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PFI STANDARD ES-30
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Random Ultrasonic Examination of Butt Welds

Prepared by
Pipe Fabrication Institute Engineering Committee



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RANDOM ULTRASONIC EXAMINATION OF BUTT WELDS

METRIC CONVERSIONS

The conversion of quantities between systems of units involves a determination of the number of significant digits to be retained. All conversions depend upon the intended precision of the original quantity and are rounded to the appropriate accuracy.

Pipe sizes together with applicable wall thicknesses are not shown with metric equivalents.

The SI (metric) values where included with the customary U. S. values in this Standard are the rounded equivalents of the U. S. values and are for reference only.

Metric units were derived utilizing the following conversion factor:

Conversion	Factor
inches to millimeter	25.4

1. Scope

- 1.1 This standard establishes the requirements for random ultrasonic examination of butt welds in piping sub-assemblies.

2. General

- 2.1 The purpose of this standard is to establish a guideline for random ultrasonic examination and acceptance of butt welds when a specific Code or Standard is not referenced in the contract.
- 2.2 This standard recognizes that random ultrasonic examination is considered to be a means of verifying a welder/weld operator's performance and is not a substitute for 100% examination.
- 2.3 Random ultrasonic examination shall be performed in the shop prior to shipment.
- 2.4 "Random ultrasonic examination" is defined as meaning 100% examination of 5% of the total of all butt welds. Welds shall be selected to insure that the work of each welder and each process is included.
- 2.5 Personnel shall be qualified in accordance with the requirements of ASNT-SNT-TC-1A.

3. Designation of Welds to Be Examined

- 3.1 In the absence of any contractual agreement, the fabricator shall select the welds to be examined.

4. Surface Condition

- 4.1 The examination surfaces shall be free of weld spatter, dirt, foreign material, and any irregularities that would interfere with the movement of the transducer or impair the ultrasonic wave transmission.
- 4.2 The weld surface shall be finished so that surface irregularities cannot mask or be confused with discontinuities.

5. Equipment

- 5.1 The examination shall be performed with a pulse-echo type ultrasonic instrument. The instrument shall be equipped with a stepped gain control calibrated in units of 20db or less.
- 5.2 The ultrasonic instrument shall provide linear vertical presentation within $\pm 5\%$ of the full screen height.
- 5.3 The ultrasonic instrument shall utilize an amplitude control, accurate over its useful range to $\pm 20\%$ of the nominal amplitude ratio, to allow measurement of indications beyond the linear range of the vertical display on the CRT.

6. Couplant

- 6.1 A liquid couplant such as water, oil, glycerin, etc., capable of transmitting ultrasonic waves from the transducer to the part may be used. Couplants shall be removed from the part at the discretion of the fabricator.

7. Calibration Standards

- 7.1 Drilled holes or notches may be used as calibration reflectors to establish a primary reference response of the equipment and to construct a distance-amplitude correction curve. These holes or notches may be located either in the production part or in a calibration standard of similar metallurgical structure and the same or an equivalent P-number grouping as the finished part. For the purposes of this paragraph, P-numbers 1, 3, 4 and 5 materials are considered equivalent.
- 7.2 A calibration standard shall be prepared as shown in Figure 1, representative of the Butt Welds to be examined i.e. when I.D. is machined, when I.D. is not machined and when a Backing Ring is used.
- 7.3 The calibration standard shall have a thickness relative to the production material thickness as shown in Figure 1. Where two or more

base material thicknesses are involved, the calibration block thickness shall be determined by the average thickness of the weld. The finish on the surfaces of the calibration standard shall be representative of the surface finishes on the component.

- 7.4 For examination of butt welds with contact curvatures 20 in. (508 mm) and greater in diameter, flat calibration standards or standards of essentially the same curvature as the part to be examined shall be used.
- 7.5 For examination of butt welds with contact surfaces less than 20 in. (508 mm) in diameter the calibration standard shall correspond to the radius of the production part within ± 10 percent.
- 7.6 The calibration hole as shown in Figure 1, shall be drilled parallel to the contact surface of the calibration standard. The location, depth and diameter of this hole shall be as given in the table in Figure 1.
- 7.7 The calibration notch as shown in Figure 1, shall be formed, using any suitable means, perpendicular to the contact surface of the calibration standard. The location, depth, width and length of these notches shall be as given in Figure 1.

8. Angle Beam Method

- 8.1 Frequency: The nominal frequency shall be 2.25-5 MHz unless variables, such as material grain structure, necessitate the use of other frequencies in order to assure adequate penetration.
- 8.2 Beam Angle: The beam angle in the production part shall be in the range of 40 to 75 degrees inclusive with respect to the perpendicular to the contact surface. Appropriate wedges or shoes may be used to produce the proper beam angle and to fit the radius of the part being examined.
- 8.3 Distance-Amplitude Correction: Compensation for the distance traversed by the ultrasonic beam as it passes through the material shall be provided by the use of curves, as shown by Figure 2, or electronically.
 - 8.3.1 Distance-Amplitude correction curves shall be constructed by utilizing the responses from the hole as shown in Figure 2. The first point on the curve is obtained by maximizing the signal from the nodal position that gives the maximum response, i.e. 2/8 node (1/2 T hole) or 1/8 node (1/4 T hole). The gain control then is set so that this response is 75% full screen height (FSH).
 - This is the primary reference level.
 - 8.3.2 If the instrument is equipped with an ELECTRONIC DISTANCE-AMPLITUDE CORRECTION DEVICE, the primary reference response shall be equalized at 75 percent of full CRT screen height over the distance range to be employed in the examination.
 - 8.3.3 Calibration Verification.
 - Calibration verification checks shall be performed prior to performing examinations or every four (4) hours, whichever is less.
- 8.4 Examination Procedure.
 - 8.4.1 Coverage. Where possible, butt welds shall be examined from both sides of the weld (usually from one surface only).
 - 8.4.2 Scanning Level.
 - Scanning shall be performed at a gain setting of 2 times (+6 db) reference level. When CRT Screen Noise levels make it impractical to scan at 2 times reference level, it shall be recorded on the examination report.
 - 8.4.3 Reference Level. The reference level for monitoring discontinuities is the primary reference corrected for distance by the distance-amplitude curve or electronically.
 - 8.4.4 Scanning
 - 8.4.4.1 For detection of defects parallel to the weld, the search unit shall be placed on the contact surface with the beam perpendicular to the weld. The search unit shall be manipulated laterally and longitudinally so that the ultrasonic beam will pass through all of the weld metal in two different approaches of the beam to the reflector.
 - a. Techniques employing two search units as shown in Figure 4 may be used to detect lack of penetration in double-welded butt joints.
 - 8.4.4.2 For detection of defects transverse to the weld, the transducer shall be placed on the base metal adjacent to the weld, making an angle of 45 degrees or less with the axis of the weld as shown in Figure 3. The transducer shall be oscillated so that coverage of the entire weld and heat affected zone is obtained.
 - 8.4.4.3 In either case, scan paths shall overlap by at least 10 percent and scanning shall not exceed the rate of 6 inches (152 mm) per second.

9. Straight Beam Method

9.1 Calibration of Equipment

- 9.1.1. **Frequency.** The nominal frequency shall be 2.25-5 MHz unless variables, such as material grain structure, necessitate the use of other frequencies in order to assure adequate penetration.
- 9.1.2. **Distance-Amplitude Correction.** A distance-amplitude correction curve need not be constructed when the thickness of material is less than 2 in. (51 mm). For greater thicknesses, using the proper calibration block (see Figure 1 or Figure 2) position the search unit for maximum response from the calibration hole at $\frac{1}{2}$ T (see Figure 1). Adjust the signal amplitude to 75 percent of full CRT screen. **THIS IS THE PRIMARY REFERENCE RESPONSE.** Without changing the gain control, position the search unit for maximum response from the calibration hole to $\frac{3}{4}$ T and mark its amplitude on the CRT screen. Join the two points with a straight line and extend its length to cover the test range (see Figure 6).
- 9.1.3. **Electronic Distance-Amplitude Correction Device.** The primary reference response shall be equalized over the distance range to be employed in the examination.
- 9.1.4. **Reference Level.** The reference level for monitoring discontinuities is the primary reference response corrected for distance by the distance-amplitude curve or electronically. (See Paragraphs 9.1.2 and 9.1.3).

9.2 Examination Procedure

- 9.2.1. **Base Material.** The volume of material through which the sound will travel in angle beam examination shall be completely scanned by the straight beam search unit to detect reflectors which might affect interpretation of angle beam results. This is not intended as an Acceptance/Rejection examination. However, lamellar discontinuities with dimensions greater than $\frac{3}{8}$ " shall be evaluated and reported.
- 9.2.2. **Scanning Motion.** The base material adjacent to the weld shall be examined by moving the search unit progressively along and across a sufficient contact area so as to scan the entire area adjacent to the weld. Scan paths shall overlap by at least 10 percent and scanning shall not exceed the rate of 6 inches (152 mm) per second.

9.2.3 Scanning Level.

Scanning shall be performed at a gain setting of 2 times (+6 db) reference level. When CRT Screen Noise levels make it impractical to scan at 2 times reference level, it shall be recorded on the examination report.

9.2.4 Penetration shall be verified by:

- Obtaining a reflection from an opposite parallel surface or,
- Obtaining the back reflection on similar material while using approximately the same length of sound travel.

10. Evaluation of Indications

- 10.1 All ultrasonic reflections are not necessarily relevant indications. Large material grain sizes, grain growth in the heat affected zone and differences in material velocities and densities (acoustic impedance mismatch) should be considered by the operator prior to the evaluation referenced in paragraph 9.2.
- 10.2. All indications which produce a response greater than 20 percent of the reference level shall be investigated to the extent that the operator can determine the shape, identity, and location of all such reflectors and evaluate them in terms of the Acceptance-Rejection Standards of paragraph 11.

11. Acceptance-Rejection Standards.

- 11.1 Cracks of any type are unacceptable.
- 11.2 Linear type discontinuities are unacceptable if the amplitude exceeds the reference level and discontinuities have length which exceeds the following:
- $\frac{1}{4}$ " (6mm) for T (where T is the thickness of the weld) up to and including $\frac{3}{4}$ " (19mm).
 - $\frac{1}{3}$ T (where T is the thickness of the weld) or $\frac{3}{4}$ " (19mm) whichever is less for thicknesses greater than $\frac{3}{4}$ " (19mm).
- 11.3 Welds not ultrasonically examined will be judged acceptable if they pass a hydrostatic test, air test, vacuum test, or initial service leak test of the erected system of which they are a part.

12. Repairs

- 12.1 Repairs shall be re-examined by the same procedures used for detection of the defect(s). Acceptability of repairs shall be determined by the same Acceptance-Rejection Standards.

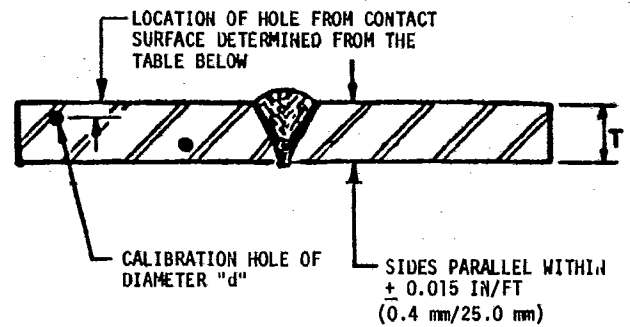
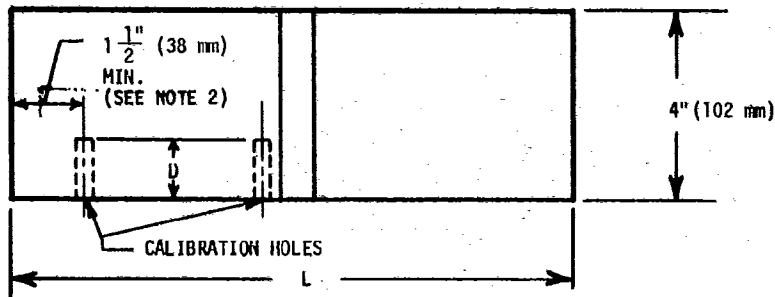
13. Report of Examination

13.1 The fabricator shall prepare an ultrasonic report. A copy of this report shall be retained in accordance with the fabricator's standard practice for retention of records. As a minimum the report shall contain the following:

13.1.1. All procedures and equipment shall be identified sufficiently to permit duplication of the examination(s) at a later date. This shall include initial calibration data for the equipment and any significant changes in subsequent rechecks.

13.1.2. A marked-up drawing or sketch indicating the weld(s) examined, the item or piece number, and identification of the operator who carried out each inspection or part thereof.

13.1.3. A record of repaired areas shall be noted as well as the results of the re-examination of the repaired areas. The fabricator shall also maintain a record of all reflections from uncorrected areas having responses that exceed 50 percent of the reference level. This record shall locate each area, the response level, the dimensions, the depth below the surface, and the classification.



L = Length of block determined by the angle of search unit and the vee-path used
 T = Thickness of basic calibration block (see table below)
 D = Depth of side-drilled hole (see table below)
 d = Diameter of side-drilled hole (see table below)
 t = Nominal production material thickness

REFERENCE STANDARD HOLE DIMENSIONS

Nominal Production Material Thickness (t), in.(mm)	Basic Calibration Block Thickness (T), in.(mm)	Hole Location	Hole Diameter (d), in.(mm)	Minimum Hole Depth (D), in.(mm)
Up to 1(25) incl.	$\frac{3}{4}$ (19) or t	$\frac{1}{2}$ T	$\frac{3}{32}$ (2)	$1\frac{1}{2}$ (38)
Over 1(25) thru 2(51)	$1\frac{1}{2}$ (38) or t	$\frac{1}{4}$ T	$\frac{1}{8}$ (3)	$1\frac{1}{2}$ (38)
Over 2(51) thru 4(102)	3 (76) or t	$\frac{1}{4}$ T	$\frac{3}{16}$ (5)	$1\frac{1}{2}$ (38)
Over 4(102) thru 6(152)	5 (127) or t	$\frac{1}{4}$ T	$\frac{1}{4}$ (6)	$1\frac{1}{2}$ (38)
Over 6(152) thru 8(203)	7 (178) or t	$\frac{1}{4}$ T	$\frac{5}{16}$ (8)	$1\frac{1}{2}$ (38)
Over 8(203) thru 10(254)	9 (229) or t	$\frac{1}{4}$ T	$\frac{3}{8}$ (10)	$1\frac{1}{2}$ (38)
Over 10(254)	t	$\frac{1}{4}$ T	See Note 1	$1\frac{1}{2}$ (38)

NOTE 1: For each increase in thickness of 2 in.(51 mm) or a fraction thereof, the hole diameter shall increase $\frac{1}{16}$ in.(2 mm)

NOTE 2: For block sizes over 3 in.(76 mm) in thickness (T), the distance from the hole to the end of the block shall be $\frac{1}{2}$ T min. to prevent coincident reflections from the hole and the corner in the 8th vee-path position. Blocks fabricated with a $1\frac{1}{2}$ in.(38 mm) minimum dimension need not be modified if the corner and hole indications can be easily resolved.

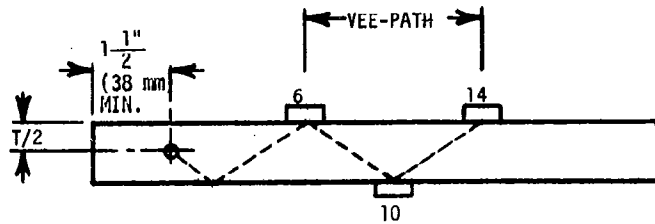
REFERENCE STANDARD NOTCH DIMENSIONS

	V-NOTCH	SQUARE NOTCH
DEPTH (% OF PART THICKNESS)	5 PERCENT	5 PERCENT
WIDTH	30° INCL. ANGLE	2 X DEPTH
LENGTH	APPROX. 1 IN.(25 mm)	APPROX. 1 IN.(25 mm)

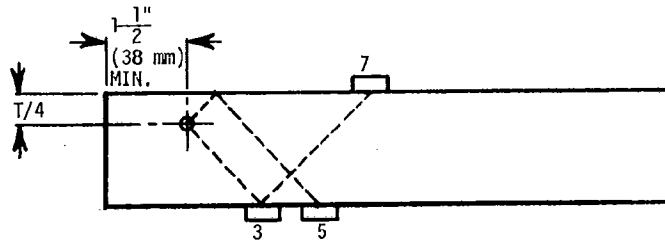
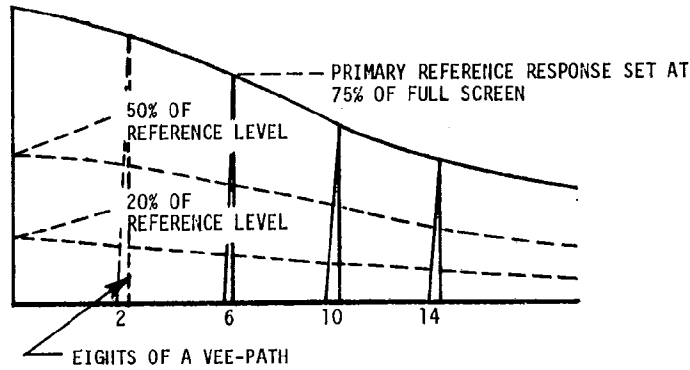
NOTES:

- The number and location of notches in a Calibration Standard will be at the discretion of the fabricator.
- A block shall be prepared for each surface condition i.e., I.D. is machined, I.D. is not machined, backing rings are used.

FIGURE 1
CALIBRATION STANDARDS



FOR THICKNESS 1 INCH (25 mm) OR LESS



FOR THICKNESS OVER 1 INCH (25 mm)

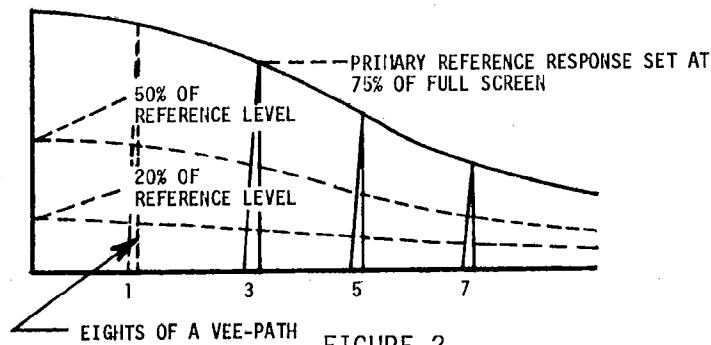


FIGURE 2

TYPICAL DISTANCE AMPLITUDE CORRECTION CURVE
[ANGLE BEAM METHOD]

(Distance in eighths of a vee-path. For example, 14 is $\frac{14}{8}$ of a vee-path.)

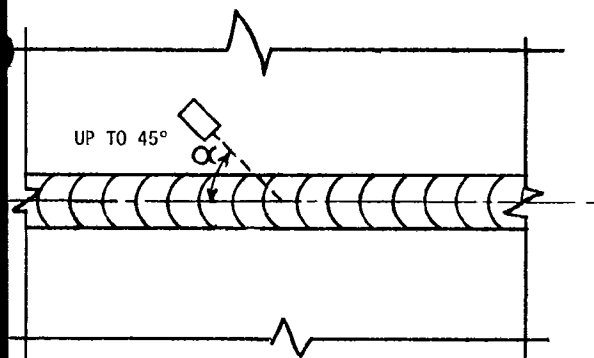
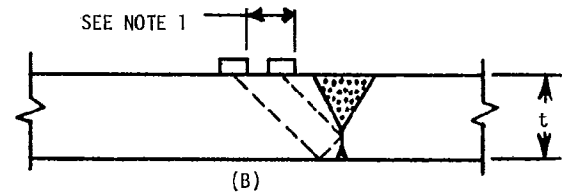
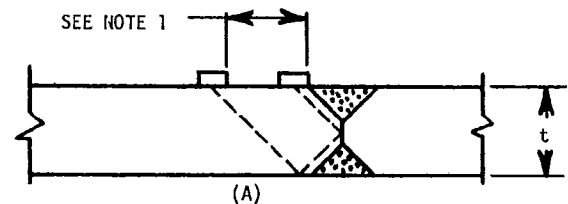


FIGURE 3

TYPICAL SEARCH TECHNIQUE
FOR DETECTING TRANSVERSE DIS-
CONTINUITIES IN WELDED JOINTS.



NOTE 1: The Search Units position will vary because
the Search Units must be located in relationship
to the sound beam travel.

FIGURE 4

TYPICAL DOUBLE SEARCH UNIT TECH-
NIQUE FOR DETECTING LACK OF PENE-
TRATION IN DOUBLE-WELDED JOINTS.

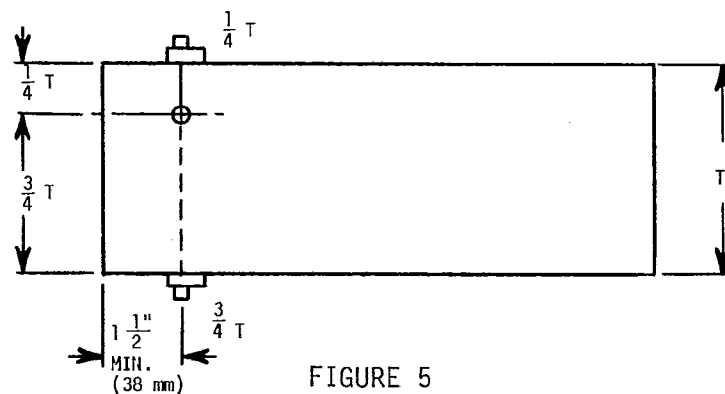


FIGURE 5

SEARCH UNIT POSITION FOR MAXIMUM RESPONSE, STRAIGHT
BEAM METHOD WHEN USED FOR WELD EXAMINATION.

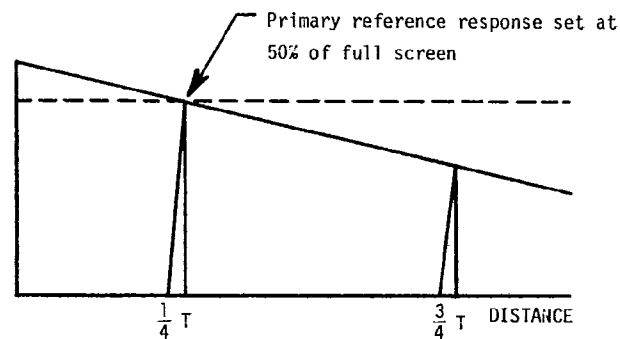


FIGURE 6

TYPICAL DISTANCE AMPLITUDE CORRECTION CURVE:
STRAIGHT BEAM METHOD WHEN USED FOR WELD
EXAMINATION.

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