 2024
QQ-A-225/9	Aluminum Alloy Bar, Rod, Wire, and Special Shapes, Rolled, Drawn, or Cold Finished, 7075.
QQ-M-31	Magnesium Alloy, Bars, Rods, And Special Shaped Sections, Extruded.

2.2 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 4928	Titanium Alloy, Annealed, 120,000 PSI Yield.

2.3 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 36	Structural Steel, Specification for.
ASTM B 594	Ultrasonic Inspection of Aluminum-Alloy Products for Aerospace Applications.
ASTM E 127	Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks, Recommended Practice for.
ASTM E 317	Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems, Without the Use of Electronic Measurement Instruments, Practice for Evaluating.
ASTM E 428	Fabrication and Control of Steel Reference Blocks Used in Ultrasonic Inspection, Recommended Practice.
ASTM E 500	Ultrasonic Testing, Definitions of Terms Relating to.

3. DEFINITIONS:

3.1 A-Scan presentation:

A method of data presentation on a cathode ray tube (CRT) screen utilizing a horizontal base line that indicates distance, or time and vertical deflections from the base line which indicate pulse amplitudes (ASTM E 500).

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 percent 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.

$$db = 20 \log_{10} A_1/A_2$$

Where:

A_1 and A_2 are amplitudes.
See figure 12.

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 (ASTM E 500).

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 percent 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 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.

3.13 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

$$N = D^2 f/4C$$

Where:

N = near field length - inches.

D = the major dimension of the transducer element - inches. For circles, D = the diameter. For rectangles or squares, D = the diagonal.

f = ultrasonic frequency - Hertz.

C = ultrasonic velocity - inches per second.

3.14 Noise:

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

3.15 Primary reference response:

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

3.16 Signal to noise ratio:

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

3.17 Straight beam examination:

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

3.18 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.

3.19 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.

3.20 Ultrasonic penetration:

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

3.21 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.

3.22 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 (ASTM E 500).

3.23 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.

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 VI). 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 to Level II or better in accordance with MIL-STD-410. Personnel qualified to a Level I Special shall be permitted to perform the NDT methods described in this standard and make applicable accept-reject decisions as specified in MIL-STD-410. Personnel qualified to a Level I shall be restricted to performance of the NDT methods described in this standard as specified in MIL-STD-410.

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. Number of this standard including latest revision letter, if applicable, and date.
d. Inspection method type and acceptance class or classes to be applied.
e. Inspection zones, if applicable.
f. Specific part number and configuration to be tested.
g. Specific material and form for which the procedure is being prepared.
h. 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.
i. Type and size of transducer. Include frequency, transducer element material, sound beam angle and description of any wedges, shoes, saddles, stand-off attachments, bubblers or squirters.
j. Description of manipulating and scanning equipment.
k. Couplant.
l. Scanning plan. Describe the surfaces from which the tests will be performed and the ultrasonic beam paths to be used.
m. Method of applying transfer, if utilized.
n. Test blocks, water path and methods of standardization and index determination.
o. Method of establishing scan sensitivity for concave and convex surfaces, if applicable.
p. Discontinuity evaluation procedure.
q. 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.

5.1.2 Standard test block materials: Standard test blocks shall be fabricated from the alloys listed in table I. For inspection of materials not listed in table I, the test block material shall be made from the same 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 standard material shall be ultrasonically inspected to class AA (see 5.5.4) using the immersion straight beam technique. The standard material shall be tested for loss of back reflection in accordance with 5.4.14.2, except that loss of back reflection shall be not greater than 35 percent in any one area. Another exception is, when a reference standard is fabricated from a section of test material, it shall be ultrasonically inspected to the next ascending more stringent class.

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 II as determined by the procedures defined in ASTM E 317. 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 II. Records of the current ASTM E 317 evaluation shall be retained.

5.2.2 Attenuator decade switch check: If the ultrasonic system is equipped with precision attenuator switches or an attenuator decade switch, these items shall be checked in accordance with the applicable method described in 5.2.2.1 or 5.2.2.2.

5.2.2.1 Decade switch - method 1:

5.2.2.1.1 With a typical straight beam transducer, any suitable reference block, and the ultrasonic instrument damping, reject, and pulse length at minimum, adjust the instrument until a response from the back surface of the block has an amplitude of 95 percent of the CRT height at a switch position of 1X (30 db). The uncalibrated gain may be adjusted to obtain this response height (see figure 1, CRT 1).

5.2.2.1.2 Switch to 0.1X (10 db) position and accept as linear any response height from 6 to 13 percent (see figure 1, CRT 2).

5.2.2.1.3 With the switch at 0.1X (10 db) position, adjust the uncalibrated gain to get a response height of 10 percent (see figure 1, CRT 3). Then switch to 1X (30 db). Accept as linear any response height from 90 to 100 percent or saturation (see figure 1, CRT 4).

5.2.2.1.4 With the switch at 1X (30 db), adjust the uncalibrated gain to get a response height of 10 percent and then switch to 10X (50 db). Accept as linear any response from 90 to 100 percent or saturation.

5.2.2.1.5 With the switch at 10X (50 db), adjust the uncalibrated gain until a response height of 95 percent is obtained. Switch to 1X (30 db) and accept as linear any response from 6 to 13 percent.

5.2.2.1.6 In the previous tests, the CRT height should be estimated to the nearest 2-1/2 percent of full screen. Table III is a summary of the response heights/switch positions.

5.2.2.2 Attenuator switches - method 2:

5.2.2.2.1 With all db attenuator switches out, maximize on a 5-0300 block using 5.0 MHz, 3/4 inch ceramic straight beam search unit. Adjust the receiver gain control for a 100 percent signal response from the hole. Fix the gain control position.

5.2.2.2.2 Using the attenuator switches, add increments of 1 db attenuation from 1 db to 21 db. At each step, record the resultant signal height on the “db attenuator check” sheet using the “A” values (see figure 2). Also plot the data. The recorded data for each step must be within the limits noted on the check sheet.

5.2.2.2.3 Reset the attenuator switches for 10 db-IN. Re-adjust the gain control to again obtain a 100 percent signal response from the hole in the 5-0300 block. Fix this gain control position.

5.2.2.2.4 Using the attenuator switches, add increments of 1 db attenuation from 10 db to 31 db. At each step, record the resultant signal height on the “db attenuator check” sheet using the “B” values which are shown in parentheses. Also plot the data. The data for each step must be within the limits noted on the check sheet.

5.2.2.2.5 If the limits cannot be met at each step, corrective action must be taken, and the attenuator calibration shall be rerun.

5.2.3 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 in conjunction with visual monitoring of the ultrasonic instrument cathode ray tube. 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 insure that it is easily detected by the operator. When immersion straight beam testing, the gate used to trigger the alarm shall be set to trigger on the front surface response of the part (first echo sychronization). This is not applicable to the reflector plate technique.

5.2.4 Voltage regulator: If fluctuations in line voltage cause variations exceeding ± 2.5 percent 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.

5.2.5 Transducers: For immersion methods (type I), transducers with active element diameters between 3/8 and 3/4 inch inclusive shall be used. (Exceptions allowing the use of “paintbrush” transducers for plate inspection are covered in 5.2.6.). Transducers with active element diameters exceeding 3/4 inch may be used provided it can be demonstrated that the search unit and instrument meet or exceed the minimum requirements of table II. For contact method (type II) only, transducers with active element dimensions (diameter for circular elements, length for rectangular elements) between 1/4 and 1 inch inclusive shall be used. All transducers shall be serialized and records of evaluation shall be maintained.

5.2.6 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 5.2.6.1 through 5.2.6.5.

5.2.6.1 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.

5.2.6.2 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.

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

5.2.6.4 Procedures for evaluation of indications detected during scan shall be made using transducers that meet the requirements of 5.2.5, including attenuation comparisons.

5.2.6.5 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.

5.2.7 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.

5.2.8 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.

5.2.9 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 E 127 or ASTM E 428, as applicable. For materials not covered by ASTM E 127 or ASTM E 428, test blocks shall be fabricated to the dimensional requirements of ASTM E 127. Test blocks used as standards for defect evaluation shall contain flat-bottom holes of standard diameters (2/64, 3/64, 5/64 and 8/64 inch). Metal travel tolerances shall be in accordance with table IV.

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 shall be used. For parts with convex radii over 4 inches, use standard flat face blocks. Correction factors for setting up on flat blocks to inspect curved surfaces shall be used only when supported by test data acceptable to the contracting officer.

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 percent of the part thickness. The outer diameter shall be within ± 10 percent 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 VI). 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, 5/64 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 E 428. The angular position of the holes shall be checked and shall be within ± 2° of the indicated orientation. After verification, all holes shall be plugged using methods which will provide an air-interface at the backface 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 percent 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 contracting officer.

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 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 percent (upper linearity limit) as shown in figure 8. Indicate if the pulser/receiver cathode ray tube has a linear amplifier or a linear db presentation (see figure 9).

5.3.3.3 For 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 standard.

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.) shall 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: When possible, initial scanning shall be parallel to the major 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 V 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 contracting officer.

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 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. As required, clean parts before ultrasonic 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. 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.

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: 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.

5.4.9.2 Angle beam inspection: Maximize the reflected signal response from the reference reflector by initially angling the transducer approximately 23° ± 4° and obtain a response from the reference reflector. The transducer will be tilted approximately 19° to 27° from the normal to the test surface to obtain a shear wave with an angle from 45° to 70° respectively in aluminum, steel and titanium. Adjust the instrument gain to provide 80 percent 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 E 127 for aluminum, ASTM E 428 for steel and 5.4.10.1 for other materials.

5.4.10.1 Distance-amplitude correction curve for other materials: Establish the curve by adjusting the instrument gain such that the reference reflector which produces the largest response is at 80 percent of the vertical limit. 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.

5.4.11 Part thickness increases: When increases in part thickness occur which cause the reference standard metal travel to become less than 75 percent 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 5.4.9.2.1, determine the total traversing distance across the test blocks through which no less than 50 percent of the primary reference response is obtained. One-half to 80 percent of the least of the distances determined 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.

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.

5.4.14 Scanning: Scan the part in accordance with 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 wth 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 percent 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 5.4.4.

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. 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.

5.4.15.1 Exception: The use of the transfer technique is not required for establishing scanning sensitivity if the signal amplitude from a reflector in each part of each piece of test material is in the range between 60 and 160 percent of the signal amplitude from an equivalent reflector in the reference standard, e.g.

$$0.6A_1 \leq A_2 \leq 1.6A_1, \text{ or in decibels,}$$
$$-4 \leq 20 \log A_2/A_1 \leq 4,$$

Where:

A_1 = amplitude of the first reflection from a reflector in test block material.
A_2 = amplitude of the first reflection from an equivalent reflector in the material being inspected.

5.4.16 Evaluation of discontinuities: Evaluate discontinuities by first resetting the sensitivity to 80 percent 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 IV, or use the applicable distance-amplitude curve established in 5.4.10. 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 VI).

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 percent of the primary reference response or 50 percent of the distance-amplitude curve. Position the transducer over one extremity of the discontinuity where signal amplitude is reduced to 50 percent 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 percent. The distance between these two positions indicate stringer length. Reject any material or part with linear discontinuities longer than the maximum allowed in the applicable class (see 5.5.4).

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 in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government 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 two hour intervals during continuous operation. 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 percent 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 VI 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: 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.

5.6.1.2 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.

TABLE I. Recommended standard test block materials.

Material to be inspected	Test block material alloy designation	Typical specification
Aluminum alloys	7075-T6	QQ-A200/11 QQ-A225/9
	2024	QQ-A-200/3 QQ-A-225/6
Magnesium alloys	ZK60A	QQ-M-31
Titanium alloys	Ti-6Al-4V annealed	AMS 4928
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	MIL-S-5000

TABLE II. Electronic equipment requirements.

Instrument characteristics minimum	Ultrasonic test frequency (MHz) 6/				
	1 4/	2-1/4	5	10	15 4/
Vertical limit, percent of full scale	100	100	100	100	100
Upper linearity limit, percent of full scale	≥ 95	≥ 95	≥ 95	≥ 95	≥ 95
Lower linearity limit, percent of full scale	≤ 10	≤ 10	≤ 10	≤ 10	≤ 10
Ultrasonic sensitivity percent	100 1/	50 3/	100 3/	100 3/	100 3/
Signal-to-noise ratio	25 1/	65 3/	100 3/	100 3/	100 3/
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, inch	0.75 1/	0.3 3/	0.2 3/	0.1 3/	0.1 3/,5/
Horizontal limit	Full scale	Full scale	Full scale	Full scale	Full scale
Horizontal linearity range, percent of horizontal limit	≥ 85	≥ 85	≥ 85	≥ 85	≥ 85

1/ ASTM reference block 2-0300 (see ASTM E 127).
2/ ASTM reference block 3-0150 (see ASTM E 127).
3/ ASTM reference block 1-0300 (see ASTM E 127).
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 percent (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 inches without satisfying the other instrument characteristics.

Table III. Allowable response height as a function of the attenuator/decade switch position.

	Decade or attenuator switch positions		
	0.1X 10 db	1X 30 db	10X 50 db
Allowable range for CRT response height, percent	10 →	90-100 or saturated	
		10 →	90-100 or saturated
		6-13 ←	95
	6-13 ←	95	
		Switch direction	

TABLE IV. 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 V. Surface resolution requirements (except for aluminum forgings).

Material thickness (t)	Resolution requirements	
	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 VI. Ultrasonic classes.

Class	Single discontinuity response 1/	Multiple discontinuities 2/	Linear discontinuity - length and response 3/, 6/	Loss of back reflection-percent 4/	Noise 5/, 6/
AAA	1/64 or 25 percent of 3/64	10 percent of 3/64 response	1/8 inch or 10 percent of 3/64 response	50	10 percent of 3/64 response
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	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 in noise signal (at least double the normal background noise signal) between the front and back surface. Applicable only to straight beam tests.

5/ Noise which exceeds the alarm level setting (see 5.2.3) is not acceptable, except for reforging stock.

6/ When inspecting titanium to class AAA, the multiple discontinuity shall be 1/8 inch-2/64 response, and noise is not applicable. When inspecting titanium to class AA, the multiple discontinuity shall be 1/4 inch-2/64 response or greater and the linear discontinuity criteria is not applicable.

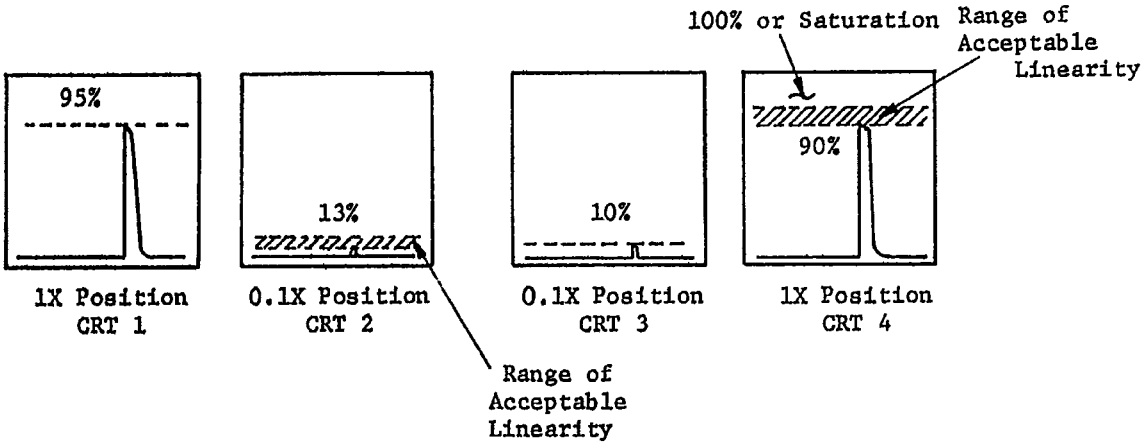


FIGURE 1. CRT displays corresponding to decade switch multiplier check.

RECEIVER NO. _____
DATE _____
BY _____

DATA SHEET A (B)

B VALUES IN PARENTHESES

dB OUT	% SCREEN HEIGHT CALC. VALUE	LIMITS MIN.	LIMITS MAX.	RECORDED A	RECORDED B
0 (10)	100.0	-	-	-	-
1 (11)	89.1	85	94		
2 (12)	79.4	75	84		
3 (13)	70.8	66	75		
4 (14)	63.1	59	68		
5 (15)	56.2	52	61		
6 (16)	50.1	46	55		
7 (17)	44.7	40	49		
8 (18)	39.8	35	44		
9 (19)	35.5	31	40		
10 (20)	31.6	27	36		
11 (21)	28.2	24	33		
12 (22)	25.1	21	30		
13 (23)	22.4	18	27		
14 (24)	20.0	15	25		
15 (25)	17.8	13	22		
16 (26)	15.8	11	20		
17 (27)	14.1	10	19		
18 (28)	12.6	8	17		
19 (29)	11.2	7	16		
20 (30)	10.0	5	15		
21 (31)	8.9	4	13		

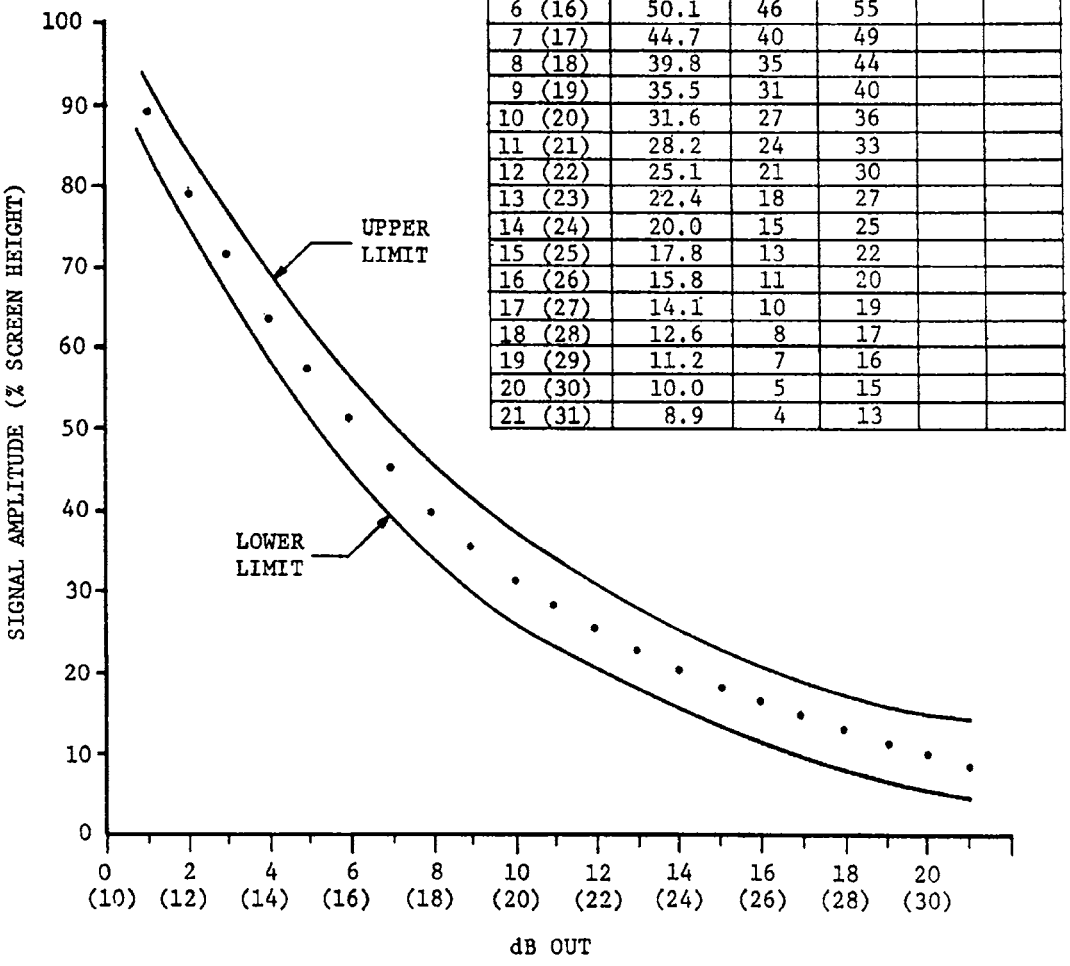
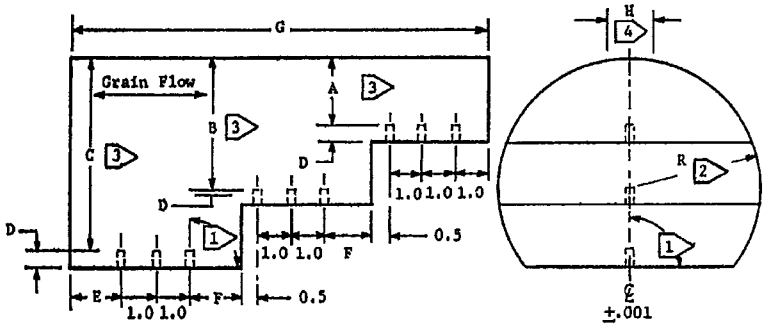
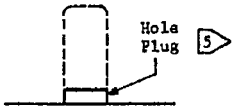


FIGURE 2. db attenuator check data sheet



CONVEX SURFACE REFERENCE BLOCK CONFIGURATION

1. 90° ± 10' 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

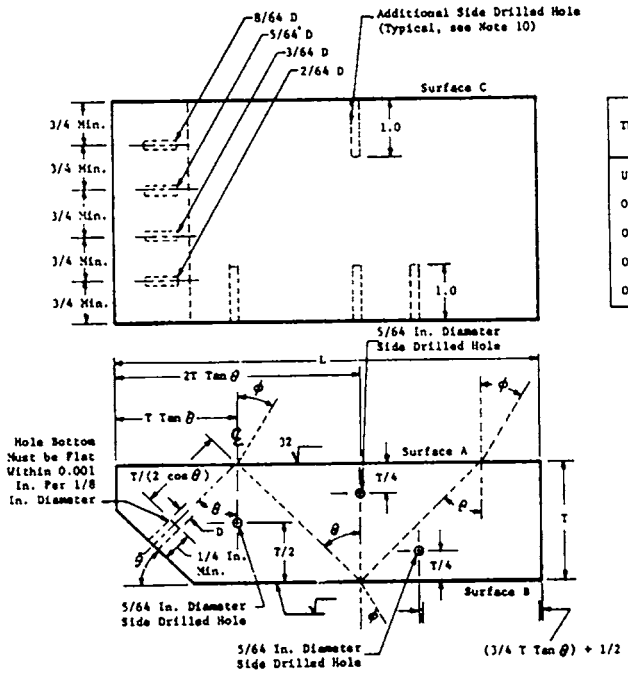
Notes: An approved alternate configuration to that of Figure 3 is to divide and construct each of the ten reference standards as three separate blocks; one containing the C dimension, one containing the B dimension, and one containing the A dimension. For this alternate construction, all dimensions of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



Thickness (t), of Part of Material to be Tested	T	L Min. (Inches)
Up to and including 1 in.	3/4 in. or t	(3T Tan θ + 1)
Over 1 in. to 2 in.	1-1/2 in. or t	
Over 2 in. to 4 in.	3 in. or t	
Over 4 in. to 6 in.	5 in. or t	
Over 6 in.	t ± 1 in.	

Notes:

1. A block fabricated with flat bottom holes 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 a fewer number of classes.
2. Side drilled holes shall not be used for T less than 3/4 in.
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 shorter test blocks the side drilled holes shall be relocated 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 $\pm 2^\circ$ of the sound beam in the part with respect to the normal to the sound entry surface. $\theta = 60^\circ$ for T = (1/2" to 1") and $\theta = 45^\circ$ for T = (over 1").
6. ϕ is the angle of the entering sound beam with respect to the normal to the sound entry surface.
7. All dimensions in inches.
8. All dimensions ± 0.03 inches except for hole diameters which are ± 3 percent of diameter specified.
9. Surface A and Surface B must be flat and parallel within 0.001 per inch.
10. For blocks, thicker than one inch, additional 5/64 inch diameter side drilled holes 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 inch, 2 inch, 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 side drilled holes.
11. All holes shall be permanently plugged in a manner to insure that they are water-tight and that an air-metal interface is preserved.

FIGURE 4. Standard ultrasonic test block for angle beam examination.

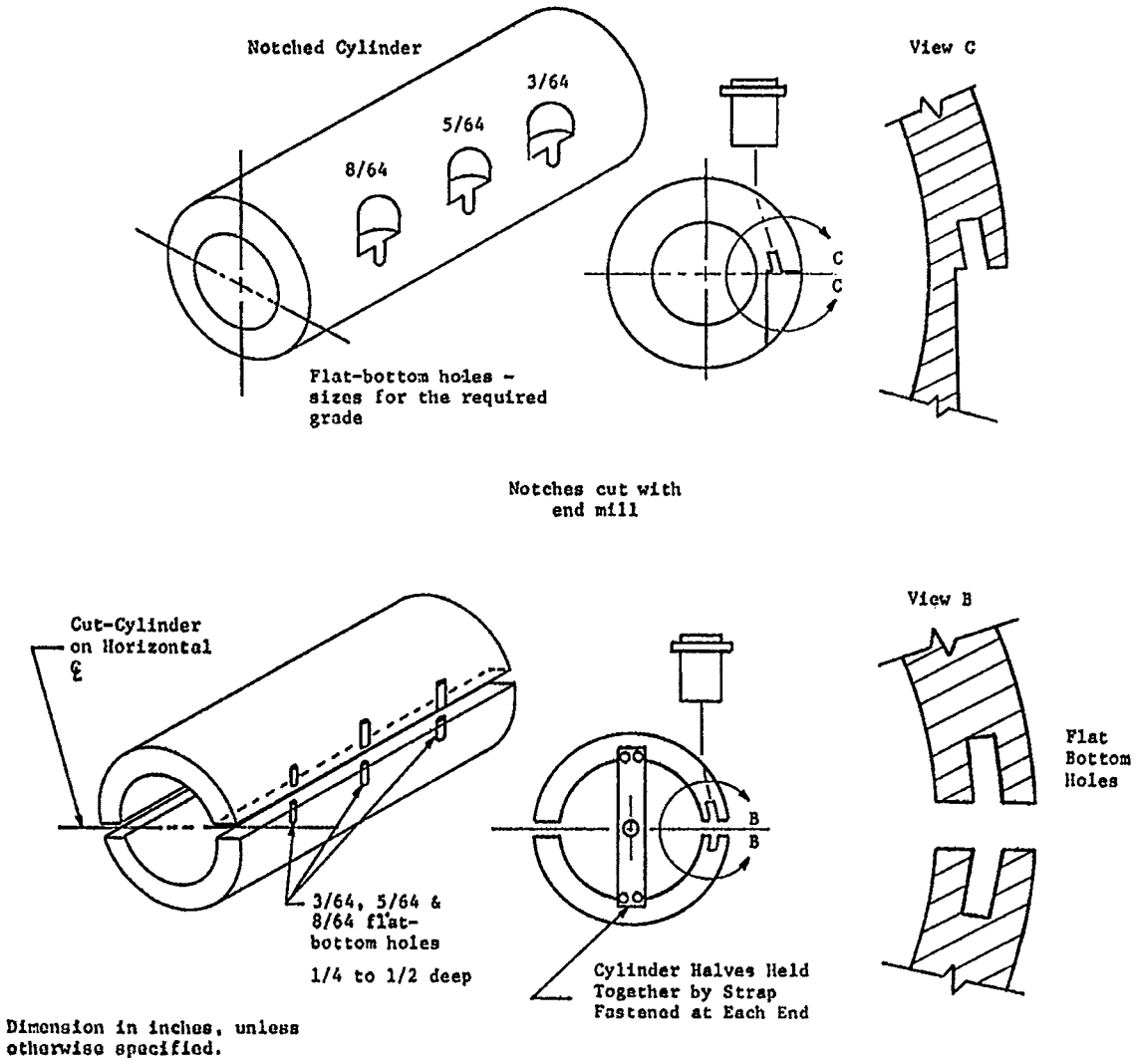
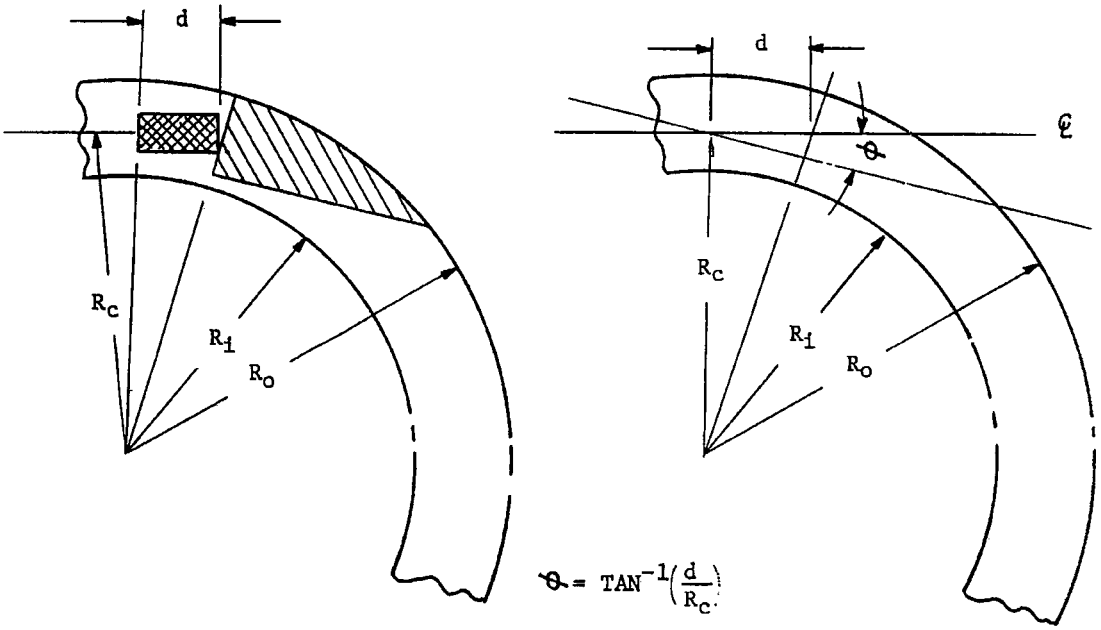


FIGURE 5. Hollow cylindrical standards.

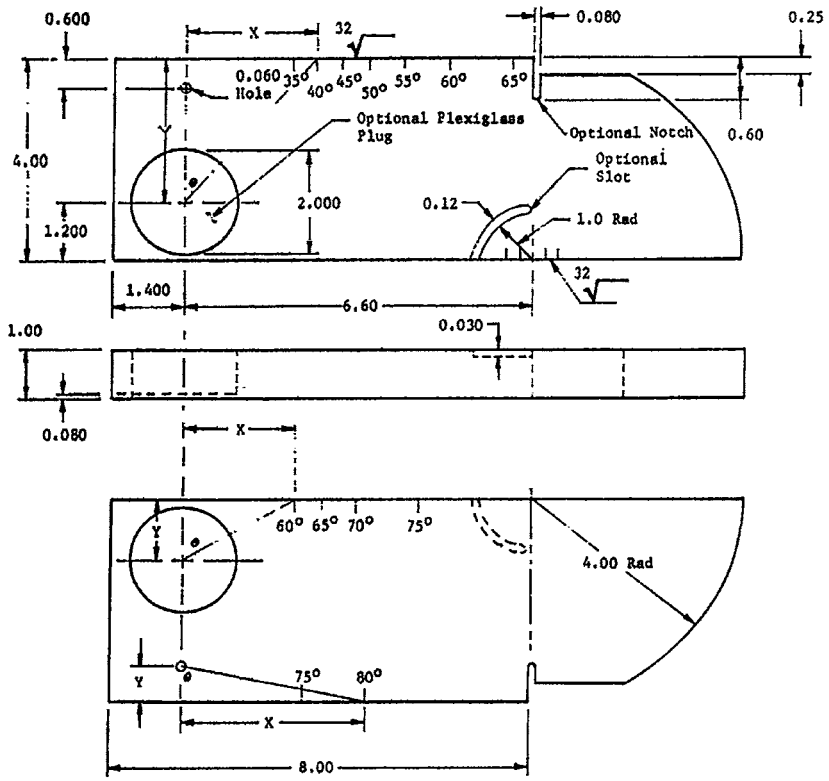


NOTES: 1. Hole Depth, d = 0.375 ± 0.125 inch.

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.



Dimension in inches, unless otherwise specified.

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 e where x = distance along the block surface from the intersection of the centerline of the applicable hole and the block surface
   e = 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.

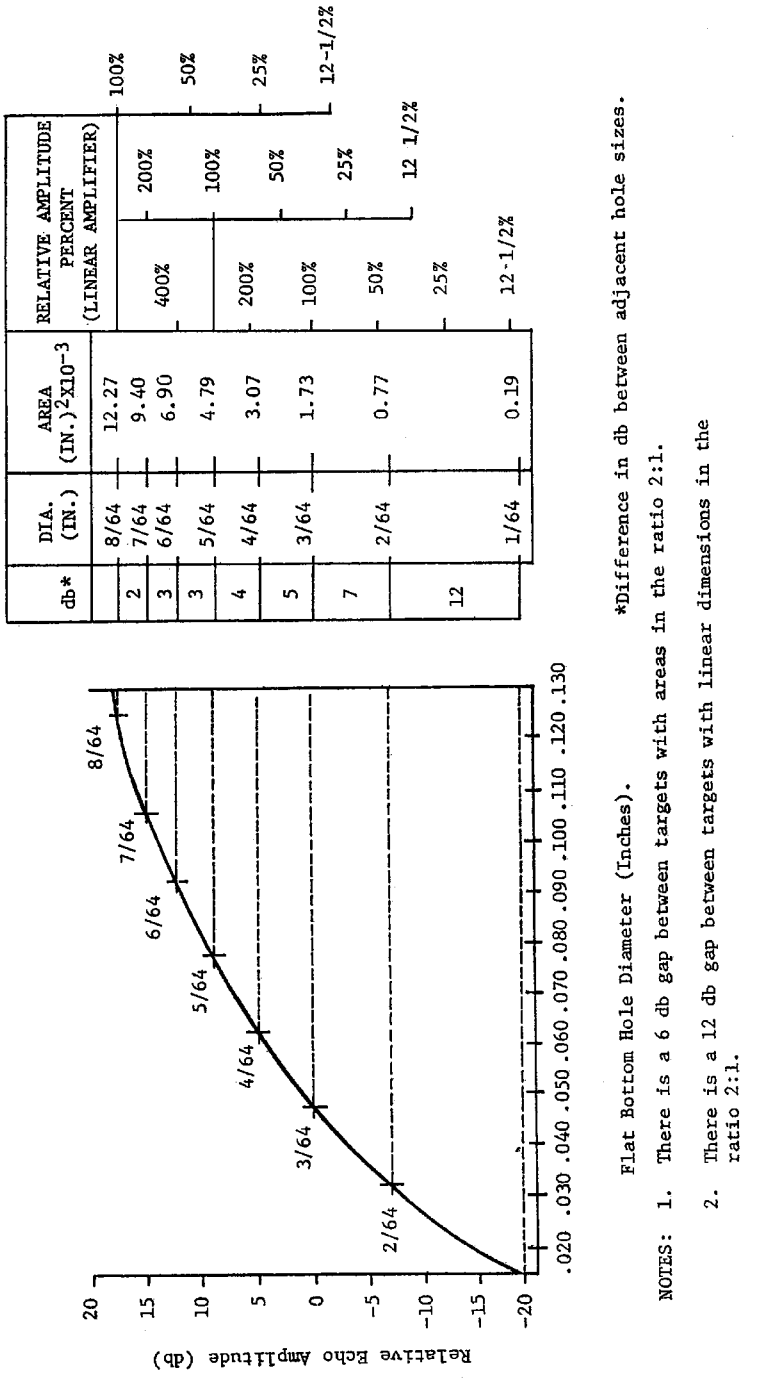
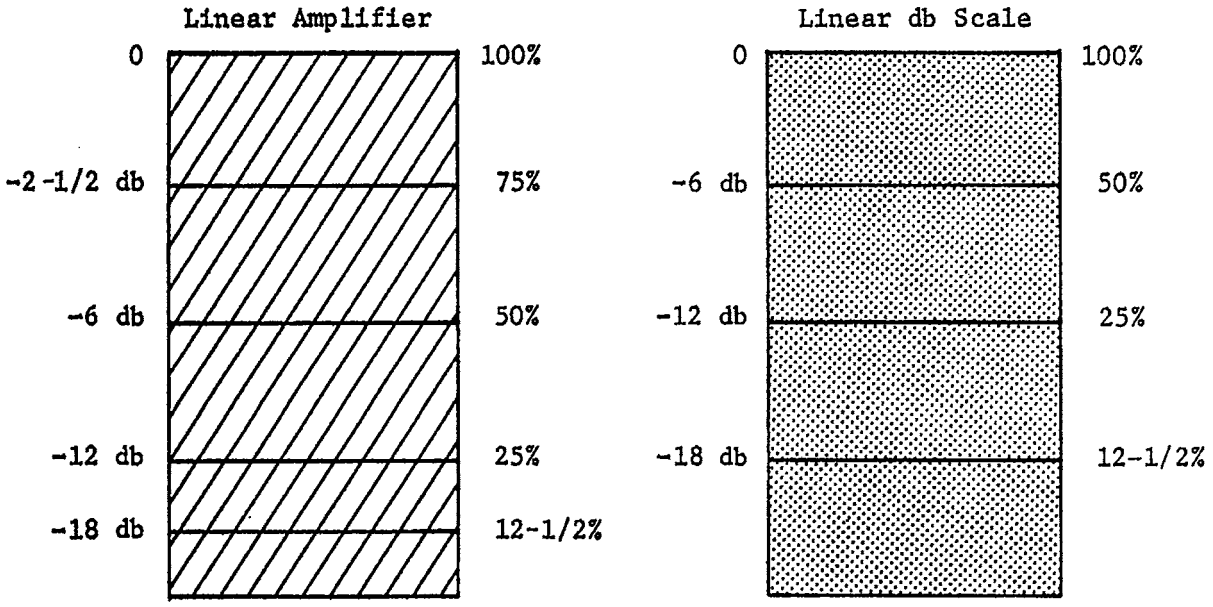
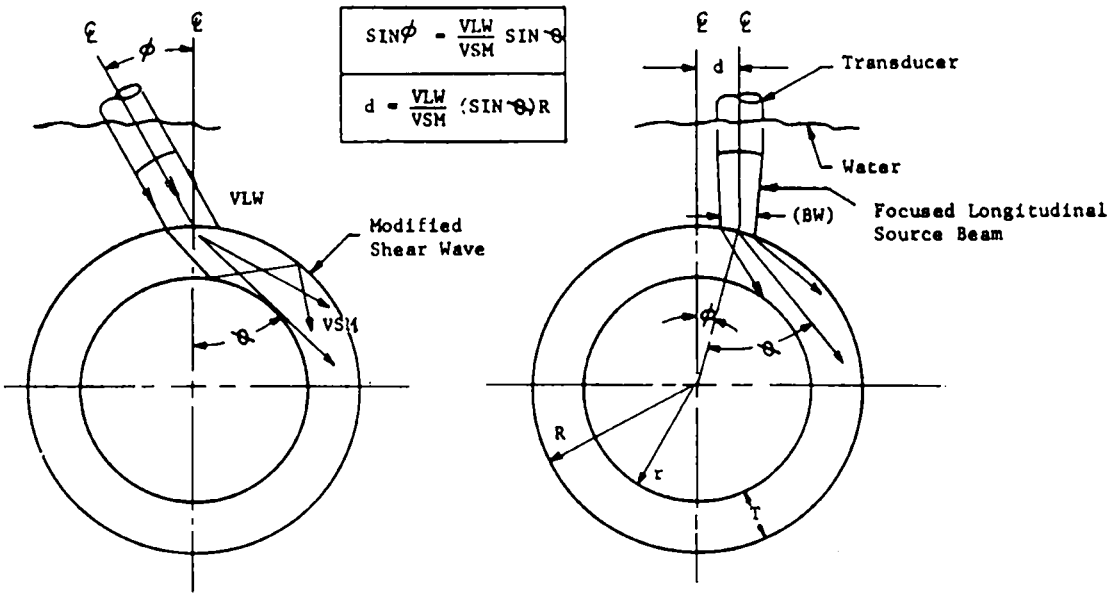


FIGURE 8. Relative amplitude vs holesize.



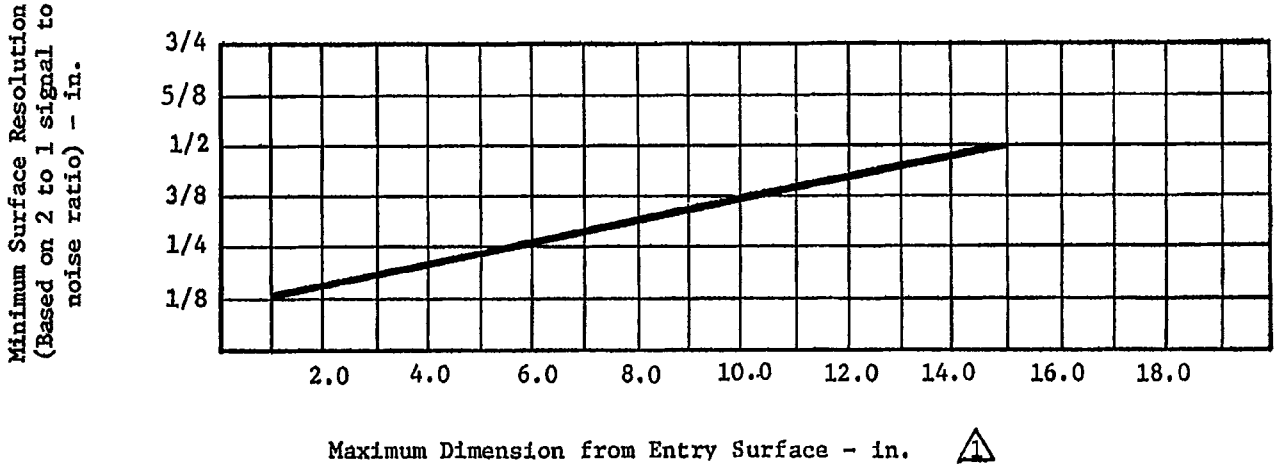
NOTE: The same 6 db difference is found for all echoes with a relative amplitude ratio of 2:1.

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.

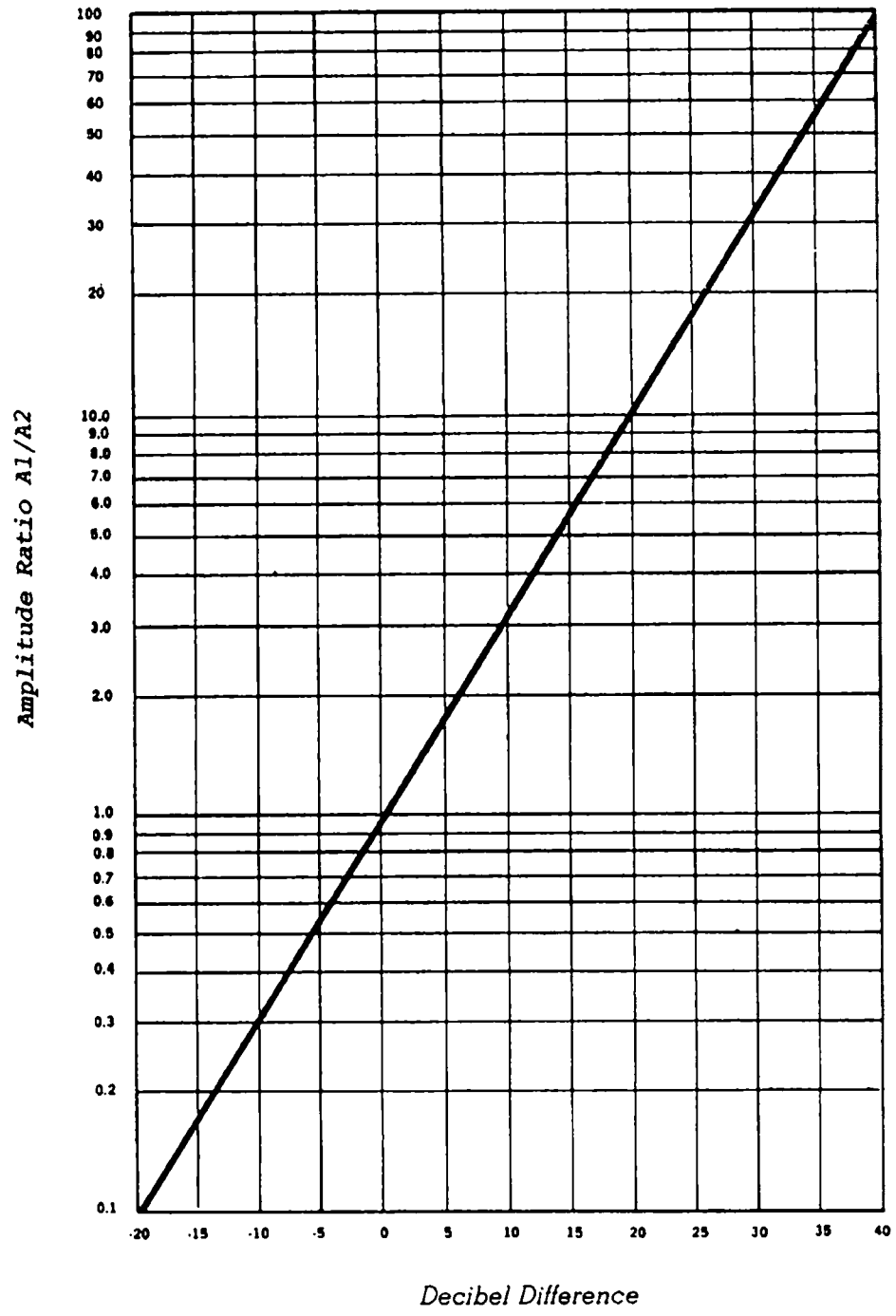


FIGURE 12. Decibel to amplitude ratio conversion chart.