ARTICLE 4
ULTRASONIC EXAMINATION METHODS FOR WELDS

T-410 SCOPE

This Article provides or references requirements for weld examinations, which are to be used in selecting and developing ultrasonic examination procedures when examination to any part of this Article is a requirement of a referencing Code Section. These procedures are to be used for the ultrasonic examination of welds and the dimensioning of indications for comparison with acceptance standards when required by the referencing Code Section; the referencing Code Section shall be consulted for specific requirements for the following:

(a) personnel qualification/certification requirements

(b) procedure requirements/demonstration, qualification, acceptance

(c) examination system characteristics

(d) retention and control of calibration blocks

(e) extent of examination and/or volume to be scanned

(f) acceptance standards

(g) retention of records

(h) report requirements

Definitions of terms used in this Article are contained in Mandatory Appendix III of Article 5.

04 T-420 GENERAL

The requirements of this Article shall be used together with Article 1, General Requirements. Refer to T-451 for special provisions for coarse grain materials and welds. Refer to T-452 for special provisions for computerized imaging techniques.

T-421 Written Procedure Requirements

T-421.1 Requirements. Ultrasonic examination shall be performed in accordance with a written procedure which shall, as a minimum, contain the requirements listed in Table T-421. The written procedure shall establish a single value, or range of values, for each requirement.

T-421.2 Procedure Qualification. When procedure qualification is specified, a change of a requirement in Table T-421 identified as an *essential variable* from the specified value, or range of values, shall require requalification of the written procedure. A change of a requirement identified as a *nonessential variable* from the specified value, or range of values, does not require requalification of the written procedure. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure shall require revision of, or an addendum to, the written procedure.

T-430 EQUIPMENT

T-431 Instrument Requirements 04

A pulse-echo-type of ultrasonic instrument shall be used. The instrument shall be capable of operation at frequencies over the range of at least 1 MHz to 5 MHz and shall be equipped with a stepped gain control in units of 2.0 dB or less. If the instrument has a damping control, it may be used if it does not reduce the sensitivity of the examination. The reject control shall be in the "off" position for all examinations, unless it can be demonstrated that it does not affect the linearity of the examination.

The instrument, when required because of the technique being used, shall have both send and receive jacks for operation of dual search units or a single search unit with send and receive transducers.

T-432 Search Units

T-432.1 General. The nominal frequency shall be from 1 MHz to 5 MHz unless variables, such as production material grain structure, require the use of other frequencies to assure adequate penetration or better resolution. Search units with contoured contact wedges may be used to aid ultrasonic coupling.

TABLE T-421
REQUIREMENTS OF AN ULTRASONIC EXAMINATION PROCEDURE 04

Requirement	Essential Variable	Nonessential Variable
Weld configurations to be examined, including thickness dimensions and base material product form (pipe, plate, etc.)	X	
The surfaces from which the examination shall be performed	X	
Technique(s) (straight beam, angle beam, contact, and/or immersion)	X	
Angle(s) and mode(s) of wave propagation in the material	X	
Search unit type(s), frequency(ies), and element size(s)/shape(s)	X	
Special search units, wedges, shoes, or saddles, when used	X	
Ultrasonic instrument(s)	X	
Calibration [calibration block(s) and technique(s)]	X	
Directions and extent of scanning	X	
Scanning (manual vs. automatic)	X	
Method for discriminating geometric from flaw indications	X	
Method for sizing indications	X	
Computer enhanced data acquisition, when used	X	
Scan overlap (decrease only)	X	
Personnel performance requirements, when required	X	
Personnel qualification requirements		X
Surface condition (examination surface, calibration block)		X
Couplant: brand name or type		X
Automatic alarm and/or recording equipment, when applicable		X
Records, including minimum calibration data to be recorded (e.g., instrument settings)		X

T-432.2 Cladding—Search Units for Technique One.[1] Dual element search units using an angled pitch-catch technique shall be used. The included angle between the beam paths shall be such that the effective focal spot of the search unit is centered in the area of interest.

T-433 Couplant

T-433.1 General. The couplant, including additives, shall not be detrimental to the material being examined.

T-433.2 Control of Contaminants

(a) Couplants used on nickel base alloys shall not contain more than 250 ppm of sulfur.

(b) Couplants used on austenitic stainless steel or titanium shall not contain more than 250 ppm of halides (chlorides plus fluorides).

T-434 Calibration Blocks

T-434.1 General

T-434.1.1 Reflectors. Known reflectors (i.e., side drilled holes, flat bottom holes, notches, etc.) shall be used to establish primary reference responses of the equipment.

T-434.1.2 Material. The material from which the block is fabricated shall be of the same product form, and material specification or equivalent P-Number grouping as one of the materials being examined. For the purposes of this paragrpah, P-Nos. 1, 3, 4, and 5 materials are considered equivalent.

T-434.1.3 Quality. Prior to fabrication, the block material shall be completely examined with a straight beam search unit. Areas that contain an indication exceeding the remaining back-wall reflection shall be excluded from the beam paths required to reach the various calibration reflectors.

T-434.1.4 Cladding. When the component material is clad, the block shall be clad by the same welding procedure as the production part. It is desirable to have component materials which have been clad before the drop outs or prolongations are removed. When the cladding is deposited using an automatic welding process, and, if due to block size, the automatic welding process is impractical, deposition of clad may be by the manual method.

T-434.1.5 Heat Treatment. The calibration block shall receive at least the minimum tempering treatment required by the material specification for the type and grade. If the calibration block contains welds other than cladding, and the component weld at the time of the examination has been heat treated, the block shall receive the same heat treatment.

[1] See paragraph T-473 for cladding techniques.

T-434.1.6 Surface Finish. The finish on the scanning surfaces of the block shall be reprentative of the scanning surface finishes on the component to be examined.

T-434.1.7 Block Curvature (Except for Piping)

T-434.1.7.1 Materials With Diameters Greater Than 20 in. (500 mm). For examinations in materials where the examination surface diameter is greater than 20 in. (500 mm), a block of essentially the same curvature, or alternatively, a flat basic calibration block, may be used.

T-434.1.7.2 Materials With Diameters 20 in. (500 mm) and Less. For examinations in materials where the examination surface diameter is equal to or less than 20 in. (500 mm), a curved block shall be used. Except where otherwise stated in this Article, a single curved basic calibration block may be used for examinations in the range of curvature from 0.9 to 1.5 times the basic calibration block diameter. For example, an 8 in (200 mm) diameter block may be used to calibrate for examinations on surfaces in the range of curvature from 7.2 in. to 12 in. (180 mm to 300 mm) in diameter. The curvature range from 0.94 in. to 20 in. (24 mm to 500 mm) in diameter requires 6 curved blocks as shown in Fig. T-434.1.7.2 for any thickness range.

T-434.1.7.3 Alternative for Convex Surface. As an alternative to the requirements in T-434.1.7.1 when examining from the convex surface by the straight beam contact technique, Appendix G may be used.

T-434.2 Non-Piping Calibration Blocks

T-434.2.1 Basic Calibration Block. The basic calibration block configuration and reflectors shall be as shown in Fig. T-434.2.1. The block size and reflector locations shall be adequate to perform calibrations for the beam angles used.

04 **T-434.2.2 Block Thickness.** When two or more base material thicknesses are involved, the calibration block thickness shall be determined by the average thickness of the weld. Alternatively, a calibration block having the greater base material thickness may be used provided the reference reflector size is based upon the average or smaller weld thickness.

04 **T-434.2.3 Block Range of Use.** When the block thickness ± 1 in. (25 mm) spans two weld thickness ranges as shown in Fig. T-434.2.1, the block's use shall be acceptable in those portions of each thickness range covered by 1 in. (25 mm) of the calibration block's thickness. As an example, a calibration block with a thickness of $1\frac{1}{2}$ in. (38 mm) could be used for weld thicknesses of 0.5 in. (13 mm) to 2.5 in. (64 mm).

T-434.2.4 Alternate Block. Alternatively, the block may be constructed as shown Nonmandatory Appendix J, Fig. J-431.

T-434.3 Piping Calibration Blocks. The basic calibration block configuration and reflectors shall be as shown in Fig. T-434.3. The basic calibration block shall be a section of pipe of the same nominal size and schedule. The block size and reflector locations shall be adequate to perform calibration for the beam angles used.

T-434.4 Cladding Calibration Blocks[2]

T-434.4.1 Calibration Block for Technique One. The basic calibration block configuration and reflectors shall be as shown in Fig. T-434.4.1. Either a side-drilled hole or a flat bottom hole may be used. The thickness of the weld overaly shall be at least as thick as that to be examined. The thickness of the base material shall be at least twice the thickness of the cladding.

T-434.4.2 Alternate Calibration Blocks for Technique One. Alternately, calibration blocks as shown in Fig. T-434.4.2.1 or T-434.4.2.2 may be used. The thickness of the weld overlay shall be at least as thick as that to be examined. The thickness of the base material shall be at least twice the thickness of the cladding.

T-434.4.3 Calibration Block for Technique Two. The basic calibration block configuration and reflectors shall be as shown in Fig. T-434.4.3. A flat bottom hole drilled to the weld metal overlay interface shall be used. This hole may be drilled from the base material or weld overlay side. The thickness of the weld overlay shall be at least as thick as that to be examined. The thickness of the base material shall be within 1 in. (25 mm) of the calibration block thickness when the examination is performed from the base material surface. The thickness of the base material on the calibration block shall be at least twice the thickness of the cladding when the examination is performed from the clad surface.

T-440 MISCELLANEOUS REQUIREMENTS

T-441 Identification of Weld Examination Areas

(a) Weld Locations. Weld locations and their identification shall be recorded on a weld map or in an identification plan.

(b) Marking. If welds are to be permanently marked, low stress stamps and/or vibratooling may be used. Markings applied after final stress relief of the component shall not be any deeper than $\frac{3}{64}$ in. (1.2 mm).

[2] See paragraph T-465, Calibration for Cladding.

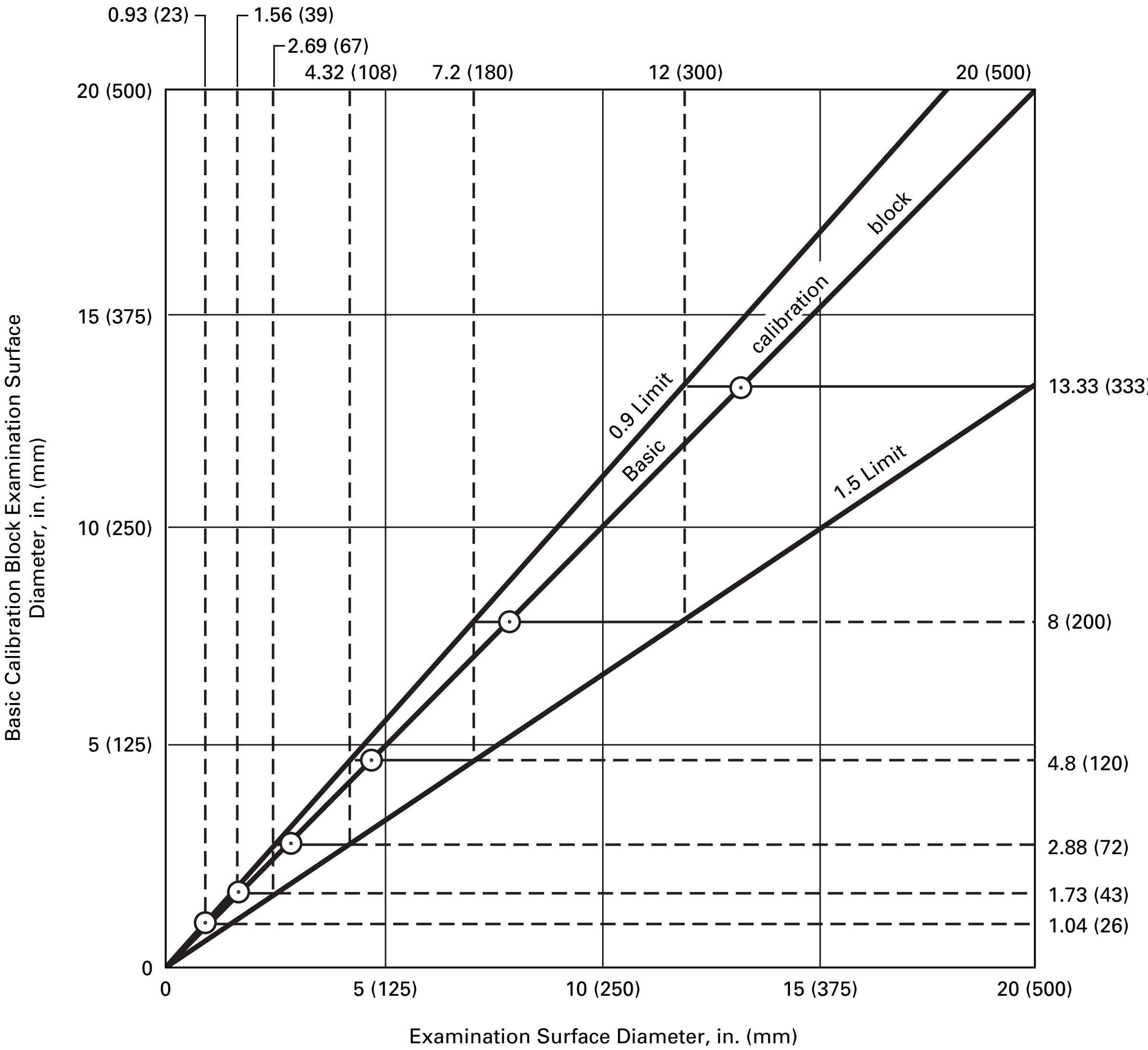


FIG. T-434.1.7.2 RATIO LIMITS FOR CURVED SURFACES

(c) Reference System. Each weld shall be located and identified by a system of reference points. The system shall permit identification of each weld center line and designation of regular intervals along the length of the weld. A general system for layout of vessel welds is described in Nonmandatory Appendix A; however, a different system may be utilized provided it meets the above requirements.

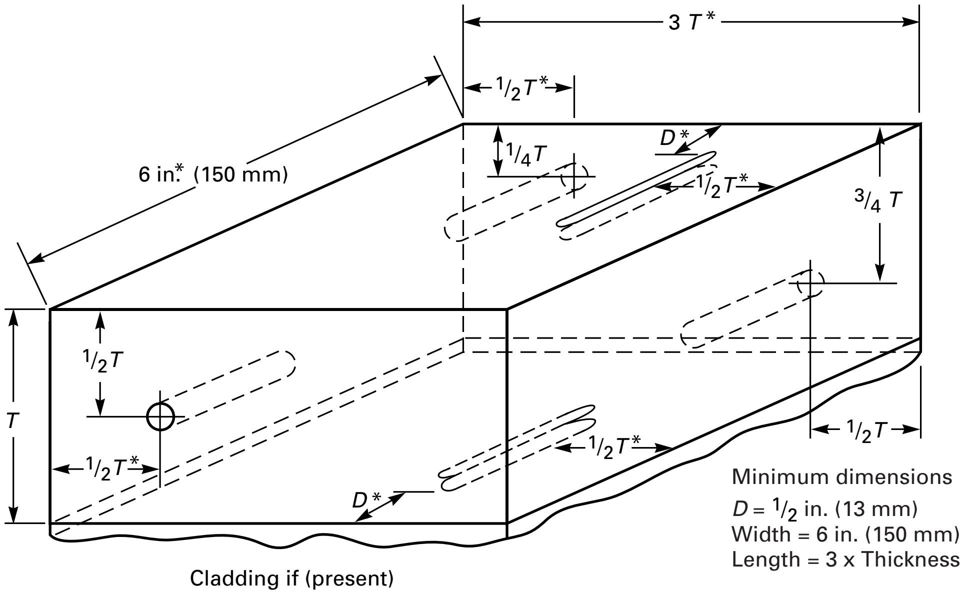
04 T-450 TECHNIQUES

The techniques described in this Article are intended for applications where either single or dual element search units are used to produce:

(a) normal incident longitudinal wave beams for what are generally termed ***straight beam*** examinations or

(b) angle beam longitudinal waves, where both refracted longitudinal and shear waves are present in the material under examination. When used for thickness measurement or clad examination, these examinations are generally considered to be straight beam examinations. When used for weld examinations, they are generally termed ***angle beam*** examinations or

(c) angle beam shear waves, where incident angles in wedges produce only refracted shear waves in the material under examination are generally termed ***angle beam*** examinations.



Weld Thickness (t) in. (mm)	Calibration Block Thickness (T) in. (mm)	Hole Diameter in. (mm)
Up to 1 (25)	$^3/_4$ (19) or t	$^3/_{32}$ (2.5)
Over 1 (25) through 2 (50)	$1^1/_2$ (38) or t	$^1/_8$ (3)
Over 2 (50) through 4 (100)	3 (75) or t	$^3/_{16}$ (5)
Over 4 (100)	$t \pm 1$ (25)	**

Notch Dimensions in. (mm)
Notch Depth = 2% T
Notch Width = $^1/_4$ (6) max.
Notch Length = 1 (25) min.

* Minimum dimension.

** For each increase in weld thickness of 2 in. (50 mm), or fraction thereof over 4 in. (100 mm), the hole diameter shall increase $^1/_{16}$ in. (1.5 mm).

GENERAL NOTES:

(a) Holes shall be drilled and reamed 1.5 in. (38 mm) deep minimum, essentially parallel to the examination surface.

(b) For components equal to or less than 20 in. (500 mm) in diameter, calibration block diameter shall meet the requirements of T-434.1.7.2. Two sets of calibration reflectors (holes, notches) oriented 90 deg from each other shall be used. Alternatively, two curved calibration blocks may be used.

(c) The tolerance for hole diameter shall be ± $^1/_{32}$ in. (0.8 mm). The tolerance for hole location through the calibration block thickness (i.e., distance from the examination surface) shall be ± $^1/_8$ in. (3 mm).

(d) All holes may be located on the same face (side) of the calibration block provided care is exercised to locate all the reflectors (holes, notches) to prevent one reflector from affecting the indication from another reflector during calibration. Notches may also be in the same plane as the inline holes (See Appendix J, FIG. J-431). As in FIG. J-431, a sufficient number of holes shall be provided for both angle and straight beam calibrations at the 1/4 T, 1/2 T and 3/4 T depths.

(e) Minimum notch depth shall be 1.6% T and maximum notch depth shall be 2.2% T plus the thickness of cladding, if present.

(f) Maximum notch width is not critical. Notches may be made by EDM or with end mills up to $^1/_4$ in. (6.4 mm) in diameter.

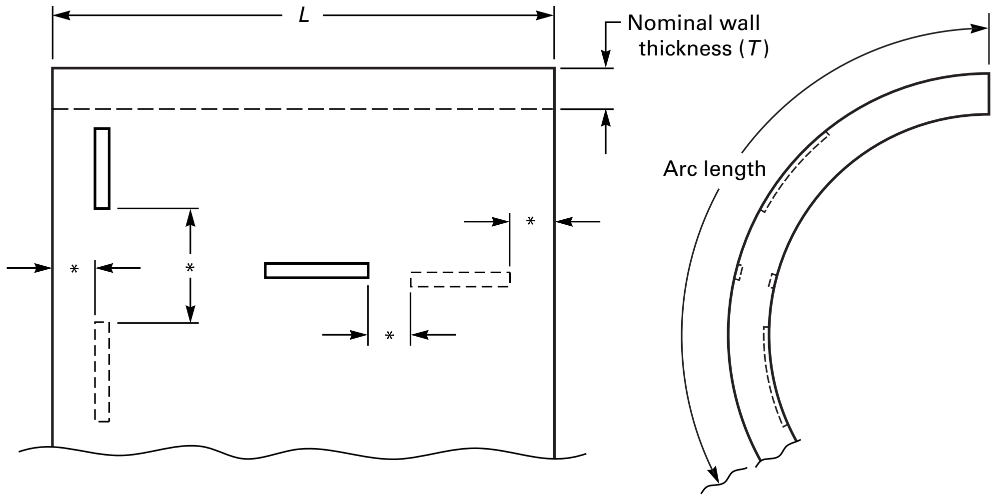
04 FIG. T-434.2.1 NON-PIPING CALIBRATION BLOCKS

Contact or immersion techniques may be used. Base materials and/or welds with metallurgical structures producing variable attenuations may require that longitudinal angle beams are used instead of shear waves. Additionally, computerized imaging techniques may enhance the detectability and evaluation of indications.

Other techniques or technology which can be demonstrated to produce equivalent or better examination sensitivity and detectability using search units with more than two transducer elements may be used. The demonstration shall be in accordance with Article 1, T-150(a).

T-451 Coarse Grain Materials

Ultrasonic examinations of high alloy steels and high nickel alloy weld deposits and dissimilar metal welds between carbon steels and high alloy steels and high nickel alloys are usually more difficult than ferritic weld



* Notches shall be located not closer than T or 1 in. (25 mm), whichever is greater, to any block edge or to other notches.

GENERAL NOTES:

(a) The minimum calibration block length (L) shall be 8 in. (200 mm) or $8T$, whichever is greater.

(b) For OD 4 in. (100 mm) or less, the minimum arc length shall be 270 deg. For OD greater than 4 in. (100 mm), the minimum arc length shall be 8 in. (200 mm) or $3T$, whichever is greater.

(c) Notch depths shall be from 8% T minimum to 11% T maximum. Notch widths shall be $\frac{1}{4}$ in. (6 mm) maximum. Notch lengths shall be 1 in. (25 mm) minimum.

(d) Maximum notch width is not critical. Notches may be made with EDM or with end mills up to $\frac{1}{4}$ in. (6 mm) in diameter.

(e) Notch lengths shall be sufficient to provide for calibration with a minimum 3 to 1 signal-to-noise ratio.

FIG. T-434.3 CALIBRATION BLOCK FOR PIPE 04

examinations. Difficulties with ultrasonic examinations can be caused by an inherent coarse-grained and/or a directionally-oriented structure, which can cause marked variations in attenuation, reflection, and refraction at grain boundaries and velocity changes within the grains. It usually is necessary to modify and/or supplement the provisions of this Article in accordance with T-150(a) when examining such welds in these materials. Additional items, which may be necessary, are weld mockups with reference reflectors in the weld deposit and single or dual element angle beam longitudinal wave transducers.

T-452 Computerized Imaging Techniques

The major attribute of Computerized Imaging Techniques (CITs) is their effectiveness when used to characterize and evaluate indications; however, CITs may also be used to perform the basic scanning functions required for flaw detection. Computer-processed data analysis and display techniques are used in conjunction with automatic or semi-automatic scanning mechanisms to produce two and three-dimensional images of flaws, which provides an enhanced capability for examining critical components and structures. Computer processes may be used to quantitatively evaluate the type, size, shape, location, and orientation of flaws detected by ultrasonic examination or other NDE methods. Descriptions for some CITs that may be used are provided in Nonmandatory Appendix E.

T-460 CALIBRATION

T-461 Instrument Linearity Checks

The requirements of T-461.1 and T-461.2 shall be met at intervals not to exceed three months or prior to first use thereafter.

T-461.1 Screen Height Linearity. The ultrasonic instrument's screen height linearity shall be evaluated in accordance with Mandatory Appendix I.

T-461.2 Amplitude Control Linearity. The ultrasonic instrument's amplitude control linearity shall be evaluated in accordance with Mandatory Appendix II.

T-462 General Calibration Requirements

T-462.1 Ultrasonic System. Calibrations shall include the complete ultrasonic system and shall be per-

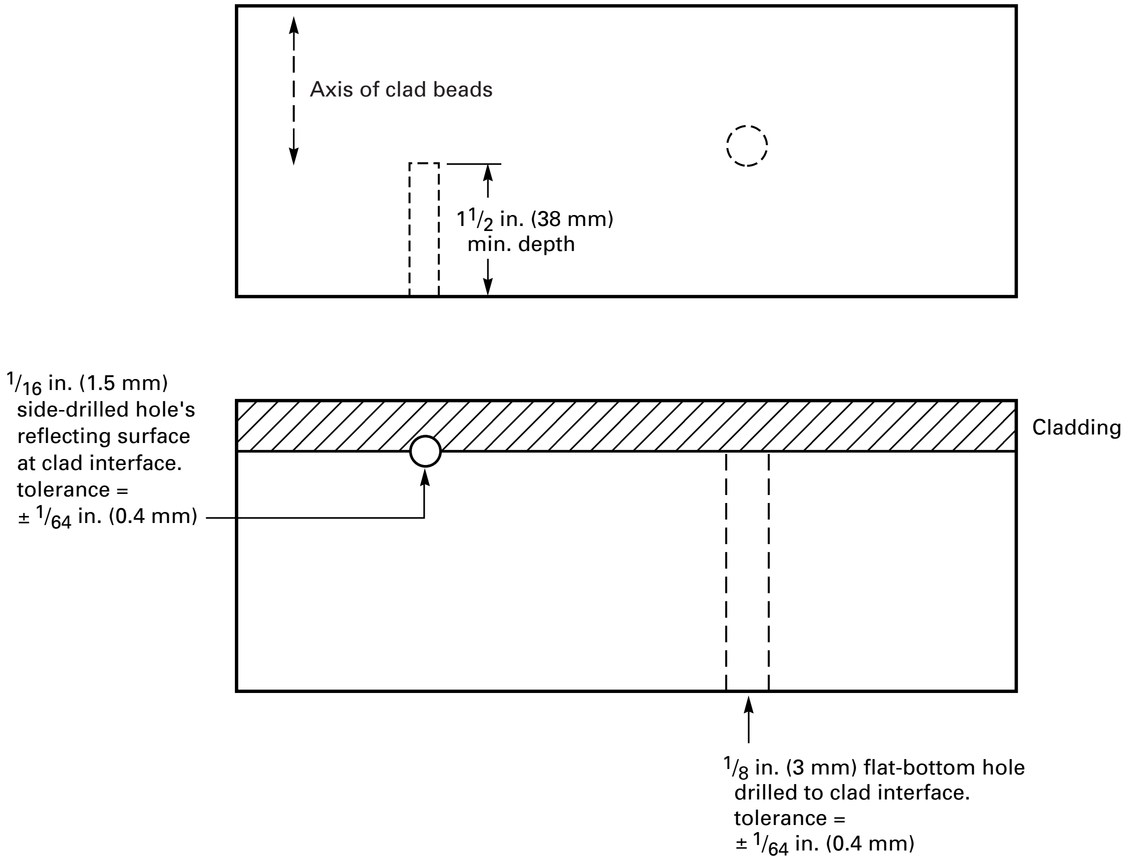


FIG. T-434.4.1 CALIBRATION BLOCK FOR TECHNIQUE ONE

formed prior to use of the system in the thickness range under examination.

T-462.2 Calibration Surface. Calibrations shall be performed from the surface (clad or unclad; convex or concave) corresponding to the surface of the component from which the examination will be performed.

T-462.3 Couplant. The same couplant to be used during the examination shall be used for calibration.

T-462.4 Contact Wedges. The same contact wedges to be used during the examination shall be used for calibration.

T-462.5 Instrument Controls. Any control which affects instrument linearity (e.g., filters, reject, or clipping) shall be in the same position for calibration, calibration checks, instrument linearity checks, and examination.

T-462.6 Temperature. For contact examination, the temperature differential between the calibration block and examination surfaces shall be within 25°F (14°C). For immersion examination, the couplant temperature for calibration shall be within 25°F (14°C) of the couplant temperature for examination.

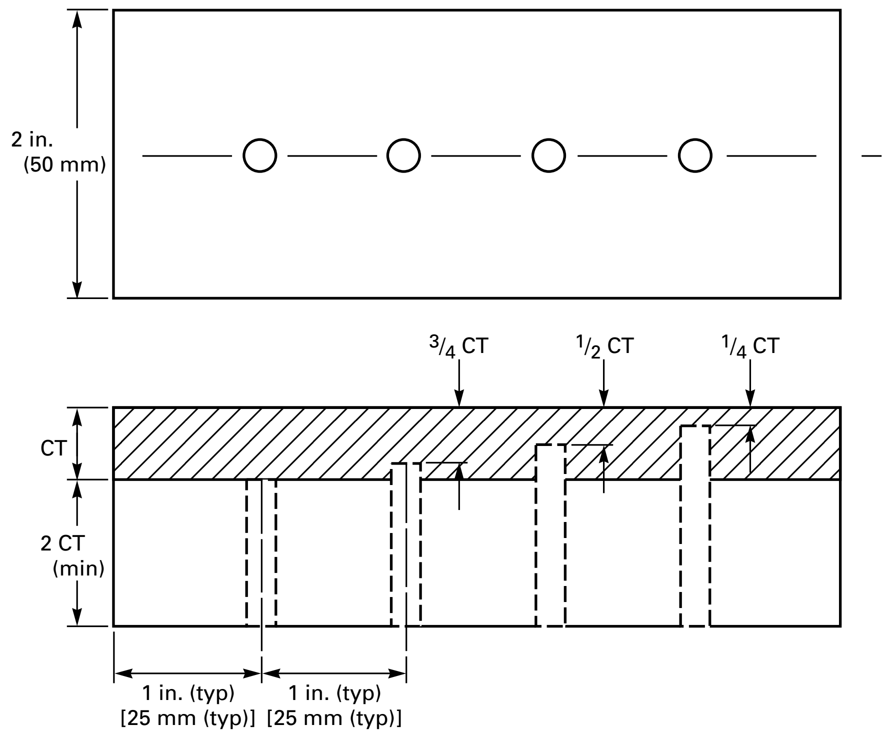
T-463 Calibration for Non-Piping

T-463.1 System Calibration for Distance Amplitude Techniques

T-463.1.1 Calibration Block(s). Calibrations shall be performed utilizing the calibration block shown in Fig. T-434.2.1.

T-463.1.2 Techniques. Nonmandatory Appendices B and C provide general techniques for both angle beam shear wave and straight beam calibrations. Other techniques may be used. 04

The angle beam shall be directed toward the calibration reflector that yields the maximum response in the area of interest. The gain control shall be set so that this response is 80% ± 5% of full screen height. This shall be the primary reference level. The search unit shall then be manipulated, without changing instrument settings, to obtain the maximum responses from the other calibration reflectors at their beam paths to generate the distance-amplitude correction (DAC) curve. These calibrations shall establish both the distance range calibration and the distance amplitude correction.



GENERAL NOTE: All flat-bottom holes are 1/8 in. (3 mm) diameter. Tolerances for hole diameter and depth with respect to the clad side of the block are ± 1/64 in. (0.4 mm).

FIG. T-434.4.2.1 ALTERNATE CALIBRATION BLOCK FOR TECHNIQUE ONE

04 **T-463.1.3 Angle Beam Calibration.** As applicable, the calibration shall provide the following measurements (Nonmandatory Appendix B contains general techniques):

(a) distance range calibration;

(b) distance-amplitude;

(c) echo amplitude measurement from the surface notch in the basic calibration block.

When an electronic distance-amplitude correction device is used, the primary reference responses from the basic calibration block shall be equalized over the distance range to be employed in the examination. The response equalization line shall be at a screen height of 40% to 80% of full screen height.

04 **T-463.1.4 Straight Beam Calibration.** The calibration shall provide the following measurements (Nonmandatory Appendix C gives a general technique):

(a) distance range calibration, and;

(b) distance-amplitude correction in the area of interest.

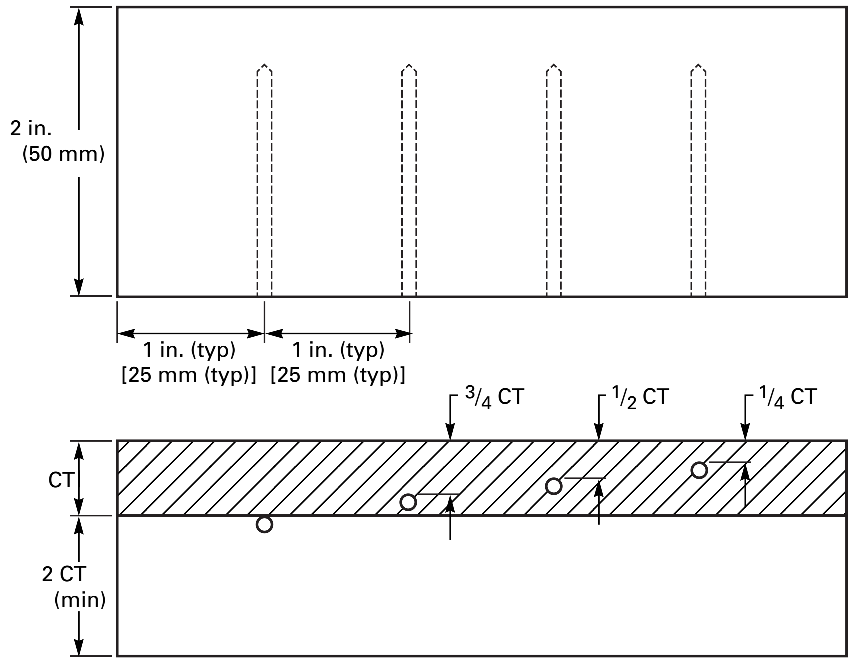
When an electronic distance-amplitude correction device is used, the primary reference responses from the basic calibration block shall be equalized over the distance range to be employed in the examination. The response equalization line shall be at a screen height of 40% to 80% of full screen height.

T-463.2 System Calibration for Non-Distance Amplitude Techniques. Calibration includes all those actions required to assure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system (whether displayed, recorded, or automatically processed) are repeated from examination to examination. Calibration may be by use of basic calibration blocks with artificial or discontinuity reflectors. Methods are provided in Nonmandatory Appendices B and C. Other methods of calibration may include sensitivity adjustment based on the examination material, etc.

T-464 Calibration for Piping

T-464.1 System Calibration for Distance Amplitude Techniques

T-464.1.1 Calibration Block(s). Calibrations shall be performed utilizing the calibration block shown in Fig. T-434.3.



GENERAL NOTE: All side-drilled holes are 1/16 in. (1.5 mm) diameter. Holes location tolerance is ± 1/64 in. (0.4 mm). All holes drilled to a minimum depth of 1.5 in. (38 mm).

FIG. T-434.4.2.2 ALTERNATE CALIBRATION BLOCK FOR TECHNIQUE ONE

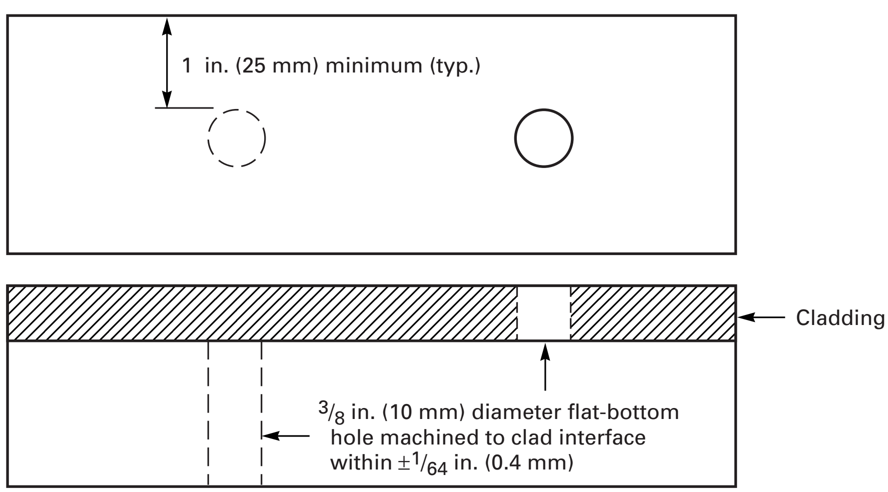


FIG. T-434.4.3 ALTERNATE CALIBRATION BLOCK FOR TECHNIQUE TWO

T-464.1.2 Angle Beam Calibration. The angle beam shall be directed toward the calibration reflector that yields the maximum response. The gain control shall be set so that this response is 80% ±5% of full screen height. This shall be the primary reference level. The search unit shall then be manipulated, without changing instrument settings, to obtain the maximum responses from the calibration reflectors at the distance increments necessary to generate a three-point distance-amplitude correction (DAC) curve. Separate calibrations shall be established for both the axial and circumferential notches. These calibrations shall establish both the distance range calibration and the distance amplitude correction.

T-464.1.3 Alternate Calibration Reflectors. Side-drilled holes may be used provided that it can be demonstrated that the hole calibration produces a sensitivity equal to or greater than the notch calibration.

04 **T-464.1.4 Straight Beam Calibration.** When required, straight beam calibrations shall be performed to the requirements of Nonmandatory Appendix C using the side drilled hole alternate calibration reflectors of T-464.1.3. This calibration shall establish both the distance range calibration and the distance amplitude correction.

T-464.2 System Calibration for Non-Distance Amplitude Techniques. Calibration includes all those actions required to assure that the sensitivity and accuracy of the signal amplitude and time outputs of the examination system (whether displayed, recorded, or automatically processed) are repeated from examination to examination. Calibration may be by use of basic calibration blocks with artificial or discontinuity reflectors. Methods are provided in Nonmandatory Appendices B and C. Other methods of calibration may include sensitivity adjustment based on the examination material, etc.

T-465 Calibration for Cladding

T-465.1 Calibration for Technique One. Calibrations shall be performed utilizing the calibration block shown in Fig. T-434.4.1. The search unit shall be positioned for the maximum response from the calibration reflector. The gain control shall be set so that this response is 80% ±5% of full screen height. This shall be the primary reference level.

T-465.2 Calibration for Technique Two. Calibrations shall be performed utilizing the calibration block shown in Fig. T-434.4.3. The search unit shall be positioned for the maximum response of the first resolvable indication from the bottom of the calibration reflector. The gain shall be set so that this response is 80% ±5% of full screen height. This shall be the primary reference level.

T-465.3 Alternate Calibration for Technique One. Calibrations shall be performed utilizing the calibration blocks shown in Fig. T-434.4.2.1 or T-434.4.2.2. The calibration shall be performed as follows:

(a) The search unit shall be positioned for maximum response from the reflector, which gives the highest amplitude.

(b) The gain shall be set so that this response is 80% ±5% of full screen height. This shall be the primary reference level. Mark the peak of the indication on the screen.

(c) Without changing the instrument settings, position the search unit for maximum response from each of the other reflectors and mark their peaks on the screen.

(d) Connect the screen marks for each reflector to provide a DAC curve.

T-466 Calibration Confirmation

T-466.1 System Changes. When any part of the examination system is changed, a calibration check shall be made on the basic calibration block to verify that distance range points and sensitivity setting(s) satisfy the requirements of T-466.3.

T-466.2 Periodic Examination Checks. A calibration check on at least one of the basic reflectors in the basic calibration block or a check using a simulator shall be made at the finish of each examination or series of similar examinations, every 4 hr during the examination, and when examination personnel (except for automated equipment) are changed. The distance range points and sensitivity setting(s) recorded shall satisfy the requirements T-466.3.

T-466.2.1 Simulator Checks. Any simulator checks that are used shall be correlated with the original calibration on the basic calibration block during the original calibration. The simulator checks may use different types of calibration reflectors or blocks (such as IIW) and/or electronic simulation. However, the simulation used shall be identifiable on the calibration sheet(s). The simulator check shall be made on the entire examination system. The entire system does not have to be checked in one operation; however, for its check, the search unit shall be connected to the ultrasonic instrument and checked against a calibration reflector. Accuracy of the simulator checks shall be confirmed, using the basic calibration block, at the conclusion of each period of extended use, or every three months, whichever is less.

T-466.3 Confirmation Acceptance Values

T-466.3.1 Distance Range Points. If any distance range point has moved on the sweep line by more than

10% of the distance reading or 5% of full sweep, whichever is greater, correct the distance range calibration and note the correction in the examination record. All recorded indications since the last valid calibration or calibration check shall be reexamined and their values shall be changed on the data sheets or re-recorded.

T-466.3.2 Sensitivity Settings. If any sensitivity setting has changed by more than 20% or 2 dB of its amplitude, correct the sensitivity calibration and note the correction in the examination record. If the sensitivity setting has decreased, all data sheets since the last valid calibration check shall be marked void and the area covered by the voided data shall be reexamined. If the sensitivity setting has increased, all recorded indications since the last valid calibration or calibration check shall be reexamined and their values shall be changed on the data sheets or re-recorded.

T-470 EXAMINATION

T-471 General Examination Requirements

04 **T-471.1 Examination Coverage.** The volume to be scanned shall be examined by moving the search unit over the scanning surface so as to scan the entire examination volume for each required search unit.

(a) Each pass of the search unit shall overlap a minimum of 10% of the transducer (piezoelectric element) dimension parallel to the direction of scan indexing. As an alternative, if the sound beam dimension parallel to the direction of scan indexing is measured in accordance with Nonmandatory Appendix B, B-466, Beam Spread measurement rules, each pass of the search unit may provide overlap of the minimum beam dimension determined.

(b) Oscillation of the search unit is permitted if it can be demonstrated that overlapping coverage is provided.

T-471.2 Pulse Repetition Rate. The pulse repetition rate shall be small enough to assure that a signal from a reflector located at the maximum distance in the examination volume will arrive back at the search unit before the next pulse is placed on the transducer.

T-471.3 Rate of Search Unit Movement. The rate of search unit movement (scanning speed) shall not exceed 6 in./s (150 mm/s), unless:

(a) the ultrasonic instrument pulse repetition rate is sufficient to pulse the search unit at least six times within the time necessary to move one-half the transducer (piezoelectric element) dimension parallel to the direction of the scan at maximum scanning speed; or,

(b) a dynamic calibration is performed on multiple reflectors, which are within ±2 dB of a static calibration and the pulse repetition rate meets the requirements of T-471.2.

T-471.4 Scanning Sensitivity Level

T-471.4.1 Distance Amplitude Techniques. The scanning sensitivity level shall be set a minimum[3] of 6 dB higher than the reference level gain setting. 04

T-471.4.2 Non-Distance Amplitude Techniques. The level of gain used for scanning shall be appropriate for the configuration being examined and shall be capable of detecting the calibration reflectors at the maximum scanning speed.

T-471.5 Surface Preparation. When the base material or weld surface interferes with the examination, the base material or weld shall be prepared as needed to permit the examination.

T-472 Weld Joint Distance Amplitude Technique

When the referencing Code Section specifies a distance amplitude technique, weld joints shall be scanned with an angle beam search unit in both parallel and transverse directions (4 scans) to the weld axis. Before performing the angle beam examinations, a straight beam examination shall be performed on the volume of base material through which the angle beams will travel to locate any reflectors that can limit the ability of the angle beam to examine the weld volume.

T-472.1 Angle Beam Technique

T-472.1.1 Beam Angle. The search unit and beam angle selected shall be 45 deg or an angle appropriate for the configuration being examined and shall be capable of detecting the calibration reflectors, over the required angle beam path. 04

T-472.1.2 Reflectors Parallel to the Weld Seam. The angle beam shall be directed at approximate right angles to the weld axis from both sides of the weld (i.e., from two directions) on the same surface when possible. The search unit shall be manipulated so that the ultrasonic energy passes through the required volume of weld and adjacent base material.

T-472.1.3 Reflectors Transverse to the Weld Seam. The angle beam shall be directed essentially parallel to the weld axis. The search unit shall be manipulated 04

[3] When the Referencing Code Section requires the detection and evaluation of all indications exceeding 20% DAC, the gain should be increased an additional amount so that no calibration reflector indication is less than 40% FSH. As an alternate, the scanning sensitivity level may be set at 14 dB higher than the reference level gain setting. (This additional gain makes the reference DAC curve a 20% DAC curve so that indications exceeding 20% DAC may be easily identified and evaluated.).

so that the ultrasonic energy passes through the required volume of weld and adjacent base material. The search unit shall be rotated 180 deg and the examination repeated.

If the weld cap is not machined or ground flat, the examination shall be performed from the base metal on both sides of the weld cap in both weld axis directions.

T-472.2 Restricted Access Welds. Welds that cannot be fully examined from two directions using the angle beam technique (e.g., corner and tee joints) shall also be examined, if possible, with a straight beam technique. These areas of restricted access shall be noted in the examination report.

T-472.3 Inacessible Welds. Welds that cannot be examined from at least one side (edge) using the angle beam technique shall be noted in the examination report. For flange welds, the weld may be examined with a straight beam or low angle longitudinal waves from the flange face provided the examination volume can be covered.

T-473 Cladding Techniques

The techniques described in these paragraphs shall be used when examinations of weld metal overlay cladding are required by a referencing Code Section. When examination for lack of bond and clad flaw indications is required, Technique One shall be used. When examination for lack of bond only is required, Technique Two may be used.

T-473.1 Technique One. The examination shall be performed from the clad surface with the plane separating the elements of the dual element search unit positioned parallel to the axis of the weld bead. The search unit shall be moved perpendicular to the weld direction.

T-473.2 Technique Two. The examination may be performed from either the clad or unclad surface and the search unit may be moved either perpendicular or parallel to the weld direction.

T-474 Non-Distance Amplitude Techniques

The number of angles and directions of the scans shall be developed in the procedure and shall demonstrate the ability to detect the minimum size rejectable discontinuities in the referencing Code Section acceptance standards. The detailed techniques shall be in conformance with the requirements of the referencing Code Section.

T-480 EVALUATION

T-481 General

It is recognized that not all ultrasonic reflectors indicate flaws, since certain metallurgical discontinuities and geometric conditions may produce indications that are not relevant. Included in this category are plate segregates in the heat-affected zone that become reflective after fabrication. Under straight beam examination, these may appear as spot or line indications. Under angle beam examination, indications that are determined to originate from surface conditions (such as weld root geometry) or variations in metallurgical structure in austenitic materials (such as the automatic-to-manual weld clad interface) may be classified as geometric indications. The identity, maximum amplitude, location, and extent of reflector causing a geometric indication shall be recorded. [For example: internal attachment, 200% DAC, 1 in. (25 mm) above weld center line, on the inside surface, from 90 deg to 95 deg.] The following steps shall be taken to classify an indication as geometric:

(a) Interpret the area containing the reflector in accordance with the applicable examination procedure.

(b) Plot and verify the reflector coordinates. Prepare a cross-sectional sketch showing the reflector position and surface discontinuities such as root and counterbore.

(c) Review fabrication or weld preparation drawings. Other ultrasonic techniques or nondestructive examination methods may be helpful in determining a reflector's true position, size, and orientation.

T-482 Evaluation Level

T-482.1 Distance Amplitude Techniques. All indications greater than 20% of the reference level shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

T-482.2 Non-Distance Amplitude Techniques. All indications longer than 40% of the rejectable flaw size shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria of the referencing Code Section.

T-483 Evaluation of Laminar Reflectors

Reflectors evaluated as laminar reflectors in base material which interfere with the scanning of examination volumes shall require the angle beam examination technique to be modified such that the maximum feasible volume is examined, and shall be noted in the record of the examination (T-493).

T-484 Alternative Evaluations

Reflector dimensions exceeding the referencing Code Section requirements may be evaluated to any alternative standards provided by the referencing Code Section.

T-490 DOCUMENTATION

T-491 Recording Indications

T-491.1 Non-Rejectable Indications. Non-rejectable indications shall be recorded as specified by the referencing Code Section.

T-491.2 Rejectable Indications. Rejectable indications shall be recorded. As a minimum, the type of indication (i.e., crack, non-fusion, slag, etc.), location, and extent (i.e., length) shall be recorded.

T-492 Examination Records

For each ultrasonic examination, the following information shall be recorded:

(a) procedure identification and revision;

(b) ultrasonic instrument identification (including manufacturer's serial number);

(c) search unit(s) identification (including manufacturer's serial number, frequency, and size);

(d) beam angle(s) used;

(e) couplant used, brand name or type;

(f) search unit cable(s) used, type and length;

(g) special equipment when used (search units, wedges, shoes, automatic scanning equipment, recording equipment, etc.);

(h) computerized program identification and revision when used;

(i) calibration block identification;

(j) simulation block(s) and electronic simulator(s) identification when used;

(k) instrument reference level gain and, if used, damping and reject setting(s);

(l) calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)];

(m) data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration;

(n) identification and location of weld or volume scanned;

(o) surface(s) from which examination was conducted, including surface condition;

(p) map or record of rejectable indications detected or areas cleared;

(q) areas of restricted access or inaccessible welds;

(r) examination personnel identity and, when required by referencing Code Section, qualification level;

(s) date and time examinations were performed.

Items *(b)* through *(m)* may be included in a separate calibration record provided the calibration record identification is included in the examination record.

T-493 Report

A report of the examinations shall be made. The report shall include those records indicated in T-491 and T-492. The report shall be filed and maintained in accordance with the referencing Code Section.

ARTICLE 4
MANDATORY APPENDICES

APPENDIX I — SCREEN HEIGHT LINEARITY

I-410 SCOPE

This Mandatory Appendix provides requirements for checking screen height linearity and is applicable to ultrasonic instruments with A-scan displays.

I-440 MISCELLANEOUS REQUIREMENTS

Position an angle beam search unit on a calibration block, as shown in Fig. I-440 so that indications from both the $\frac{1}{2}$ and $\frac{3}{4}T$ holes give a 2:1 ratio of amplitudes between the two indications. Adjust the sensitivity (gain) so that the larger indication is set at 80% of full screen height (FSH). Without moving the search unit, adjust sensitivity (gain) to successively set the larger indication from 100% to 20% of full screen height, in 10% increments (or 2 dB steps if a fine control is not available), and read the smaller indication at each setting. The reading shall be 50% of the larger amplitude, within 5% of FSH. The settings and readings shall be estimated to the nearest 1% of full screen. Alternatively, a straight beam search unit may be used on any calibration block that provides amplitude differences, with sufficient signal separation to prevent overlapping of the two signals.

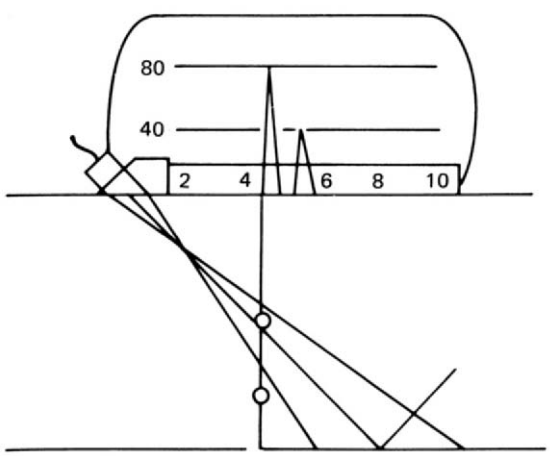


FIG. I-440 LINEARITY

APPENDIX II — AMPLITUDE CONTROL LINEARITY

II-410 SCOPE

This Mandatory Appendix provides requirements for checking amplitude control linearity and is applicable to ultrasonic instruments with A-scan displays.

II-440 MISCELLANEOUS REQUIRMENTS

Position an angle beam search unit on a basic calibration block, as shown in Fig. I-440 so that the indication from the $\frac{1}{2}T$ side-drilled hole is peaked on the screen. Adjust the sensitivity (gain) as shown in the following table. The indication shall fall within the specified limits. Alternatively, any other convenient reflector from any calibration block may be used with angle or straight beam search units.

Indication Set at % of Full Screen	dB Control Change	Indication Limits % of Full Screen
80%	–6 dB	32 to 48%
80%	–12 dB	16 to 24%
40%	+6 dB	64 to 96%
20%	+12 dB	64 to 96%

The settings and readings shall be estimated to the nearest 1% of full screen.

ARTICLE 4
NONMANDATORY APPENDICES

APPENDIX A — LAYOUT OF VESSEL REFERENCE POINTS

A-410 SCOPE

This Appendix provides requirements for establishing vessel reference points.

A-440 MISCELLANEOUS REQUIREMENTS

The layout of the weld shall consist of placing reference points on the center line of the weld. The spacing of the reference points shall be in equal increments (e.g., 12 in., 3 ft, 1 m, etc.) and identified with numbers (e.g., 0, 1, 2, 3, 4, etc.). The increment spacing, number of points, and starting point shall be recorded on the reporting form. The weld center line shall be the divider for the two examination surfaces.

A-441 Circumferential (Girth) Welds

The standard starting point shall be the 0 deg axis of the vessel. The reference points shall be numbered in a clockwise direction, as viewed from the top of the vessel or, for horizontal vessels, from the inlet end of the vessel. The examination surfaces shall be identified (e.g., for vertical vessels, as being either above or below the weld).

A-442 Longitudinal Welds

Longitudinal welds shall be laid out from the center line of circumferential welds at the top end of the weld or, for horizontal vessels, the end of the weld closest to the inlet end of the vessel. The examination surface shall be identified as clockwise or counterclockwise as viewed from the top of the vessel or, for horizontal vessels, from the inlet end of the vessel.

A-443 Nozzle-to-Vessel Welds

The external reference circle shall have a sufficient radius so that the circle falls on the vessel's external surface beyond the weld's fillet. The internal reference circle shall have a sufficient radius so that the circle falls within $\frac{1}{2}$ in. (13 mm) of the weld center-line. The 0 deg point on the weld shall be the top of the nozzle. The 0 deg point for welds of veritcally oriented nozzles shall be located at the 0 deg axis of the vessel, or, for horizontal vessels, the point closest to the inlet end of the vessel. Angular layout of the weld shall be made clockwise on the external surface and counterclockwise on the internal surface. The 0 deg, 90 deg, 180 deg, and 270 deg lines will be marked on all nozzle welds examined; 30 deg increment lines shall be marked on nozzle welds greater than a nominal 8 in. (200 mm) diameter; 15 deg increment lines shall be marked on nozzle welds greater than a nominal 24 in. (600 mm) diameter; 5 deg increment lines shall be marked on nozzle welds greater than 48 in. (1 200 mm) diameter.

APPENDIX B — GENERAL TECHNIQUES FOR ANGLE BEAM CALIBRATIONS

B-410 SCOPE 04

This Appendix provides general techniques for angle beam calibration. Other techniques may be used.

Descriptions and figures for the general techniques relate position and depth of the reflector to eighths of the V-path. The sweep range may be calibrated in terms of units of metal path,[1] projected surface distance or actual depth to the reflector (as shown in Figs. B-461.1, B-461.2, and B-461.3). The particular method may be selected according to the preference of the examiner.

B-460 CALIBRATION 04

B-461 Sweep Range Calibration

B-461.1 Side Drilled Holes (See Fig. B-461.1.1)

B-461.1.1 Delay Control Adjustment. Position the search unit for the maximum first indication from the

[1] Reflections from concentric cylindrical surfaces such as provided by some IIW blocks and the AWS distance calibration block may be used to adjust delay zero and sweep range for metal path calibration.

$^1\!/_4T$ side-drilled hole (SDH). Adjust the left edge of this indication to line 2 on the screen with the delay control.

B-461.1.2 Range[2] Control Adjustment. Position the search unit for the maximum indication from the $^3\!/_4T$ SDH. Adjust the left edge of this indication to line 6 on the screen with the range control.

B-461.1.3 Repeat Adjustments. Repeat delay and range control adjustments until the $^1\!/_4T$ and $^3\!/_4T$ SDH indications start at sweep lines 2 and 6.

B-461.1.4 Notch Indication. Position the search unit for maximum response from the square notch on the opposite surface. The indication will appear near sweep line 8.

B-461.1.5 Sweep Readings. Two divisions on the sweep now equal $^1\!/_4T$.

B-461.2 IIW Block (See Fig. B-461.2). IIW Reference Blocks may be used to calibrate the sweep range displayed on the instrument screen. They have the advantage of providing reflectors at precise distances that are not affected by side drilled hole location inaccuracies in the basic calibration block or the fact that the reflector is not at the side drilled hole centerline. These blocks are made in a variety of alloys and configurations. Angle beam range calibrations are provided from the 4 in. (100 mm) radius and other reflectors. The calibration block shown in Fig. B-461.2 provides an indication at 4 in. (100 mm) and a second indication from a reflection from the vertical notches at the center point 8 in. (200 mm) back to the radius and returning to the transducer when the exit point of the wedge is directly over the center point of the radius. Other IIW blocks provide signals at 2 in. (50 mm) and 4 in. (100 mm) and a third design provides indications at 4 in. (100 mm) and 9 in. (225 mm).

B-461.2.1 Search Unit Adjustment. Position the search unit for the maximum indication from the 4 in. (100 mm) radius while rotating it side to side to also maximize the second reflector indication.

B-461.2.2 Delay and Range Control Adjustment. Without moving the search unit, adjust the range and delay controls so that the indications start at their respective metal path distances.

B-461.2.3 Repeat Adjustments. Repeat delay and range control adjustments until the two indications are at their proper metal path on the screen.

B-461.2.4 Sweep Readings. Two divisions on the sweep now equal $^1\!/_5$ of the screen range selected.

[2] Range has been replaced on many new instruments with "velocity".

B-461.3 Piping Block (See Fig. B-461.3). The notches in piping calibration blocks may be used to calibrate the distance range displayed on the instrument screen. They have the advantage of providing reflectors at precise distances to the inside and outside surfaces.

B-461.3.1 Delay Control Adjustment. Position the search unit for the maximum first indication from the inside surface notch at its actual beam path on the instrument screen. Adjust the left edge of this indication to its metal path on the screen with the delay control.

B-461.3.2 Range Control Adjustment. Position the search unit for the maximum second indication from the outside surface notch. Adjust the left edge of this indication to its metal on the screen with the range control or velocity control.

B-461.3.3 Repeat Adjustments. Repeat delay and range control adjustments until the two indications are at their proper metal paths on the screen.

B-461.3.4 Sweep Readings. Two divisions on the sweep now equal $^1\!/_5$ of the screen range selected.

B-462 Distance–Amplitude Correction

B-462.1 Calibration for Side Drilled Holes Primary Reference Level From Clad Side (See Fig. B-462.1)

(a) Position the search unit for maximum response from the SDH, which gives the highest amplitude.

(b) Adjust the sensitivity (gain) control to provide an indication of 80% (±5%) of full screen height (FSH). Mark the peak of the indication on the screen.

(c) Position the search unit for maximum response from another SDH.

(d) Mark the peak of the indication on the screen.

(e) Position the search unit for maximum amplitude from the third SDH and mark the peak on the screen.

(f) Position the search unit for maximum amplitude from the $^3\!/_4T$ SDH after the beam has bounced from the opposite surface. The indication should appear near sweep line 10. Mark the peak on the screen for the $^3\!/_4T$ position.

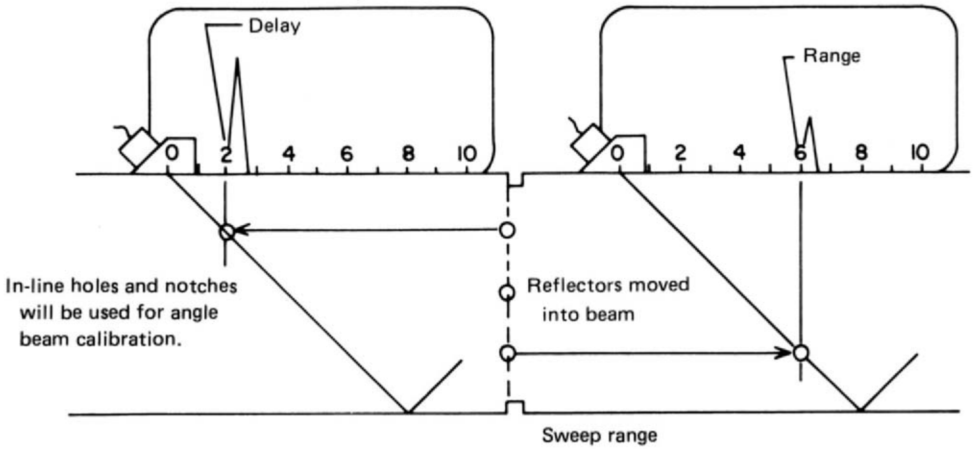
(g) Connect the screen marks for the SDHs to provide the distance–amplitude curve (DAC).

(h) For calibration correction for perpendicular reflectors at the opposite surface, refer to B-465.

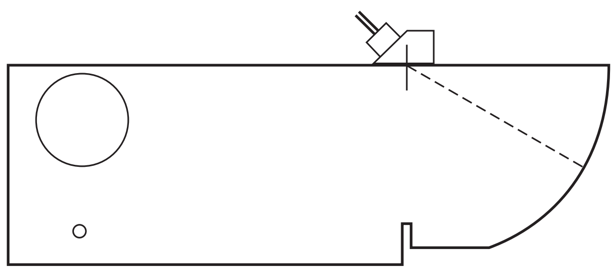
B-462.2 Calibration for Side Drilled Holes Primary Reference Level From Unclad Side (See Fig. B-462.1)

(a) From the clad side of the block, determine the dB change in amplitude between the $^3\!/_4T$ and $^5\!/_4T$ SDH positions.

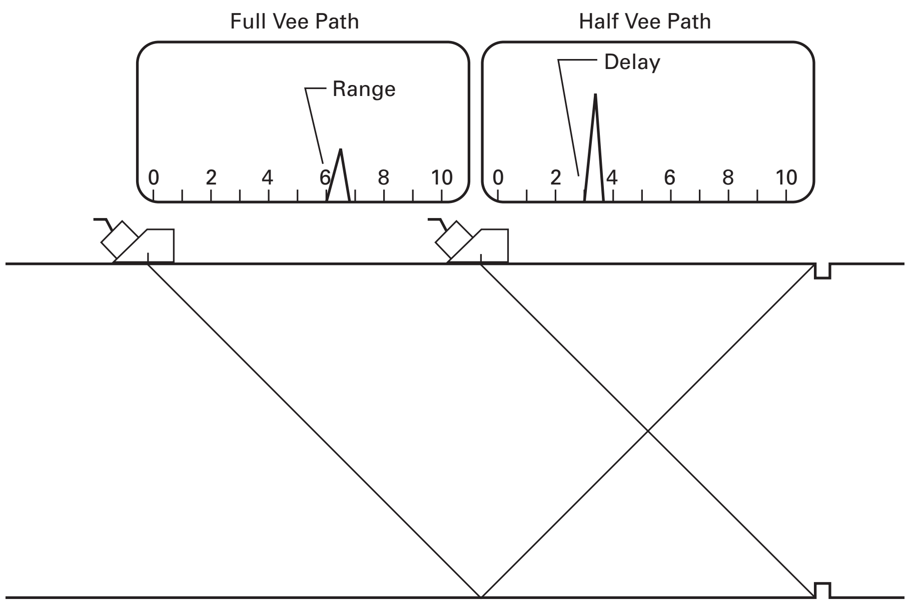
(b) From the unclad side, perform calibrations as noted in B-462.1(a) through B-462.1(e).



04 FIG. B-461.1 SWEEP RANGE (SIDE DRILLED HOLES)



04 FIG. B-461.2 SWEEP RANGE (IIW TYPE I BLOCK)



04 FIG. B-461.3 SWEEP RANGE (NOTCHES)

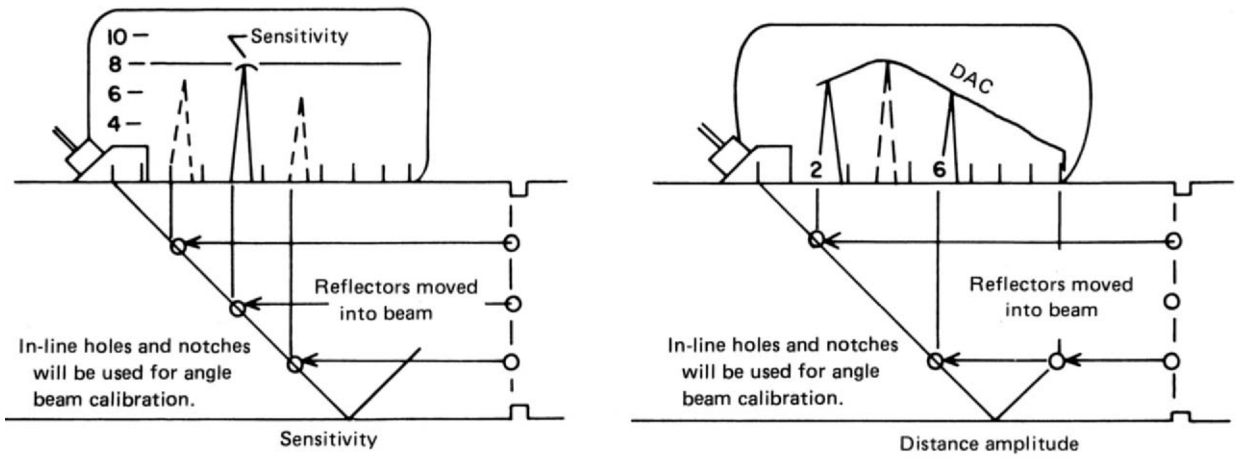


FIG. B-462.1 SENSITIVITY AND DISTANCE–AMPLITUDE CORRECTION (SIDE DRILLED HOLES) 04

(c) To determine the amplitude for the $\frac{5}{4}T$ SDH position, position the search unit for maximum amplitude from the $\frac{3}{4}T$ SDH. Decrease the signal amplitude by the number of dB determined in *(a)* above. Mark the height of this signal amplitude at sweep line 10 ($\frac{5}{4}T$ position).

(d) Connect the screen marks to provide the DAC. This will permit evaluation of indications down to the clad surface (near sweep line 8).

(e) For calibration correction for perpendicular planar reflectors near the opposite surface, refer to B-465.

B-462.3 Calibration for Piping Notches Primary Reference Level (See Fig. B-462.3)

(a) Position the search unit for maximum response from the notch which gives the highest amplitude.

(b) Adjust the sensitivity (gain) control to provide an indication of 80% (±5%) of full screen height (FSH). Mark the peak of the indication on the screen.

(c) Without changing the gain, position the search unit for maximum response from another notch.

(d) Mark the peak of the indication on the screen.

(e) Position the search unit for maximum amplitude from the remaining notch at its Half Vee, Full Vee or $\frac{3}{2}$ Vee beam paths and mark the peak on the screen.

(f) Position the search unit for maximum amplitude from any additional Vee Path(s) when used and mark the peak(s) on the screen.

(g) Connect the screen marks for the notches to provide the distance–amplitude curve (DAC).

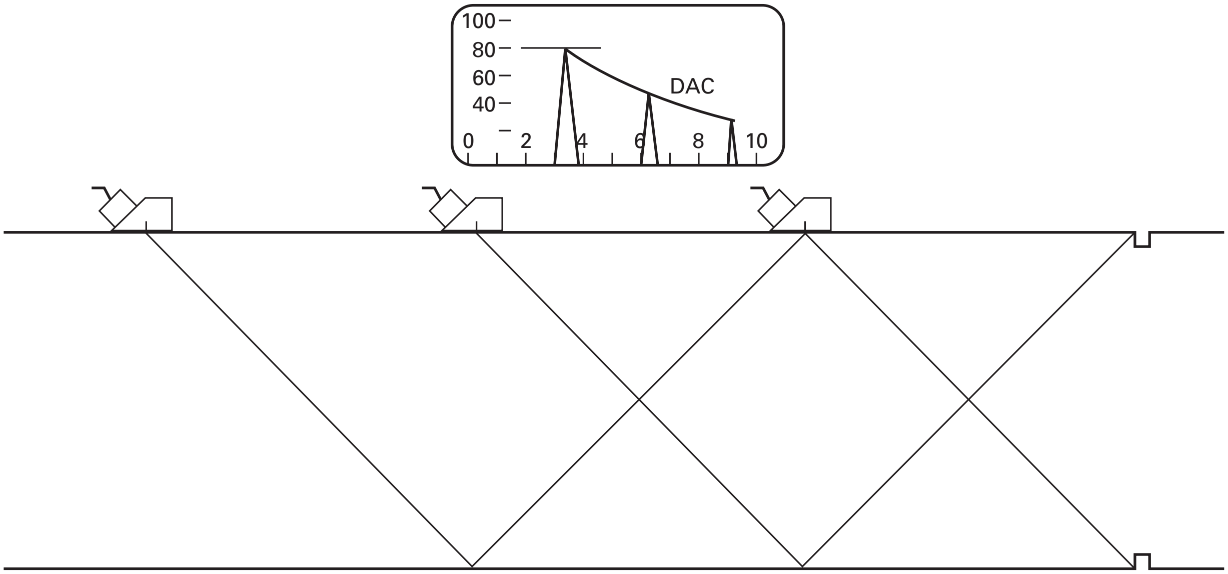
(h) These points also may be captured by the ultrasonic instrument and electronically displayed.

B-463 Distance–Amplitude Correction Inner $\frac{1}{4}$ Volume (See Appendix J, Fig. J-431 View A)

B-463.1 Number of Beam Angles. The $\frac{1}{4}$ volume angle calibration requirement may be satisfied by using one or more beams as required to calibrate on $\frac{1}{8}$ in. (3 mm) maximum diameter side drilled holes in that volume.

B-463.2 Calibration From Unclad Surface. When the examination is performed from the outside surface, calibrate on the $\frac{1}{8}$ in. (3 mm) diameter side drilled holes to provide the shape of the DAC from $\frac{1}{2}$ in. (13 mm) to $\frac{1}{4}$ T depth. Set the gain to make the indication from $\frac{1}{8}$ in. (3 mm) diameter side drilled hole at $\frac{1}{4}$ T depth the same height as the indication from the $\frac{1}{4}$ T depth hole as determined in B-462.1 or B-462.2 above. Without changing the gain, determine the screen height of the other near surface indications from the remaining $\frac{1}{8}$ in. (3 mm) diameter side drilled holes from $\frac{1}{2}$ in. (13 mm) deep to the $\frac{1}{8}$ in. (3 mm) diameter side drilled hole just short of the $\frac{1}{4}$ T depth. Connect the indication peaks to complete the near surface DAC curve. Return the gain setting to that determined in B-462.1 or B-462.2.

B-463.3 Calibration From Clad Surface. When the examination is performed from the inside surface, calibrate on the $\frac{1}{8}$ in. (3 mm) diameter side drilled holes to provide the shape of the DAC and the gain setting, as per B-463.2 above.



04 FIG. B-462.3 SENSITIVITY AND DISTANCE—AMPLITUDE CORRECTION (NOTCHES)

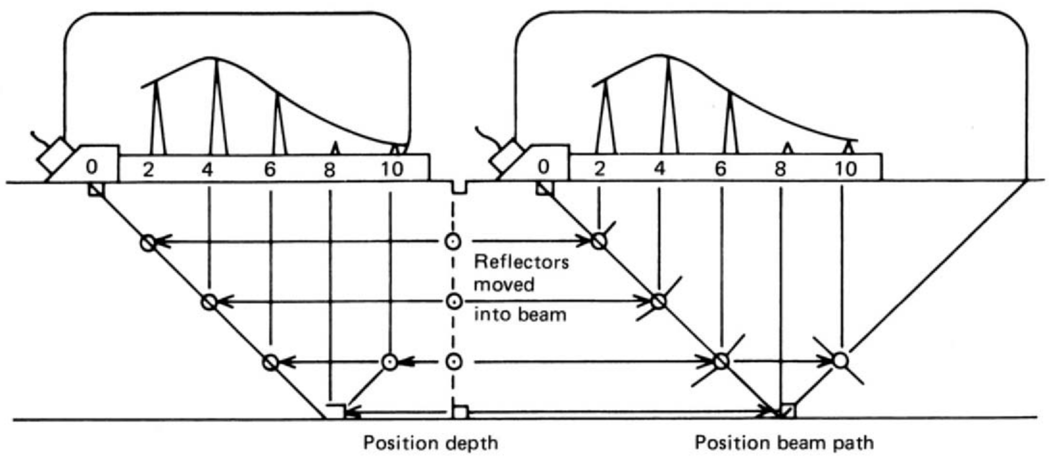


FIG. B-464 POSITION DEPTH AND BEAM PATH

B-464 Position Calibration (See Fig. B-464)

The following measurements may be made with a ruler, scale, or marked on an indexing strip.[3]

B-464.1 $^1/_4T$ SDH Indication. Position the search unit for maximum response from the $^1/_4T$ SDH. Place one end of the indexing strip against the front of the search unit, the other end extending in the direction of the beam. Mark the number 2 on the indexing strip at the scribe line which is directly above the SDH. (If the search unit covers the scribe line, the marks may be made on the side of the search unit.)

B-464.2 $^1/_2T$ and $^3/_4T$ SDH Indications. Position the search unit for maximum indications from the $^1/_2T$ and $^3/_4T$ SDHs. Keep the same end of the indexing strip against the front of the search unit. Mark the numbers 4 and 6 on the indexing strip at the scribe line, which are directly above the SDHs.

B-464.3 $^5/_4$T SDH Indication. If possible, position the search unit so that the beam bounces from the opposite surface to the $^3/_4T$ SDH. Mark the number 10 on the

[3] The balance of the calibrations in this Appendix is written based upon the use of the indexing strip. However, the procedures may be transformed for other methods of measurements at the discretion of the examiner.

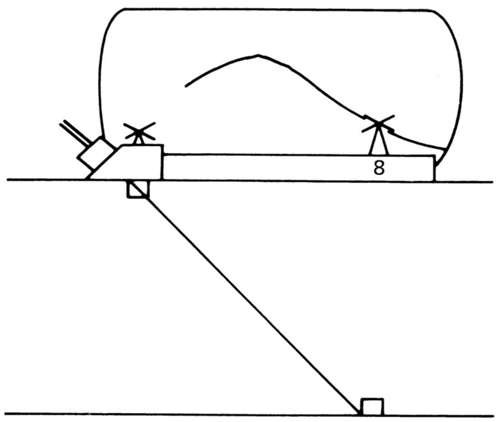


FIG. B-465 PLANAR REFLECTIONS

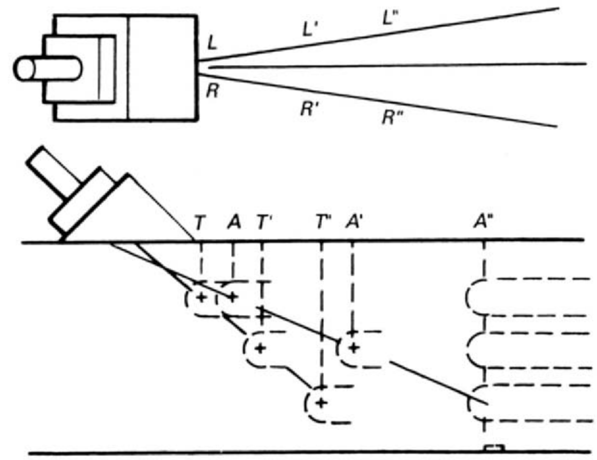


FIG. B-466 BEAM SPREAD

indexing strip at the scribe line, which is directly above the SDH.

B-464.4 Notch Indication. Position the search unit for the maximum opposite surface notch indication. Mark the number 8 on the indexing strip at the scribe line, which is directly above the notch.

B-464.5 Index Numbers. The numbers on the indexing strip indicate the position directly over the reflector in sixteenths of the V-path.

B-464.6 Depth. The depth from the examination surface to the reflector is T at 8, $\frac{3}{4}T$ at 6 and 10, $\frac{1}{2}T$ at 4, $\frac{1}{4}T$ at 2, and 0 at 0. Interpolation is possible for smaller increments of depth. The position marks on the indexing strip may be corrected for the radius of the hole if the radius is considered significant to the accuracy of reflector's location.

B-465 Calibration Correction for Planar Reflectors Perpendicular to the Examination Surface at or Near the Opposite Surface (See Fig. B-465)

A 45 deg angle beam shear wave reflects well from a corner reflector. However, mode conversion and redirection of reflection occurs to part of the beam when a 60 deg angle beam shear wave hits the same reflector. This problem also exists to a lesser degree throughout the 50 deg to 70 deg angle beam shear wave range. Therefore, a correction is required in order to be equally critical of such an imperfection regardless of the examination beam angle.

B-465.1 Notch Indication. Position the search unit for maximum amplitude from the notch on the opposite surface. Mark the peak of the indication with an "X" on the screen.

B-465.2 45 deg vs. 60 deg. The opposite surface notch may give an indication 2 to 1 above DAC for a 45 deg shear wave, but only $\frac{1}{2}$ DAC for a 60 deg shear wave. Therefore, the indications from the notch shall be considered when evaluating reflectors at the opposite surface.

B-466 Beam Spread (See Fig. B-466)

Measurements of beam spread shall be made on the hemispherical bottom of round bottom holes (RBHs). The half maximum amplitude limit of the primary lobe of the beam shall be plotted by manipulating the search unit for measurements on reflections from the RBHs as follows.

B-466.1 Toward $\frac{1}{4}T$ Hole. Set the maximum indication from the $\frac{1}{4}T$ RBH at 80% of FSH. Move search unit toward the hole until the indication equals 40% of FSH. Mark the beam center line "toward" position on the block.

B-466.2 Away From $\frac{1}{4}T$ Hole. Repeat B-466.1, except move search unit away from the hole until the indication equals 40% of FSH. Mark the beam center line "away" position on the block.

B-466.3 Right of $\frac{1}{4}T$ Hole. Reposition the search unit for the original 80% of FSH indication from the $\frac{1}{4}T$ RBH. Move the search unit to the right without pivoting the beam toward the reflector until the indication equals 40% of FSH. Mark the beam center line "right" position on the block.[4]

[4] When manually positioning the search unit, a straight edge may be used to guide the search unit while moving to the right and left to assure that axial positioning and beam alignment are maintained.

B-466.4 Left of $^1\!/_4T$ Hole. Repeat B-466.3, except move the search unit to the left without pivoting the beam toward the reflector until the indication equals 40% of FSH. Mark the beam center line "left" position on the block.[3]

B-466.5 $^1\!/_2T$ and $^3\!/_4T$ Holes. Repeat the steps in B-466.1 through B-466.4 for the $^1\!/_2T$ and $^3\!/_4T$ RBHs.

B-466.6 Record Dimensions. Record the dimensions from the "toward" to "away" positions and from the "right" to "left" positions marked on the block.

B-466.7 Perpendicular Indexing. The smallest of the three "toward" to "away" dimensions shall not be exceeded when indexing between scans perpendicular to the beam direction.

B-466.8 Parallel Indexing. The smallest of the three "right" to "left" dimensions shall not be exceeded when indexing between scans parallel to the beam direction.

B-466.9 Other Metal Paths. The projected beam spread angle determined by these measurements shall be used to determine limits as required at other metal paths.

NOTE If laminar reflectors are present in the basic calibration block, the beam spread readings may be affected; if this is the case, beam spread measurements must be based on the best available readings.

APPENDIX C — GENERAL TECHNIQUES FOR STRAIGHT BEAM CALIBRATIONS

C-410 SCOPE

This Appendix provides general techniques for straight beam calibration. Other techniques may be used.

C-460 CALIBRATION

04 **C-461 Sweep Range Calibration[5] (See Fig. C-461)**

C-461.1 Delay Control Adjustment. Position the search unit for the maximum first indication from the $^1\!/_4T$ SDH. Adjust the left edge of this indication to line 2 on the screen with the delay control.

C-461.2 Range Control Adjustment. Position the search unit for the maximum indication from $^3\!/_4T$ SDH. Adjust the left edge of this indication to line 6 on the screen with the range control.

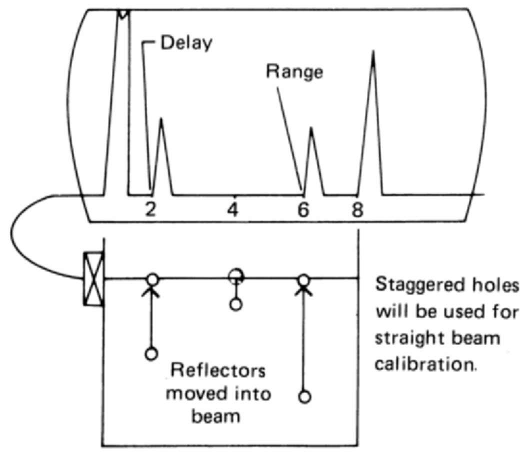


FIG. C-461 SWEEP RANGE

C-461.3 Repeat Adjustments. Repeat the delay and range control adjustments until the $^1\!/_4T$ and $^3\!/_4T$ SDH indications start at sweep lines 2 and 6.

C-461.4 Back Surface Indication. The back surface indication will appear near sweep line 8.

C-461.5 Sweep Readings. Two divisions on the sweep equal $^1\!/_4T$.

C-462 Distance–Amplitude Correction (See Fig. C-462)

The following is used for calibration from either the clad side or the unclad side:

(a) Position the search unit for the maximum indication from the SDH, which gives the highest indication.

(b) Adjust the sensitivity (gain) control to provide an 80% (±5%) of FSH indication. This is the primary reference level. Mark the peak of this indication on the screen.

(c) Position the search unit for maximum indication from another SDH.

(d) Mark the peak of the indication on the screen.

(e) Position the search unit for maximum indication from the third SDH and mark the peak on the screen.

(f) Connect the screen marks for the SDHs and extend through the thickness to provide the distance–amplitude curve.

APPENDIX D — DATA RECORD EXAMPLE FOR A PLANAR REFLECTOR

D-10 SCOPE

This Appendix provides an example of the data required to dimension a 120% DAC reflector found when

[5] Calibration by beam path measurement may be used by range control positioning by the block back reflection to the sweep division number (or multiple) equal to the measured thickness. The $^1\!/_4T$ SDH indication must be delay control positioned to $^1\!/_4$ of the sweep division number.

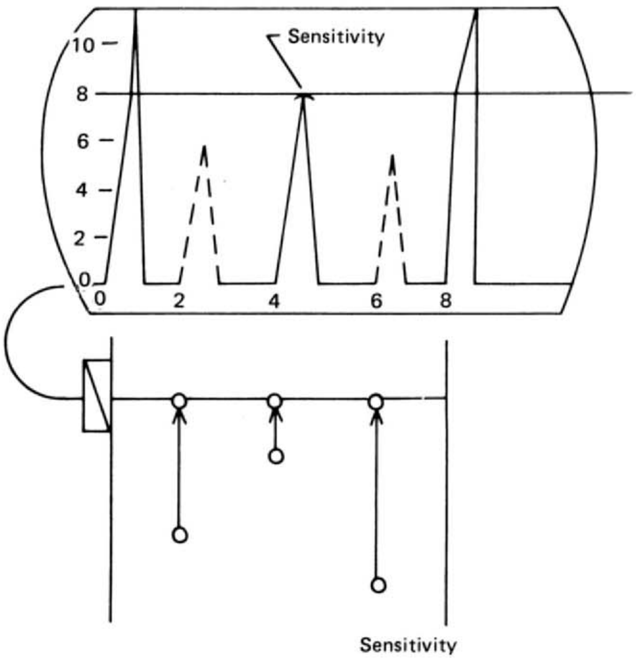


FIG. C-462 SENSITIVITY AND DISTANCE–AMPLITUDE CORRECTION

scanning perpendicular to a weld. Figure D-10 is an illustration of the maximum amplitude scan and tabulation of that data with additional scan data that might be taken on the reflector.

D-90 DOCUMENTATION

Position the search unit to give the maximum amplitude from the reflector.

(a) Read and record the *maximum* amplitude in *percent of DAC*.

(b) Read and record the *sweep reading* to reflector (at the left side of the indication on the sweep).

(c) Read and record the *search unit position* with respect to the reference line.

(d) Read and record the *location* of the indication at the beam center line intersection with respect to the reference line from the weld layout reference points.

Move the search unit toward the reflector until the amplitude falls to 60% DAC (half maximum amplitude).

(e) Read and record the *minimum sweep reading*.

(f) Read and record the *minimum search unit position.*

Move the search unit away from the reflector past the maximum amplitude position until the amplitude falls to 60% DAC (half maximum amplitude).

(g) Read and record the *maximum sweep reading*.

(h) Read and record the *maximum search unit position*.

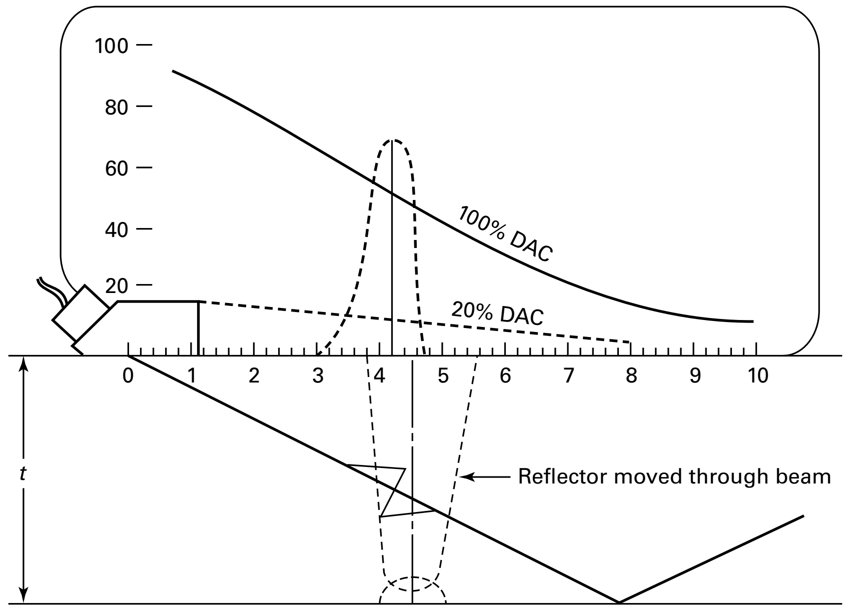
Data points *(a)* through *(h)* above shall be read and recorded during the examination. Computations for *(i)* depth, *(j)* distance from surface, and length of the reflector shall be made prior to completion of the examination report.

(i) Subtract the minimum sweep reading from the maximum sweep reading and divide by the sweep reading for one wall thickness. Multiply by 100 and record as *depth* in % of t (t = weld thickness)

(j) Subtract the maximum sweep reading from the sweep reading for one wall thickness or use the minimum sweep reading, whichever gives the smaller number. Divide the number by the sweep reading for one wall thickness. Multiply by 100 and record as *distance* from surface in % of t and length of reflection.

Successively read and record data along scan paths at increments no greater than nine-tenths of the transducer (measured parallel to the scan increment change) at 60% DAC (half maximum amplitude). Continue scans until the maximum amplitude found at the end points of the reflector is 20% DAC.

The length of the reflector is the distance between the end points measured at the reflector. The length shall be divided by t and multiplied by 100 to give length in % of t. The data tabulated in Fig. D-10 is carried out on either side of the maximum indicated signal until the 20% DAC point is reached on both ends of the indication. It



GENERAL NOTE: As the reflector is moved through the beam, the flaw indication reaches 20% DAC at 4.4 sweep divisions, increases in amplitude to 120% DAC at 4.0 sweep divisions, and falls to 20% DAC at 3.6 sweep divisions. The 20% DAC change in sweep reading, divided by the thickness sweep reading, times 100 represents the reflector depth (that is, 10% of t) or the 2 (a) dimension of the subsurface flaw indication.

FIG. D-10 REFLECTOR READING

DATA TABULATION FOR FIG. D-10

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	
				20% DAC				% of t		
				Minimum		Maximum				
Maximum % DAC	Sweep Reading	Search Unit Position, mm	Location, mm	Sweep Reading	Position	Sweep Reading	Position	Depth	Distance From Surface	Computation or Remarks
120	4.0	4.6	23	3.6	4.2	4.4	5.2	10	45	$\frac{4.4-3.6}{8.0}$
80	4.0	4.6	22.1	3.8	4.3	4.2	4.8	5	47.5	$\frac{4.2-3.8}{8.0}$
20	4.0	4.6	21.7	. . .	. . .	. . .	. . .	0	50	. . .
90	4.1	4.7	23.9	3.7	4.3	4.3	5.2	7.5	46	$\frac{4.3-3.7}{8.0}$
70	4.1	4.7	24.8	3.9	4.4	4.3	5.2	5	46	$\frac{4.3-3.9}{8.0}$
20	4.2	4.6	25	. . .	. . .	. . .	. . .	0	50	. . .
										depth: 10% of t
										length: 3.3 mm

GENERAL NOTE: Column letters refer to D-90 subparagraphs. The units of measure are arbitrary but must be consistent.

is only necessary to record the data to obtain the length (3.3) and depth, (10% of *t*). The first, third, and sixth lines of the data tabulation are all that are necessary to define the through wall and length of the indication in this example.

APPENDIX E — COMPUTERIZED IMAGING TECHNIQUES

E-410 SCOPE

This Appendix provides requirements for computer imaging techniques.

E-420 GENERAL

Computerized imaging techniques (CITs) shall satisfy all of the basic instrument requirements described in T-431 and T-461. The search units used for CIT applications shall be characterized as specified in B-466. CITs shall be qualified in accordance with the requirements for flaw detection and/or sizing that are specified in the referencing Code Section.

The written procedure for CIT applications shall identify the specific test frequency and bandwidth to be utilized. In addition, such procedures shall define the signal processing techniques, shall include explicit guidelines for image interpretation, and shall identify the software code/program version to be used. This information shall also be included in the examination report. Each examination report shall document the specific scanning and imaging processes that were used so that these functions may be accurately repeated at a later time if necessary.

The computerized imaging process shall include a feature that generates a dimensional scale (in either two or three dimensions, as appropriate) to assist the operator in relating the imaged features to the actual, relevant dimensions of the component being examined. In addition, automated scaling factor indicators shall be integrally included to relate colors and/or image intensity to the relevant variable (i.e., signal amplitude, attenuation, etc.).

E-460 CALIBRATION

Calibration of computer imaging systems shall be conducted in such a manner that the gain levels are optimized for data acquisition and imaging purposes. The traditional DAC-based calibration process may also be required to establish specific scanning and/or flaw detection sensitivity levels.

For those CITs that employ signal processing to achieve image enhancement (SAFT-UT, L-SAFT, and broadband holography), at least one special lateral resolution and depth discrimination block for each specified examination shall be used in addition to the applicable calibration block required by Article 4. These blocks shall comply with J-431.

The block described in Fig. E-460.1 provides an effective resolution range for 45 deg and 60 deg search units and metal paths up to about 4 in. (100 mm). This is adequate for piping and similar components, but longer path lengths are required for reactor pressure vessels. A thicker block with the same sizes of flat-bottom holes, spacings, depths, and tolerances is required for metal paths greater than 4 in. (100 mm), and a 4 in. (100 mm) minimum distance between the edge of the holes and the edge of the block is required. These blocks provide a means for determining lateral resolution and depth discrimination of an ultrasonic imaging system.

Lateral resolution is defined as the minimum spacing between holes that can be resolved by the system. The holes are spaced such that the maximum separation between adjacent edges of successive holes is 1.000 in. (25.40 mm). The spacing progressively decreases by a factor of two between successive pairs of holes, and the minimum spacing is 0.015 in. (0.38 mm). Depth discrimination is demonstrated by observing the displayed metal paths (or the depths) of the various holes. Because the hole faces are not parallel to the scanning surface, each hole displays a range [about 0.1 in. (2.5 mm)] of metal paths. The "A" row has the shortest average metal path, the "C" row has the longest average metal path, and the "B" holes vary in average metal path.

Additional blocks are required to verify lateral resolution and depth discrimination when 0 deg longitudinal-wave examination is performed. Metal path lengths of 2 in. and 8 in. (50 mm and 200 mm), as appropriate, shall be provided as shown in Fig. E-460.2 for section thicknesses to 4 in. (100 mm), and a similar block with 8 in. (200 mm) metal paths is needed for section thicknesses over 4 in. (100 mm).

E-470 EXAMINATION

E-471 Synthetic Aperture Focusing Technique for Ultrasonic Testing (SAFT-UT)

The Synthetic Aperture Focusing Technique (SAFT) refers to a process in which the focal properties of a large-aperture focused search unit are synthetically generated from data collected while scanning over a large area using a small search unit with a divergent sound beam. The processing required to focus this collection of data

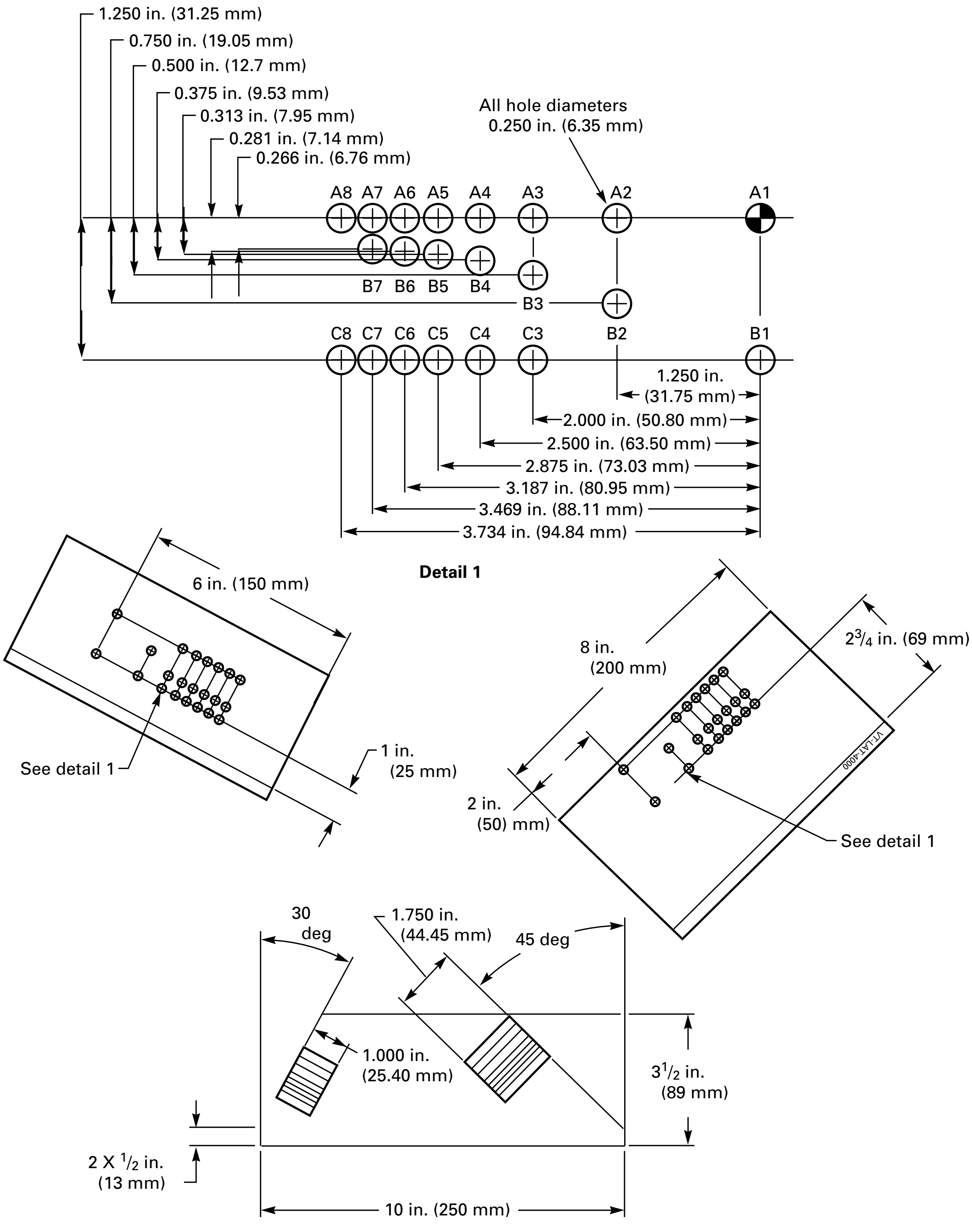


FIG. E-460.1 LATERAL RESOLUTION AND DEPTH DISCRIMINATION BLOCK FOR 45 deg AND 60 deg APPLICATIONS
(Not to Scale)

NOTES TO FIG. E-460.1:

GENERAL NOTES:

(a) View rotated for clarity.

(b) Insonification surface is shown at bottom.

(c) Tolerances: decimals: 0.XX = ± 0.03; 0.XXX = ± 0.005; angular: ± 1 deg.

(d) Hole identification:

   (1) Engrave or stamp as shown with the characters upright when the large face of the block is up.

   (2) Nominal character height is 0.25 in. (6 mm)

   (3) Start numbering at the widest-spaced side.

   (4) Label row of eight holes A1–A8.

   (5) Label diagonal set of seven holes B1–B7.

   (6) Label remaining six holes C3–C8.

(e) Hole spacing: minimum 0.010 in. (0.25 mm) material between hole edges.

(f) Hole depths: 30 deg. face: 1.000 in. (25.40 mm); 45 deg. face: 1.750 in. (44.45 mm)

(g) Drawing presentation: holes are shown from drilled face of block.

(h) Hole ends to be flat and parallel to drilled surface within 0.001 in. (0.03 mm) across face of hole.

(i) Maximum radius between side and face of hole is 0.005 in. (0.13 mm)

is a three-dimensional process called beam-forming, coherent summation, or synthetic aperture processing. The SAFT-UT process offers an inherent advantage over physical focusing processes because the resulting image is a full-volume, focused characterization of the material volume being examined. Traditional physical focusing processes provide focused data over only the depth of the focus zone of the transducer.

For the typical pulse-echo data collection scheme used with SAFT-UT, a focused search unit is positioned with the focal point located at the surface of the material under examination. This configuration produces a divergent ultrasonic beam in the material. Alternatively, a small-diameter contact search unit may be used to generate a divergent beam. As the search unit is scanned over the surface of the material, the A-scan record (RF waveform) is digitized for each position of the search unit. Any reflector present produces a collection of echoes in the A-scan records. For an elementary single-point reflector, the collection of echoes will form a hyperbolic surface within the data-set volume. The shape of the hyperboloid is determined by the depth of the reflector and the velocity of sound in the material. The relationship between echo location in the series of A-scans and the actual location of reflectors within the material makes it possible to reconstruct a high-resolution image that has a high signal-to-noise ratio. Two separate SAFT-UT configurations are possible: (a) the single-transducer, pulse-echo configuration; and (b) the dual-transducer, tandem configuration (TSAFT).

In general, the detected flaws may be categorized as volumetric, planar, or cracks. Flaw sizing is normally performed by measuring the vertical extent (cracks) or the cross-sectional distance (volumetric/planar) at the –6 dB levels once the flaw has been isolated and the image normalized to the maximum value of the flaw. Multiple images are often required to adequately categorize (classify) the flaw and to characterize the actual flaw shape and size. Tandem sizing and analysis uses similar techniques to pulse-echo, but provides images that may be easier to interpret.

The location of indications within the image space is influenced by material thickness, velocity, and refracted angle of the UT beam. The SAFT algorithm assumes isotropic and homogeneous material; i.e., the SAFT algorithm requires (for optimum performance) that the acoustic velocity be accurately known and constant throughout the material volume.

Lateral resolution is the ability of the SAFT-UT system to distinguish between two objects in an x-y plane that is perpendicular to the axis of the sound beam. Lateral resolution is measured by determining the minimum spacing between pairs of holes that are clearly separated in the image. A pair of holes is considered separated if the signal amplitude in the image decreases by at least 6 dB between the peak signals of two holes.

Depth resolution is the ability of a SAFT-UT system to distinguish between the depth of two holes whose axes are parallel to the major axis of the sound beam. Depth resolution is measured by determining the minimum difference in depth between two holes.

The lateral resolution for a SAFT-UT system is typically 1.5 wavelengths (or better) for examination of wrought ferritic components, and 2.0 wavelengths (or better) for examination of wrought stainless steel components. The depth resolution for these same materials will typically be 0.25 wavelengths (or better).

E-472 Line-Synthetic Aperture Focusing Technique (L-SAFT)

The Line Synthetic Aperture Focusing Technique (L-SAFT) is useful for analyzing detected indications. L-SAFT is a two-dimensional process in which the focal properties of a large-aperture, linearly focused search unit

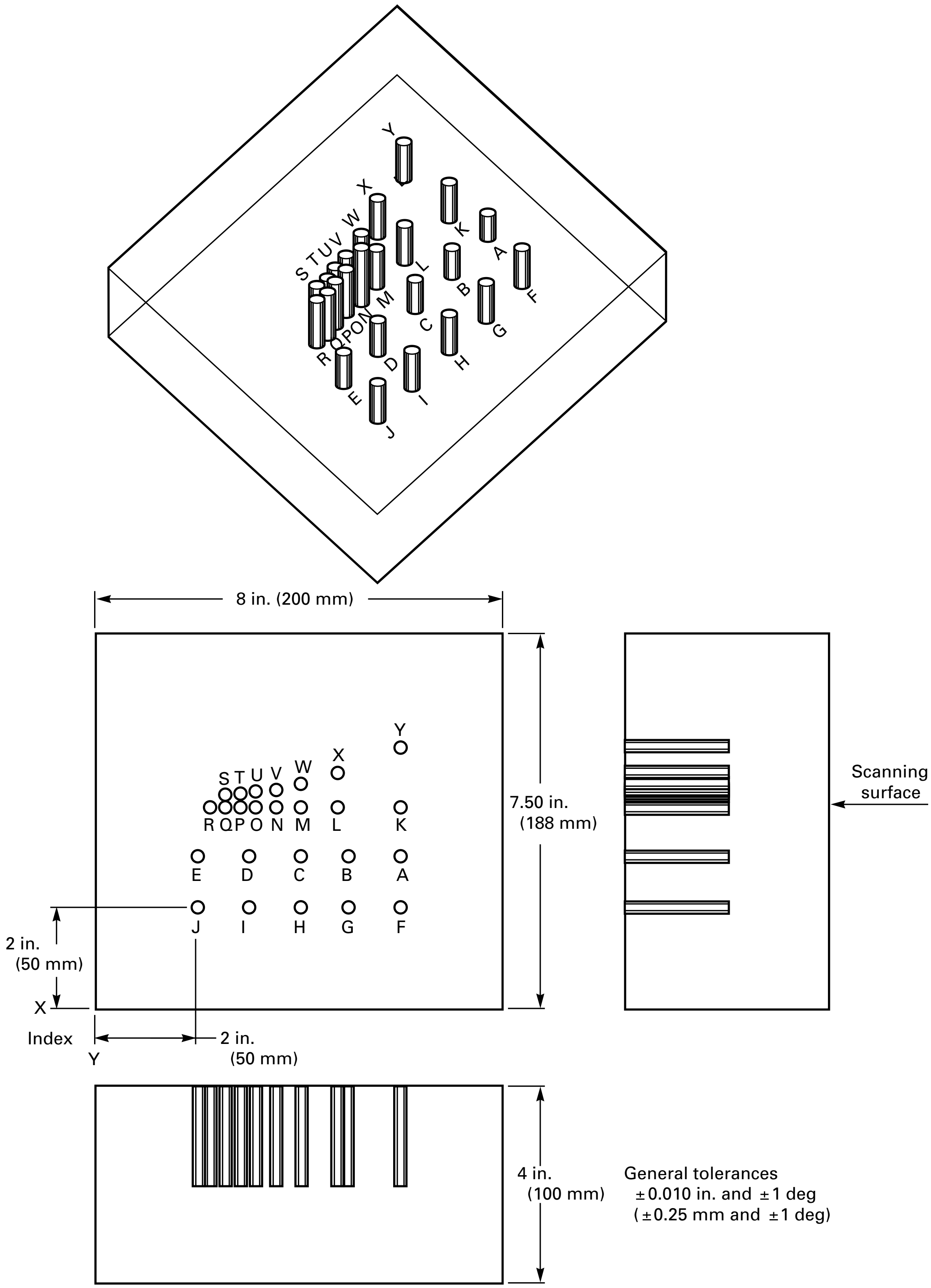


FIG. E-460.2 LATERAL AND DEPTH RESOLUTION BLOCK FOR 0 deg APPLICATIONS are synthetically generated from data collected over a scan line using a small search unit with a diverging sound beam. The processing required to impose a focusing effect of the acquired data is also called synthetic aperture processing. The L-SAFT system can be operated like conventional UT equipment for data recording. It will function with either single- or dual-element transducers.

Analysis measurements, in general, are performed to determine flaw size, volume, location, and configuration. To decide if the flaw is a crack or volumetric, the crack-tip-diffraction response offers one criterion, and the superimposed image of two measurements made using different directions of incidence offers another.

All constraints for SAFT-UT apply to L-SAFT and vice versa. The difference between L-SAFT and SAFT-UT is that SAFT-UT provides a higher resolution image than can be obtained with L-SAFT.

E-473 Broadband Holography Technique

The holography technique produces an object image by calculation based on data from a diffraction pattern. If the result is a two-dimensional image and the data are acquired along one scan, the process is called "line-holography." If the result is a two-dimensional image based upon an area scanned, then it is called "holography." For the special case of applying holography principles to ultrasonic testing, the image of flaws (in more than one dimension) can be obtained by recording the amplitude, phase, and time-of-flight data from the scanned volume. The holography process offers a unique feature because the resulting image is a one- or two-dimensional characterization of the material.

This technique provides good resolution in the axial direction by using broadband search units. These search units transmit a very short pulse, and therefore the axial resolution is improved. The maximum bandwidth may be 20 MHz without using filtering, and up to 8 MHz using an integrated filter.

Analysis measurements, in general, are performed to obtain information on size, volume, location, and configuration of detected flaws. The results of the holography-measurements per scan line show a two-dimensional image of the flaw by color-coded display. The size of flaws can be determined by using the 6 dB drop in the color code. More information on the flaw dimensions is obtained by scans in different directions (i.e., parallel, perpendicular) at different angles of incidence. To decide if the flaw is a crack or a volumetric flaw, the crack tip technique offers one criterion and comparison of two measurements from different directions of incidence offers another. Measurement results obtained by imaging techniques always require specific interpretation. Small variations in material thickness, sound velocity, or refracted beam angle may influence the reconstruction results. The holography processing calculations also assume that the velocity is accurately known and constant throughout the material.

E-474 UT-Phased Array Technique

The UT-Phased Array Technique is a process wherein UT data are generated by controlled incremental variation of the ultrasonic beam angle in the azimuthal or lateral direction while scanning the object under examination. This process offers an advantage over processes using conventional search units with fixed beam angles because it acquires considerably more information about the reflecting object by using more aspect angles in direct impingement.

Each phased array search unit consists of a series of individually wired transducer elements on a wedge that are activated separately using a pre-selectable time delay pattern. With a linear delay time between the transmitter pulses, an inclined sound field is generated. Varying the angle of refraction requires a variation of the linear distribution of the delay time. Depending on the search unit design, it is possible to electronically vary either the angle of incidence or the lateral/skew angle. In the receiving mode, acoustic energy is received by the elements and the signals undergo a summation process utilizing the same time delay pattern as was used during transmission.

Flaw sizing is normally performed by measuring the vertical extent (in the case of cracks) or the cross-sectional distance (in the case of volumetric/planar flaws) at the 6 dB levels once the flaw has been isolated and the image normalized. Tandem sizing and analysis uses techniques similar to pulse-echo but provides images that are easier to interpret since specular reflection is used for defects oriented perpendicular to the surface. For cracks and planar defects, the result should be verified using crack-tip-diffraction signals from the upper and lower ends of the flaw, since the phased array approach with tomographic reconstruction is most sensitive to flaw tip indications and is able to give a clear reconstruction image of these refraction phenomena. As with other techniques, the phased array process assumes isotropic and homogeneous material whose acoustic velocity is constant and accurately known.

E-475 UT-Amplitude Time-Of-Flight Locus-Curve Analysis Technique

The UT-amplitude time-of-flight locus-curve analysis technique utilizes multiple search units in pulse-echo, transmitter-receiver, or tandem configuration. Individually selectable parameters control the compression of the

A-scan information using a pattern-recognition algorithm, so that only the relevant A-scan amplitudes are stored and further processed.

The parameter values in the A-scan compression algorithm determine how many pre-cursing and how many post-cursing half-wave peaks must be smaller than a specific amplitude, so that this largest amplitude is identified as as relevant signal. These raw data can be displayed in B-, C-, and D-scan (side, top, and end view) presentations, with selectable color-code increments for amplitude and fast zoom capabilities. This operating mode is most suitable for detection purposes. For discrimination, a two-dimensional spatial-filtering algorithm is applied to search for correlation of the time-of-flight raw data with reflector-typical time-of-flight trajectories.

Tandem sizing and analysis uses techniques similar to pulse-echo but provides images that may be easier to interpret since the specular reflections from flaws oriented perpendicular to the surface are used. For cracks and planar flaws, the results should be verified with crack-tip-diffraction signals from the upper and lower end of the flaw since the acoustic parameters are very sensitive to flaw tip indications and a clear reconstruction image of these refraction phenomena is possible with this technique.

The location of indications within the image space is influenced by material thickness and actual sound velocity (i.e., isotropic and homogeneous material is assumed). However, deteriorating influences from anisotropic material (such as cladding) can be reduced by appropriate selection of the search unit parameters.

E-476 Automated Data Acquisition and Imaging Technique

Automated data acquisition and imaging is a multichannel technique that may be used for acquisition and analysis of UT data for both contact and immersion applications. This technique allows interfacing between the calibration, acquisition, and analysis modes; and for assignment of specific examination configurations. This technique utilizes a real-time display for monitoring the quality of data being collected, and provides for display of specific amplitude ranges and the capability to analyze peak data through target motion filtering. A cursor function allows scanning the RF data one waveform at a time to aid in crack sizing using tip-diffraction. For both peak and RF data, the technique can collect, display, and analyze data for scanning in either the axial or circumferential directions.

This technique facilitates detection and sizing of both volumetric and planar flaws. For sizing volumetric flaws, amplitude-based methods may be used; and for sizing planar flaws, the crack-tip-diffraction method may be used. An overlay feature allows the analyst to generate a composite image using several sets of ultrasonic data. All data displayed in the analyze mode may be displayed with respect to the physical coordinates of the component.

APPENDIX F — NOZZLE EXAMINATION

F-410 SCOPE

This Appendix provides requirements for equipment and procedure qualification and/or requalification of manual or automated ultrasonic examinations of the nozzle inside radius. The Manufacturer, examination agency, or other user of this Appendix shall be responsible for qualifying the technique, equipment, and written procedure(s) in accordance with this Appendix, and/or as required by the referencing Code Section.

The equipment and procedure performance demonstration requirements specified in this Appendix may be satisified simultaneously or in conjunction with other qualification(s)/verification and/or requalification demonstration in accordance with this Appendix.

F-420 GENERAL

The equipment and procedure shall be considered qualified for detection of flaws upon successfully completing the performance demonstration specified in F-423, Procedure Qualification.

F-421 Personnel Requirements

Personnel shall be qualified and certified in accordance with the requirements of the referencing Code.

F-422 Written Procedure Requirements

F-422.1 Written Procedure. Ultrasonic nozzle inside radius examination shall be performed in accordance with a written procedure. The procedure shall be qualified to the extent specified in this Subsection. The examination procedure shall contain a statement of scope that specifically defines the limits of procedure applicability. The examination procedure shall specify a single value or a range of values for the listed essential variables. The examination procedure shall specify, as a minimum, the following essential variables:

(a) instrument or system description including Manufacturer and model of pulser, receiver, and amplifier;

(b) ultrasonic technique;

(c) search units, including:

(1) number, size, shape, and configuration of active elements

(2) center frequency and either bandwidth or waveform for each active element

(3) mode of sound propagation (e.g., longitudinal, shear, etc.)

(d) scanning equipment (when applicable);

(1) type; manipulator(s), bridges, semi-automatic devices

(2) indexing controls, scanners

(3) number of ultrasonic connectors; and length of cable

(e) scanning technique(s), including:

(1) scan pattern (modeling) and primary beam direction

(2) maximum scan speed

(3) minimum and maximum pulse repetition rate

(4) minimum sampling rate (automatic recording systems)

(5) extent of scanning and action to be taken for geometrical restrictions.

(f) methods of calibration for detection. Calibration methods include all those actions required to assure that the accuracy of the signal amplitude and sweep locations of the examination system (whether displayed, recorded, or automatically processed) are repeatable from examination to examination. Any method of achieving the system calibration shall be recorded. A description of the calibrated sensitivity shall be included in the procedure.

(g) minimum inspection/calibration data to be recorded, and medium (i.e., calibration sheet and/or magnetic disk)

(h) method of data recording, and recording equipment (strip chart, analog tape, digitizing);

(i) method and criteria for the discrimination of indications (e.g., geometric versus flaw), and for depth of flaws; surface condition requirements, scanner's mounting requirements;

(j) surface condition requirements, scanner's mounting requirements;

(k) identification of qualification specimen, overall configuration; material, product form, shell thickness, bore barrel thickness and diameter(s);

(l) essential variable range(s).

F-422.2 Essential Variable Requalification. When the essential variables exceed the tolerances specified within the qualification procedure, the qualification test shall be repeated in accordance with F-423.

F-423 Procedure Qualification

The procedure shall be considered qualified for detection when all qualifying reflectors are located within 1.5 in. (38 mm) of their true position (x and y). Sizing qualification, when required, shall be in accordance with referencing Code requirements.

F-424 Procedure Requalification

The procedure shall require requalification when an essential variable of the qualified procedure has been changed and/or exceeded.

F-430 EQUIPMENT

F-431 Instrument Requirements

(a) A pulse-echo type of ultrasonic instrument and/or examination system shall be used. The instrument/system shall be equipped with a stepped gain control calibrated in units of 2.0 dB or less.

(b) The system shall exhibit the following:

(1) Center Frequency:

(a) For examination systems with bandwidths less than 30%, the center frequency shall not change more than ±5%.

(b) For examination systems with bandwidths 30% or greater, the system center frequency shall not vary more than ±10%.

(2) Bandwidth:

(a) The examination bandwidth shall not change more than ±10%.

NOTE: Bandwidth is measured at the −6 dB points.

F-432 Qualification Specimen

(a) The qualification process shall be conducted using a full-scale or partial section nozzle (mockup), which is dimensionally sufficient to contain the maximum beam path, examination volume, and the necessary reflectors that are to be detected.

(b) If the examining beams pass only through the nozzle forging, the mockup may be a nozzle forging, or segment of a forging, which may be fixed in a structure to simulate adjacent vessel surfaces as required for examination alignment. If the examining beams pass through the nozzle to shell weld, the mockup shall contain nozzle weld and shell components of sufficient size to permit qualification.

(c) The qualification specimen shall meet the requirements of the vessel specification(s) with respect to:

(1) the basic calibration block material requirements (J-431).

(2) *Curvature.* The examination and reflection surface curvatures on the nozzle mockup shall be similar to those curvatures on the nozzle in the vessel. The size

ranges in F-432(c)(6) below shall be considered to be similar curvatures.

(3) welding process (when applicable).

(4) Cladding. If the inside surface of the nozzle in the vessel is clad, the inside surface of the nozzle mockup shall be clad using the same welding method (i.e., roll bonded, manual weld deposited, automatic wire deposited, or automatic strip deposited). In the event the cladding method is not known or is impractical to apply on the mockup, cladding may be applied using the manual weld deposit method. If the inside surface of the nozzle to be examined is not clad, the inside surface of the nozzle mockup may be clad, as long as the reflectors are contained within the base metal interface to the required volume.

NOTE: Vessel cladding direction, where known, should be simulated.

(5) Thickness. Calibration specimen and/or mockup shall equal or exceed the maximum component thickness in the region to be qualified.

(6) Ratio limits for curved surfaces. Mockup diameter range in the area of qualification shall be determined by Fig. J-431. For diameters greater than 4 in. (100 mm), mockup curvature shall be in the range of 0.9 to 1.5 times the nozzle under examination.

F-432.1 Qualification Specimen Reflectors. The qualification specimen shall contain a minimum of three reflectors within the examination volume for detection qualification. Optionally, induced or embedded cracks may be used in lieu of machined reflectors. Additionally these reflectors may be employed for demonstration of the procedure's sizing capabilities, when required by the referencing Code.

F-432.2 Reflectors. The qualification reflectors shall be distributed within the examination volume and shall meet the following requirements.

(a) Reflectors shall be distributed radially in two zones with at least one reflector in each zone. Zone 1 ranges between 0 deg and 180 deg (±45 deg), Zone 2 is the remaining two quadrants, centered as the nozzle's horizontal axis.

(b) Machined reflectors shall be placed within the nozzle inner radii examination volume and specified to be oriented parallel to the axial radial plane of the nozzle within a manufacturing tolerance of ±2 deg.

(c) Machined reflectors shall be specified to be oriented perpendicular to the ID surface of the nozzle within a manufacturing tolerance of ±2 deg.

(d) Reflectors shall have a maximum length of 1.0 in. (25 mm), and a nominal width of $^1/_{16}$ in. (1.5 mm) (±10%).

(e) Machined reflectors shall have depth ranges, measured from the inside surface of the base material.

(1) Reflector No. 1 — 0.201–0.350 (5 mm — 9 mm)

(2) Reflector No. 2 — 0.351–0.550 (9 mm — 14 mm)

(3) Reflector No. 3 — 0.551–0.750 (14 mm — 19 mm)

(f) Induced crack reflectors are permitted, provided they are located in accordance with F-432.2(a) and (b) and their depths are within the range of reflectors in F-432.2(e).

F-460 CALIBRATION

Calibration is defined as all of the processes necessary to configure the examination system prior to the examination that must be performed in order to satisfactorily qualify the equipment and procedure. Instrument calibration settings used during procedure qualification shall be repeated during subsequent field exams. Calibration simulators may be employed for field instrument calibration provided they can be correlated with the original calibration on the basic calibration block (if used) during the original calibration.

F-461 Calibration Checks

If used, subsequent calibration checks may be performed on the qualification specimen, mockup, and/or simulator calibration block(s).

APPENDIX G — ALTERNATE CALIBRATION BLOCK CONFIGURATION

G-410 SCOPE

This Appendix provides guidance for using flat basic calibration blocks of various thicknesses to calibrate the examination of convex surface materials greater than 20 in. (500 mm) in diameter. An adjustment of receiver gain may be required when flat calibration blocks are used. The gain corrections apply to the far field portion of the sound beam.

G-460 CALIBRATION

G-461 Determination of Gain Correction

To determine the required increase in gain, the ratio of the material radius, R, to the critical radius of the transducer, R_c, must be evaluated as follows.

(a) When the ratio of R/R_c, the radius of curvature of the material R divided by the critical radius of the transducer R_c from Table G-461 and Fig. G-461(a), is equal to or greater than 1.0, no gain correction is required.

TABLE G-461
TRANSDUCER FACTOR F_1 FOR VARIOUS ULTRASONIC TRANSDUCER DIAMETERS AND FREQUENCIES

U.S. Customary Units

Frequency MHz	Transducer Diameters, in. 0.25	0.5	0.75	1.0	1.125
	F_1, in.				
1.0	2.58	10.3	23.2	41.3	52.3
2.25	5.81	23.2	52.2	92.9	118
5.0	12.9	51.2	116	207	262
10.0	25.8	103	232	413	523

SI Units

Frequency MHz	Transducer Diameters, mm 6.4	13	19	25	29
	F_1, mm				
1.0	65.5	262	590	1 049	1 328
2.25	148	590	1 327	2 360	2 987
5.0	328	1 314	2 958	5 258	6 655
10.0	655	2 622	5 900	10 490	13 276

(b) When the ratio of R/R_c is less than 1.0, the gain correction must be obtained from Fig. G-461(b).

(c) Example. Material with a 10 in. (250 mm) radius (R) will be examined with a 1 in. (25 mm) diameter 2.25 MHz boron carbide faced search unit using glycerine as a couplant.

(1) Determine the appropriate transducer factor, F_1 from Table G-461; $F_1 = 92.9$.

(2) Determine the R_c from Fig. G-461(a); $R_c = 100$ in. (2 500 mm).

(3) Calculate the R/R_c ratio; 10 in./100 in. = 0.1 (250 mm/2 500 mm = 0.1).

(4) Using Fig. G-461(b), obtain the gain increase required; 12 dB.

This gain increase calibrates the examination on the curved surface after establishing calibration sensitivity on a flat calibration block.

APPENDIX H — RECORDING ANGLE BEAM EXAMINATION DATA FOR PLANAR REFLECTORS

H-410 SCOPE

This Appendix describes a method for recording angle beam examination data for planar reflectors when amplitude based dimensioning is to be performed.

H-490 RECORDS/DOCUMENTATION

(a) Record all reflectors that produce a response equal to or greater than 20% of the distance-amplitude correction (DAC). However, the clad interface metallurgical reflectors and back wall reflections need not be recorded. Record surface reflectors that produce a response equal to or exceeding the calibration amplitude established per T-463.1.3(c). Record all search unit position and location dimensions to the nearest tenth of an inch.

(b) Obtain data from successive scans at increments no greater than nine-tenths of the transducer dimension measured parallel to the scan increment change (10% overlap). Record data for the end points as determined by 20% of DAC. Emphasis must be placed on measurement of the parameters determining the reflector length and height and the distances from the examination surface to the top and bottom of the reflector, since these dimensions are the factors most critical in determining ultimate evaluation and disposition of the flaw (see Appendix D for an illustrated example).

(c) The following reflector data shall be recorded when a reflector exceeds 20% DAC.

(1) Maximum percent of DAC, sweep reading of indication, search unit position, location along the length of the weld, and beam direction.

(2) Through-Wall Dimension

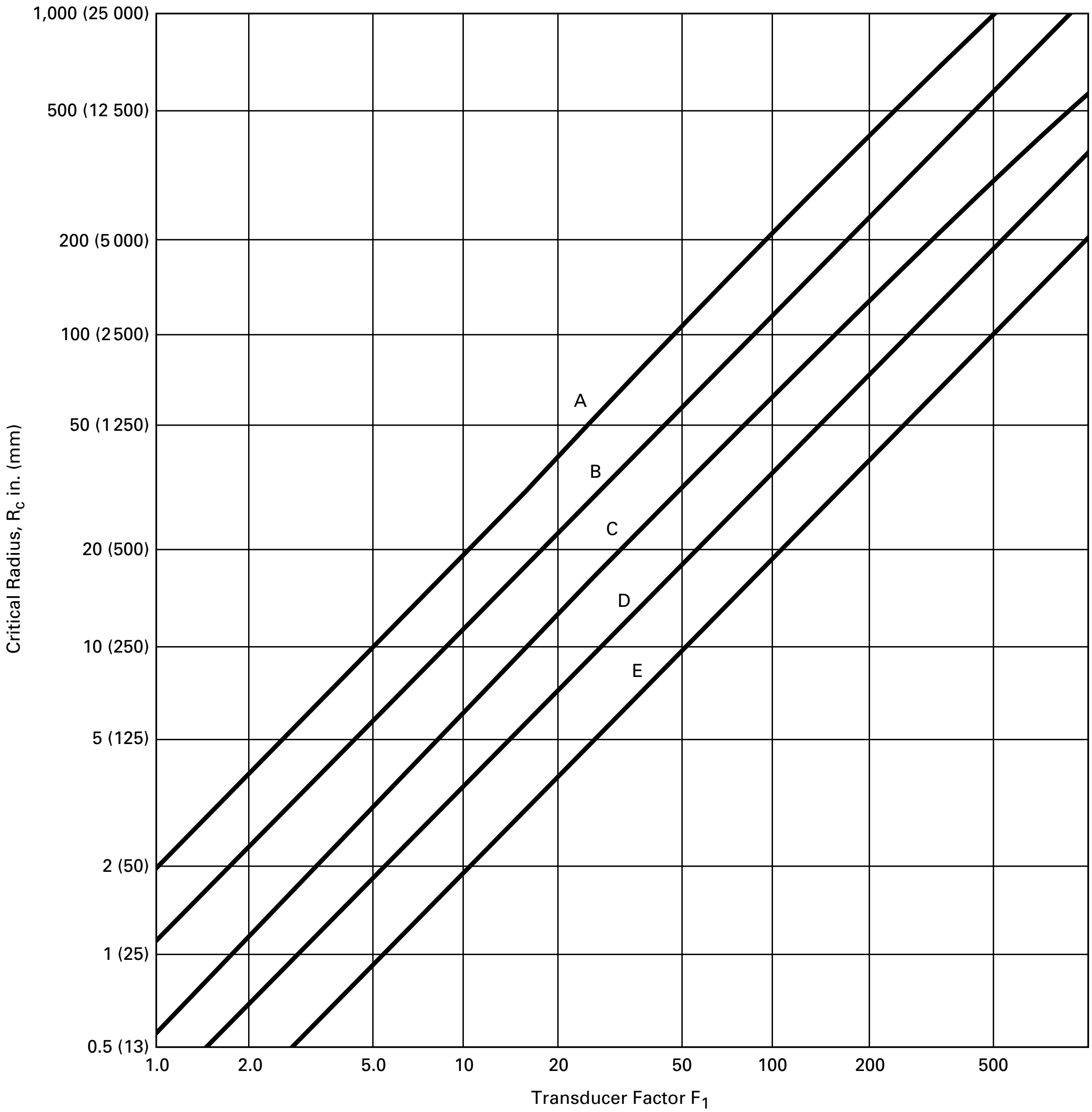
(a) For reflectors 20% to 100% DAC, the minimum sweep reading and its position and location along the length of the reflector for 20% DAC when approaching the reflector from the maximum signal direction.

(b) For reflectors 20% to 100% DAC, the maximum sweep reading and its position and location along the length of the reflector for 20% DAC when moving away from the reflector's maximum signal direction.

(c) For reflectors exceeding 100% DAC, minimum sweep reading and its position and location along the length of the reflector for 50% of the maximum amplitude when approaching the reflector from the maximum signal direction.

(d) For reflectors exceeding 100% DAC, maximum sweep reading and its position and location along the length of the reflector for 50% of the maximum amplitude when moving away from the reflector's maximum signal direction.

(3) Length Dimension. The length of the reflector shall be obtained by recording the position and location along the length of weld as determined by 20% of DAC for each end of the reflector.



Curve	Couplant	Transducer Wearface
A	Motor oil or water	Aluminum Oxide or Boron Carbide
B	Motor oil or water	Quartz
	Glycerine or syn. ester	Aluminum Oxide or Boron Carbide
C	Glycerine or syn. ester	Quartz
D	Motor oil or water	Plastic
E	Glycerine or syn. ester	Plastic

FIG. G-461(a) CRITICAL RADIUS R_C FOR TRANSDUCER/COUPLANT COMBINATIONS

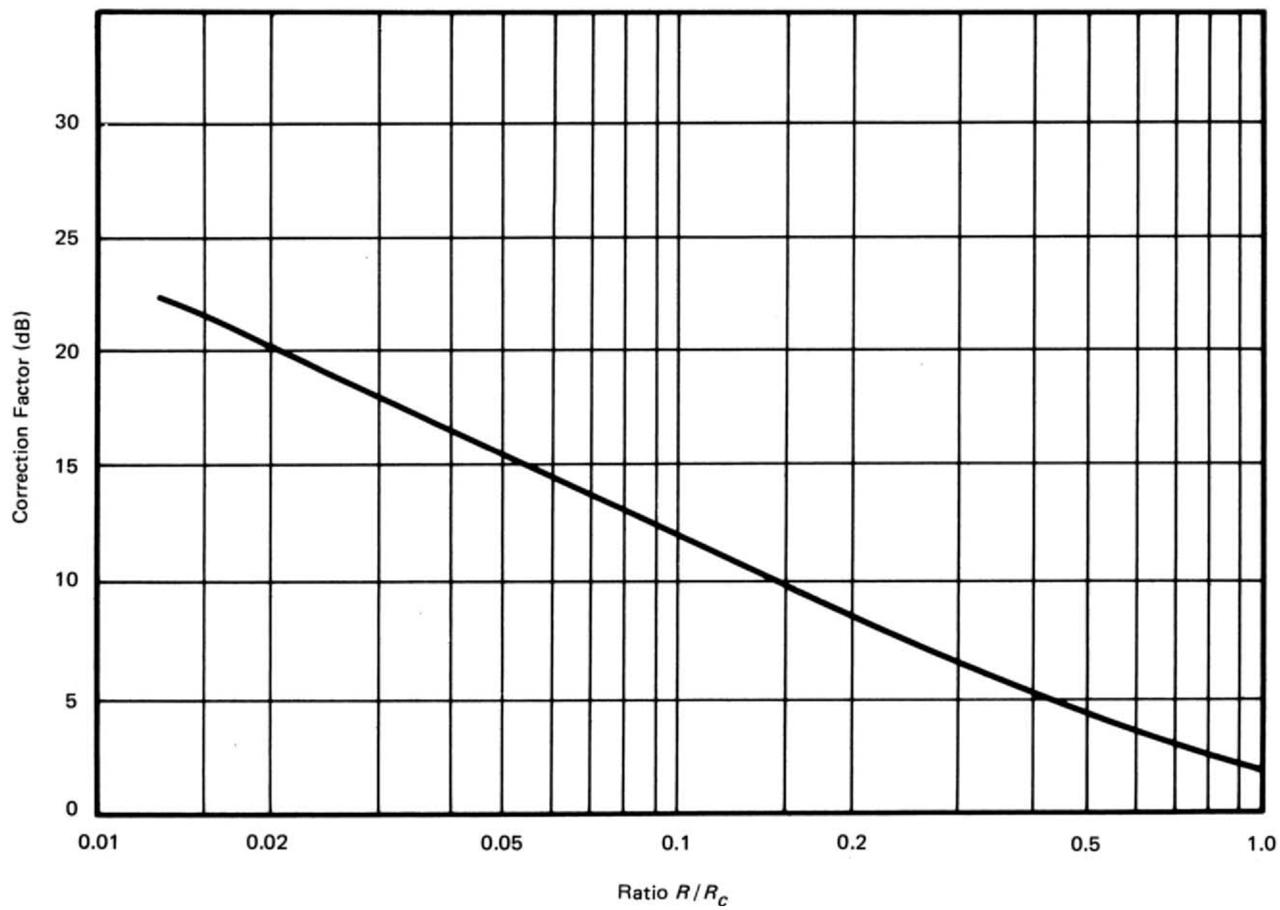


FIG. G-461(b) CORRECTION FACTOR (GAIN) FOR VARIOUS ULTRASONIC EXAMINATION PARAMETERS

APPENDIX I — EXAMINATION OF WELDS USING ANGLE BEAM SEARCH UNITS

I-410 SCOPE

This Appendix describes a method of examination of welds using angle beam search units.

I-470 EXAMINATION

I-471 General Scanning Requirements

Three angle beams, having nominal angles of 45 deg, 60 deg, and 70 deg (with respect to a perpendicular to the examination surface), shall generally be used. Beam angles other than 45 deg and 60 deg are permitted provided the measured difference between angles is at least 10 deg. Additional $\frac{t}{4}$ volume angle beam examination shall be conducted on the material volume within $\frac{1}{4}$ of the thickness adjacent to the examination surface. Single or dual element longitudinal or shear wave angle beams in the range of 60 deg through 70 deg (with respect to perpendicular to the examination surface) shall be used in this $\frac{t}{4}$ volume.

I-472 Exceptions To General Scanning Requirements

Other angles may be used for examination of:

(a) flange welds, when the examination is conducted from the flange face;

(b) nozzles and nozzle welds, when the examination is conducted from the nozzle bore;

(c) attachment and support welds;

(d) examination of double taper junctures.

I-473 Examination Coverage

Each pass of the search unit shall overlap a minimum of 50% of the active transducer (piezoelectric element) dimension perpendicular to the direction of the scan.

APPENDIX J — ALTERNATIVE BASIC CALIBRATION BLOCK

J-410 SCOPE

This Appendix contains the description for an alternative to Article 4, T-434.2 for basic calibration blocks used for distance-amplitude correction (DAC) calibration techniques.

J-430 EQUIPMENT

J-431 Basic Calibration Block

The basic calibration block(s) containing basic calibration reflectors to establish a primary reference response of the equipment and to construct a distance-amplitude correction curve shall be as shown in Fig. J-431. The basic calibration reflectors shall be located either in the component material or in a basic calibration block.

J-432 Basic Calibration Block Material

(a) Block Selection. The material from which the block is fabricated shall be from one of the following:

(1) nozzle dropout from the component;

(2) a component prolongation;

(3) material of the same material specification, product form, and heat treatment condition as the material to which the search unit is applied during the examination.

(b) Clad. Where the component material is clad and the cladding is a factor during examination, the block shall be clad to the component clad nominal thickness $\pm^1/_8$ in. (3 mm). Deposition of clad shall be by the same method (i.e., rollbonded, manual weld deposited, automatic wire deposited, or automatic strip deposited) as used to clad the component to be examined. When the cladding method is not known or the method of cladding used on the component is impractical for block cladding, deposition of clad may be by the manual method. When the parent materials on opposite sides of a weld are clad by different methods, the cladding on the calibration block shall be applied by the method used on the side of the weld from which the examination will be conducted. When the examination is conducted from both sides, the calibration block shall provide for calibration for both methods of cladding.

(c) Heat Treatment. The calibration block shall receive at least the minimum tempering treatment required by the material specification for the type and grade and a postweld heat treatment of at least 2 hr.

(d) Surface Finish. The finish on the surfaces of the block shall be representative of the surface finishes of the component.

(e) Block Quality. The calibration block material shall be completely examined with a straight beam search unit. Areas that contain indications exceeding the remaining back reflection shall be excluded from the beam paths required to reach the various calibration reflectors.

J-433 Calibration Reflectors

(a) Basic Calibration Reflectors. The side of a hole drilled with its axis parallel to the examination surface is the basic calibration reflector. A square notch shall also be used. The reflecting surface of the notches shall be perpendicular to the block surface. See Fig. J-431.

(b) Scribe Line. A scribe line as shown in Fig. J-431 shall be made in the thickness direction through the in-line hole center lines and continued across the two examination surfaces of the block.

(c) Additional Reflectors. Additional reflectors may be installed; these reflectors shall not interfere with establishing the primary reference.

(d) Basic Calibration Block Configuration. Figure J-431 shows block configuration with hole size and location. Each weld thickness on the component must be represented by a block having a thickness relative to the component weld as shown in Fig. J-431. Where the block thickness ±1 in. (25 mm) spans two of the weld thickness ranges shown in Fig. J-431, the block's use shall be acceptable in those portions of each thickness range covered by 1 in. (25 mm). The holes shall be in accordance with the thickness of the block. Where two or more base material thicknesses are involved, the calibration block thickness shall be sufficient to contain the entire examination beam path.

(e) Welds in Materials With Diameters Greater Than 20 in. (500 mm). For examination of welds in materials where the examination surface diameter is greater than 20 in. (500 mm), a single curved basic calibration block may be used to calibrate the straight and angle beam examinations on surfaces in the range of curvature from 0.9 to 1.5 times the basic calibration block diameter. Alternatively, a flat basic calibration block may be used provided the minimum convex, concave, or compound curvature radius to be examined is greater than the critical radius determined by Appendix A. For the purpose of this determination, the dimension of the straight or angle beam search units flat contact surface tangent to the minimum radius shall be used instead of the transducer diameter in Table A-10.

(f) Welds in Materials With Diameters 20 in. (500 mm) and Less. The basic calibration block shall be curved for welds in materials with diameters 20 in. (500 mm) and less. A single curved basic calibration block may be used to calibrate the examination on surfaces in the range of

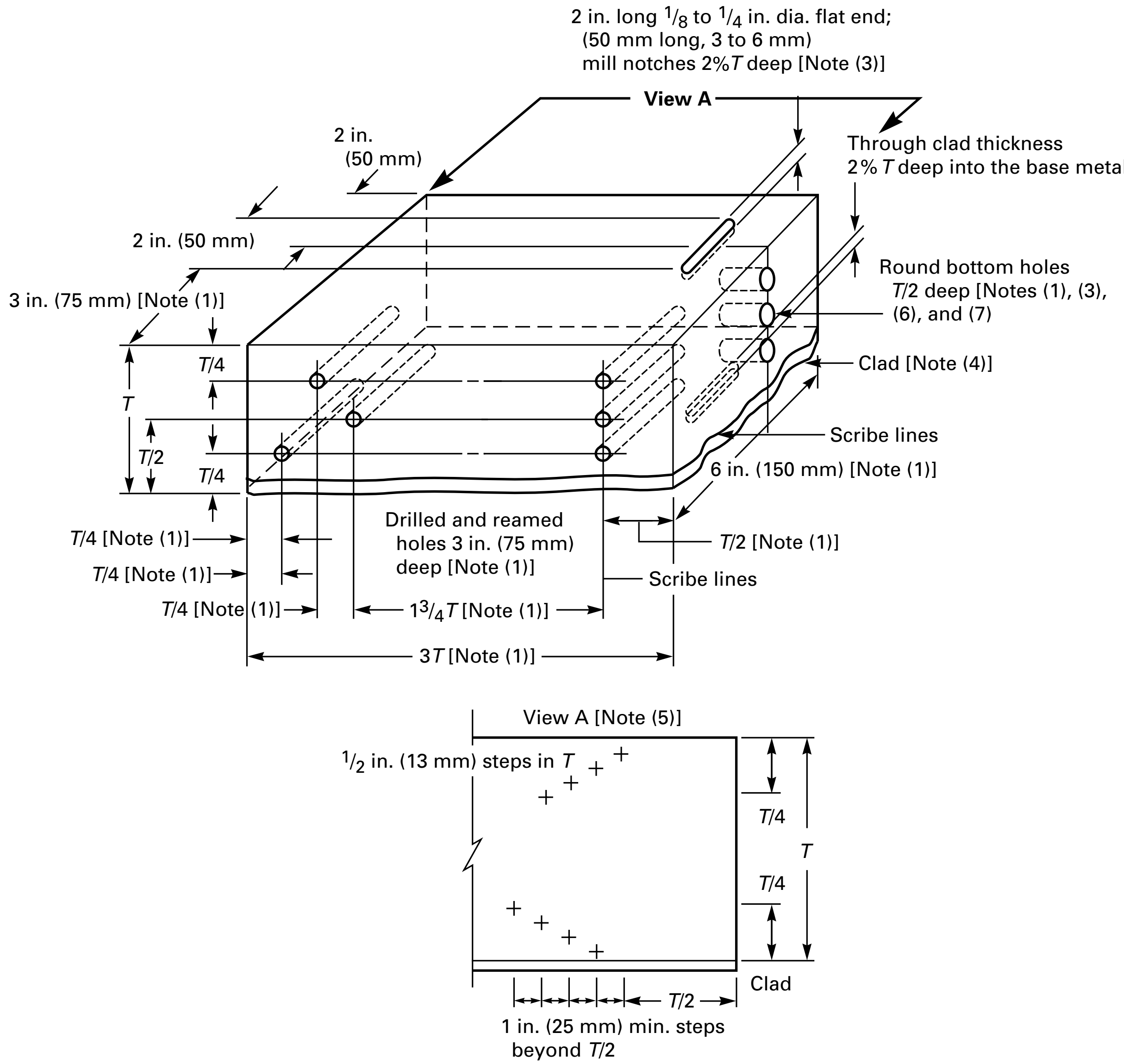


FIG. J-431 BASIC CALIBRATION BLOCK

curvature from 0.9 to 1.5 times the basic calibration block diameter. For example, an 8 in. (200 mm) diameter curved block may be used to calibrate the examination on surfaces in the range of curvature from 7.2 in. to 12 in. (180 mm to 300 mm) diameter. The curvature range from 0.94 in. to 20 in. (24 mm to 500 mm) diameter requires six block curvatures as indicated in Fig. T-434.1.7.2 for any thickness range as indicated in Fig. J-431.

(g) Retention and Control. All basic calibration blocks for the examination shall meet the retention and control requirements of the referencing Code Section.

APPENDIX K — RECORDING STRAIGHT BEAM EXAMINATION DATA FOR PLANAR REFLECTORS

K-410 SCOPE

This Appendix describes a method for recording straight beam examination data for planar reflectors when amplitude based dimensioning is to be performed.

NOTES TO FIG. J-431:

Weld Thickness t, in. (mm)	Basic Calibration Block Thickness T, in. (mm)	Side Drilled Hole Diameter, in. (mm) [Note (3)]	Round Bottom Hole Diameter, in. (mm) [Notes (3) and (6)]
Over 2 through 4 (50 through 100)	3 or t (75 or t)	$^3/_{16}$ (5)	$^3/_8$ (10)
Over 4 through 6 (100 through 150)	5 or t (125 or t)	$^1/_4$ (6)	$^7/_{16}$ (11)
Over 6 through 8 (150 through 200)	7 or t (175 or t)	$^5/_{16}$ (8)	$^1/_2$ (13)
Over 8 through 10 (200 through 250)	9 or t (225 or t)	$^3/_8$ (10)	$^9/_{16}$ (14)
Over 10 through 12 (250 through 300)	11 or t (275 or t)	$^7/_{16}$ (11)	$^5/_8$ (16)
Over 12 through 14 (300 through 350)	13 or t (325 or t)	$^1/_2$ (13)	$^{11}/_{16}$ (17)
Over 14 (350)	$t \pm 1$ ($t \pm 25$)	[Note (2)]	[Note (2)]

NOTES:
(1) Minimum dimensions.
(2) For each increase in weld thickness of 2 in. (50 mm) or fraction thereof over 14 in. (356 mm), the hole diameter shall increase $^1/_{16}$ in. (1.5 mm).
(3) The tolerances for the hole diameters shall be ± $^1/_{32}$ in. (0.8 mm); tolerances on notch depth shall be + 10 and − 20% (need only be held at the thinnest clad thickness along the reflecting surface of the notch); tolerance on hole location through the thickness shall be ± $^1/_8$ in. (3 mm); perpendicular tolerances on notch reflecting surface shall be ± 2 deg; tolerance on notch length shall be ± $^1/_4$ in. (± 6 mm).
(4) Clad shall not be included in T.
(5) Subsurface calibration holes $^1/_8$ in. (3 mm) (maximum) diameter by $1^1/_2$ in. (38 mm) deep (minimum) shall be drilled at the clad-to-base metal interface and at $^1/_2$ in. (13 mm) increments through T/4 from the clad surface, also at $^1/_2$ in. (13 mm) from the unclad surface and at $^1/_2$ in. (13 mm) increments through T/4 from the unclad surface. In each case, the hole nearest the surface shall be drilled at T/2 from the edge of the block. Holes at $^1/_2$ in. (13 mm) thickness increments from the near surface hole shall be drilled at 1 in. (25 mm) minimum intervals from T/2.
(6) Round (hemispherical) bottom holes shall be drilled only when required by a Referencing Code Section for beam spread measurements (see T-434.1) and the technique of B-60 is used. The round bottom holes may be located in the largest block in a set of basic calibration blocks, or in a separate block representing the maximum thickness to be examined.
(7) T/2 hole may be located in the opposite end of the block.

K-470 EXAMINATION

K-471 Overlap

Obtain data from successive scans at increments no greater than nine-tenths of the transducer dimension measured parallel to the scan increment change (10% overlap). Record data for the end points as determined by 50% of DAC.

K-490 RECORDS/DOCUMENTATION

Record all reflectors that produce a response equal to or greater than 50% of the distance-amplitude correction (DAC). However, clad interface and back wall reflections need not be recorded. Record all search unit position and location dimensions to the nearest tenth of an inch.

APPENDIX L — TOFD SIZING DEMONSTRATION/DUAL PROBE — COMPUTER IMAGING TECHNIQUE

L-410 SCOPE

This Appendix provides a methodology that can be used to demonstrate a UT system's ability to accurately determine the depth and length of surface machined notches originating on the examination surface from the resulting diffracted signals when a nonamplitude, Time-of-Flight-Diffraction (TOFD), dual probe, computer imaging technique (CIT) is utilized and includes a flaw classification/sizing system.

L-420 GENERAL

Article 4 requirements apply except as modified herein.

L-430 EQUIPMENT

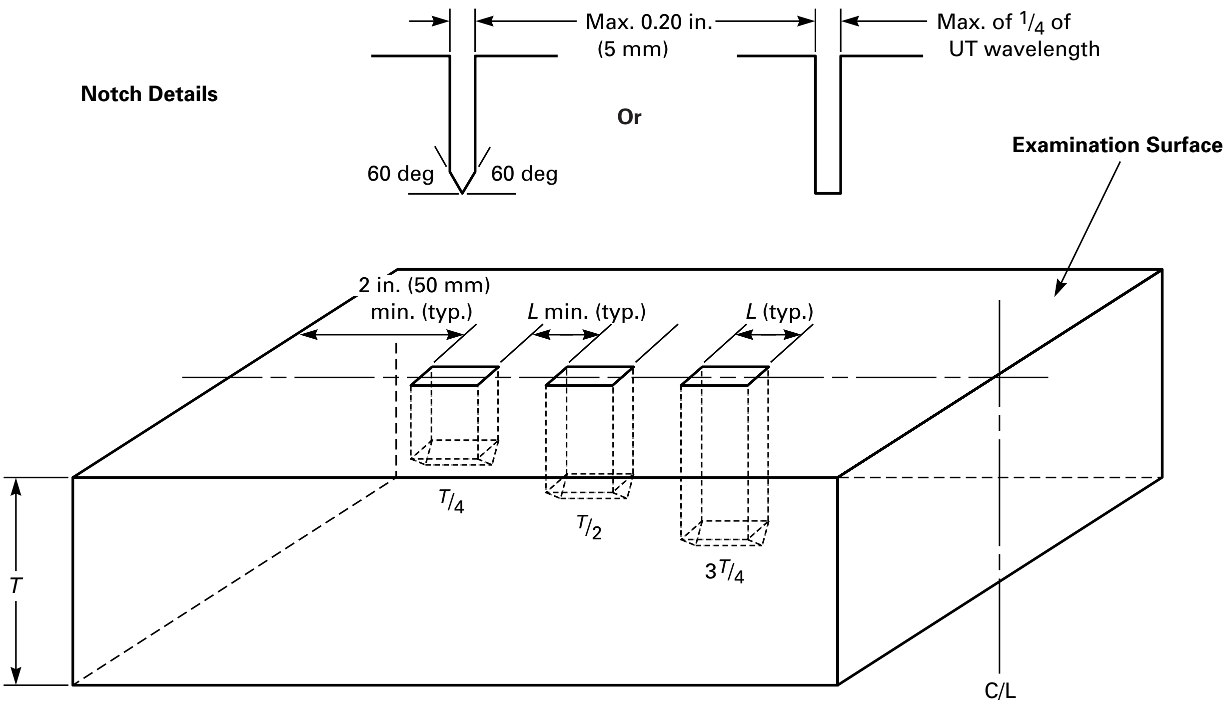
L-431 System

System equipment [e.g., UT unit, computer, software, scanner(s), search unit(s), cable(s), couplant, encoder(s), etc.] shall be described in the written procedure.

L-432 Demonstration Block

(a) The block material and shape (flat or curved) shall be the same as that desired to demonstrate the system's accuracy.

(b) The block shall contain a minimum of three notches machined to depths of T/4, T/2, and 3T/4 and with lengths (L) and, if applicable, orientation as that



GENERAL NOTE: Block length and width to be adequate for UT System Scanner.

FIG. L-432 EXAMPLE OF A FLAT DEMONSTRATION BLOCK CONTAINING THREE NOTCHES

desired to demonstrate the system's sizing accuracy. See Fig. L-432 for an example.

Additional notches may be necessary depending on:

(1) the thickness of the block;

(2) the number of examination zones the block thickness is divided into;

(3) whether or not the zones are of equal thickness (for example: three zones could be broken into a top $\frac{1}{3}$, middle $\frac{1}{3}$, and bottom $\frac{1}{3}$ vs. top $\frac{1}{4}$, middle $\frac{1}{2}$, and bottom $\frac{1}{4}$); and

(4) the depths desired to be demonstrated.

(c) Prior to machining the notches, the block material through which the sound paths must travel shall be examined with the system equipment to ensure that it contains no reflectors that will interfere with the demonstration.

L-460 CALIBRATION

L-461 System

The system shall be calibrated per the procedure to be demonstrated.

L-462 System Checks

The following checks shall be performed prior to the demonstration:

(a) Positional Encoder Check. The positional encoder shall be moved through a measured distance of 20 in. (500 mm). The system read-out shall be within ±1% [±0.2 in. (5 mm)] of the measured distance. Encoders failing this check shall be re-calibrated and this check repeated.

(b) Thickness Check. A free-run shall be made on the measuring block. The distance between the lateral wave and first back-wall signal shall be within ±0.02 in. (0.5 mm) of the block's measured thickness. Set-ups failing this check shall have the probe separation distance either adjusted or its programmed value changed and this check repeated.

L-470 EXAMINATION

The demonstration block shall be scanned per the procedure and the data recorded.

Demonstrations may be performed utilizing:

(a) D-scan (non-parallel scan) techniques

(b) B-scan (parallel scan) techniques

(c) D-scan (non-parallel scan) techniques with the notches offset by varying amounts to either side of being centered.

L-480 EVALUATION

L-481 Sizing Determinations

The depth of the notches from the scanning surface and their length shall be determined per the procedure to be demonstrated.

L-482 Sizing Accuracy Determinations

Sizing accuracy (%) shall be determined by the following formulas:

(a) Depth:

$$\frac{D_d - D_m}{D_m} \times 100$$

(b) Length:

$$\frac{L_d - L_m}{L_m} \times 100$$

where:

D_d and L_d are the notches depth and lengths, respectively, as determined by the UT system being demonstrated, and

D_m and L_m are the notches depth and lengths, respectively, as determined by physical measurement (i.e., such as replication)

NOTE: Use consistent units.

L-483 Classification/Sizing System

L-483.1 Sizing. Flaws shall be classified as follows:

(a) Top-surface Connected Flaws. Flaw indications consisting solely of a lower-tip diffracted signal and with an associated weakening, shift, or interruption of the lateral wave signal, shall be considered as extending to the top-surface unless further evaluated by other NDE methods.

(b) Embedded Flaws. Flaw indications with both an upper and lower-tip diffracted signal or solely an upper-tip diffracted signal and with no associated weakening, shift, or interruption of the back-wall signal shall be considered embedded.

(c) Bottom-surface Connected Flaws. Flaw indications consisting solely of an upper-tip diffracted signal and with an associated shift of the backwall or interruption of the back-wall signal, shall be considered as extending to the bottom surface unless further evaluated by other NDE methods.

L-483.2 Flaw Height Determination. Flaw height (thru-wall dimension) shall be determined as follows:

(a) Top-surface Connected Flaws. The height of a top-surface connected flaw shall be determined by the distance between the top-surface lateral wave and the lower-tip diffracted signal.

(b) Embedded Flaws. The height (h) of an embedded flaw shall be determined by:

(1) the distance between the upper-tip diffracted signal and the lower-tip diffracted signal or,

(2) the following calculation for flaws with just a singular upper-tip diffracted signal:

$$h = [\,(c\,(t_d + t_p)/2)^2 - s^2\,)\,]^{1/2} - d$$

where:

c = longitudinal sound velocity
s = half the distance between the two probes' index points
t_d = the time-of-flight at depth d
t_p = the length of the acoustic pulse
d = depth of the flaw below the scanning surface

NOTE: Use consistent units.

(c) Bottom-surface connected flaws. The height of a bottom-surface connected flaw shall be determined by the distance between the upper-tip diffracted signal and the back-wall signal.

L-483.3 Flaw Length Determination. The flaw length shall be determined by the distance between end fitting hyperbolic cursurs or the flaw end points after a synthetic aperture focusing technique (SAFT) program has been run on the data.

L-490 DOCUMENTATION

L-491 Demonstration Report

In addition to the applicable items in T-492, the report of demonstration shall contain the following information:

(a) computerized program identification and revision;
(b) mode(s) of wave propagation used;
(c) demonstration block configuration (material, thickness, and curvature);
(d) notch depths, lengths, and, if applicable, orientation (i.e., axial or circumferential);
(e) instrument settings and scanning data;
(f) accuracy results.