Designation: E1961 – 16

Standard Practice for Mechanized Ultrasonic Testing of Girth Welds Using Zonal Discrimination with Focused Search Units[1]

This standard is issued under the fixed designation E1961; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the requirements for mechanized ultrasonic examination of girth welds. Evaluation is based upon the results of mechanized ultrasonic examination. Acceptance criteria are based upon flaw limits defined by an Engineering Critical Assessment (ECA) or other accept/reject criteria defined by the Contracting Agency.

1.2 This practice shall be applicable to the development of an examination procedure agreed upon between the users of this practice.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

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

2.2 *ASTM Standards:*[2]

E164 Practice for Contact Ultrasonic Testing of Weldments

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

2.3 *ASNT Standard:*[3]

ASNT Practice SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

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

2.4 *AIA Standard:*

NAS-410 Nondestructive Testing Personnel Qualification and Certification[4]

2.5 *API Standard:*

API STD–1104 Welding of Pipeline and Related Facilities[5]

2.6 *CSA Standard:*

CSA Z-662 Oil and Gas Pipelines Systems[6]

2.7 *ISO Standards*[7]

ISO 9712 Nondestructive Testing—Qualification and Certification of NDT Personnel

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions relating to ultrasonic examination, that appear in Terminology E1316 shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceptance criteria*—definition of acceptable/rejectable flaws as defined by an Engineering Critical Assessment (ECA), such as defined in CSA-Z662 or API 1104, or workmanship criteria as defined by the contracting agency.

3.2.2 *contract document*—any document specified in the contract between the contracting agency and contractor, including the purchase order, specification, drawings or other written material.

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[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.06 on Ultrasonic Method.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.

[4] Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, http://www.aia-aerospace.org.

[5] Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org.

[6] Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, http://www.csa.ca.

[7] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

***A Summary of Changes section appears at the end of this standard**

3.2.3 *contracting agency*—a government agency, prime contractor or subcontractor procuring ultrasonic examination services.

3.2.4 *contractor*—the nondestructive examination contractor engaged by the contracting agency in work covered by this practice.

3.2.5 *mapping type presentations*—an ultrasonic image presentation whereby the digitized A-scan signal is represented as colors or grayscale for amplitude variation along one axis representing time of flight and the other axis is the sampling position, or the distance along the weld.

3.2.6 *operator(s)*—the term "operator(s)" as used in this practice shall mean the operator(s) of ultrasonic equipment who is (are) certified according to the requirements in 5.2 and at a level deemed acceptable to the contracting agency.

4. Significance and Use

4.1 This practice is intended primarily for the mechanized ultrasonic examination of pipe girth welds used in the construction of gas and oil pipelines. This practice, with appropriate modifications due to changes in weld profile, may also be used to examine repaired welds. Manual techniques such as described in Practice E164 may also be used to examine production or repaired welds. This practice, with appropriate modifications, may also be used to examine other forms of butt welds including long seams.

4.2 Techniques used are to be based on zonal discrimination whereby the weld is divided into approximately equal vertical examination sections (zones) each being assessed by a pair of ultrasonic search units. See Fig. 1 for typical zones.

4.3 Thicknesses of material examined are normally 7 to 25 mm (0.28 to 1.00 in.) and pipe diameters 15 cm (6.0 in.) and greater but this standard may apply to other thicknesses and diameters if the techniques can be proven to provide the required zonal discrimination.

4.4 Examination zones are typically 2 to 3 mm (0.08 to 0.12 in.) in height. For most applications this will require the use of contact focused search units to avoid interfering signals originating from off-axis geometric reflectors and to avoid excessive overlap with adjacent zones.

5. Basis of Application

5.1 The following items are subject to contractual agreement between the parties using or referencing this standard.

5.2 *Personnel Qualification:*

5.2.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally or internationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, NAS-410, ISO 9712, or a similar document and certified by the employer or certifying agency, as applicable. The practice or standard used and its applicable revision shall be identified in the contractual agreement between the using parties.

5.3 *Qualification of Nondestructive Agencies*—If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Practice E543. The applicable edition of Practice E543 shall be specified in the contractual agreement.

5.4 *Procedures and Techniques*—The procedures and techniques to be used shall be as specified in the contractual agreement.

5.5 *Surface Preparation*—The pre-examination surface preparation criteria shall be in accordance with 10.2, unless otherwise specified.

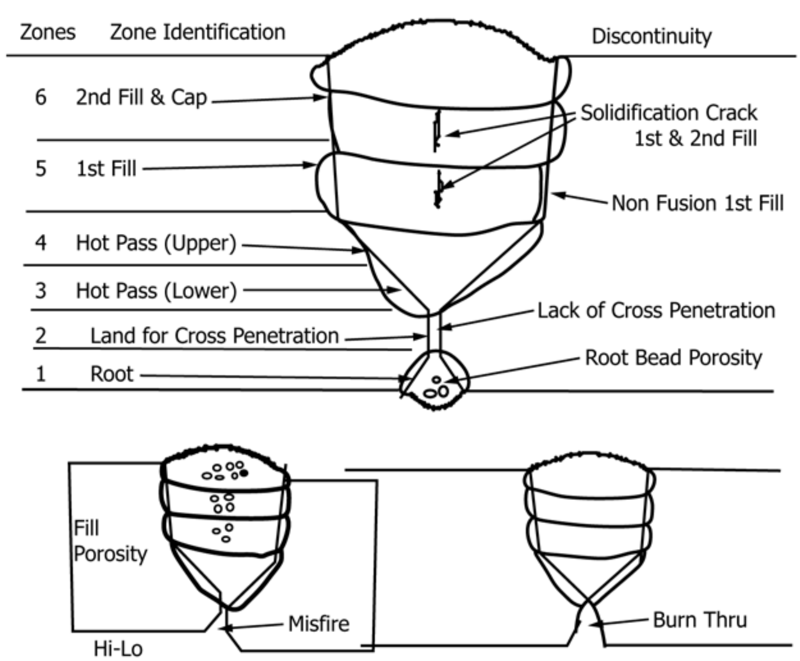


FIG. 1 Schematic Representation of Weld Zones and Discontinuities

5.6 *Timing of Examination*—The timing of examination shall be in accordance with 10.3, unless otherwise specified.

5.7 *Extent of Examination*—The extent of examination shall be in accordance with Section 8, unless otherwise specified.

5.8 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with Section 11, unless otherwise specified. Since acceptance criteria are not specified in this standard, they shall be specified in the contractual agreement.

5.9 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this standard and if required shall be specified in the contractual agreement.

6. Examination Methods

6.1 *Visual Examination*—All welds shall be visually examined after completion and assessed in accordance with the requirements of surface conditions for ultrasonic examination.

6.2 All bevels shall be examined immediately after machining to ensure compliance with the applicable welding procedure. This examination should be combined with scribing the reference line as described in 10.4.

6.3 Any items of non-compliance shall be referred to the contracting agency representative for corrective action.

6.4 *Ultrasonic Examination*—All girth welds identified for mechanized ultrasonic examination shall be examined for 100 % of their circumference and assessed in accordance with the contracting agency's acceptance criteria. Examination should be conducted in accordance with procedures approved by the contracting agency.

7. Ultrasonic Equipment

7.1 *Ultrasonic System*—The system shall provide an adequate number of examination channels to ensure the complete volumetric examination of the weld through thickness in one circumferential scan. The instrument shall provide a linear "A" scan presentation for each channel selected. The examination channels will allow the volume of the weld scanned to be assessed in accordance with the examination zones as typically defined in Fig. 1. Instrument linearity shall be determined according to the procedures detailed in Practice E317, within six months of the intended end use date. The contractor shall retain a copy of the calibration certificate. Instrument linearity shall be such that the accuracy of any indicated amplitude is within 5 % of the actual full scale amplitude. This shall apply to both linear and logarithmic amplifiers. Each examination channel shall be selective for: pulse-echo or through-transmission mode, gate position and length for a minimum of two gates, and gain. Recording thresholds shall be selectable to display signals between 0 and 100 % of full screen height for simple amplitude and transit time recording and shall be from 0 to 100 % for B-scan or "mapping" type recording of data. Two recordable signal outputs per gate shall be available, being either analog or digital and representative of signal height and time of flight. These will be suitable for recording on a multi-channel recorder or computer data acquisition software display.

7.2 *Recording System:*

7.2.1 A distance measuring circuit or device suitable for connection to the recorder or acquisition system shall provide a means of electronically determining circumferential weld distance to an accuracy of typically ±1 cm (0.4 in.) or better, as required by the contracting agency, over the circumference of the weld (an optical encoder is typically used for such distance measurement). Programmed scan lengths shall be sufficient to ensure all probes will travel the maximum circumferential distance required for a pipe having a diameter with the maximum tolerance allowed by the contracting agency's specification. For equipment with encoders traveling on a track or welding guide-band a correction factor will be incorporated to ensure the circumferential distance recorded on the chart corresponds to the search unit position on the pipe outer surface. The recording or marking system shall clearly indicate the location of discontinuities relative to the marked starting position of the scan, with a ±1 cm (0.4 in.) accuracy. There shall be recordings from each search unit for weld discontinuities and confirmation of the acoustic coupling arranged on the chart or display in a manner acceptable to the contracting agency.

7.2.2 B-scan or other form of "mapping" displays will be used for volumetric flaw detection and characterizations and Time of Flight Diffraction (TOFD) techniques may be added to improve characterization and sizing. TOFD techniques may augment pulse-echo techniques but shall not replace pulse-echo techniques.

7.2.3 Where TOFD techniques are employed the recording system shall be capable of a 256-level grayscale display and be capable of recording full R-F wave forms for the TOFD search unit pairs.

7.3 *Coupling*—The coupling shall be obtained by using a medium suitable for the purpose. An environmentally safe wetting agent may be required to enhance acoustic coupling. No residue should remain on the pipe surface after the liquid has evaporated. For examination where ambient temperatures are below 0°C (32°F) a methyl alcohol washer fluid or a similar medium may be used. This liquid medium may be recovered and filtered for re-use. For examination where pipe cool-down may be required after welding, water spray or other agents may be used with contracting agency approval.

7.4 *Search Units:*

7.4.1 Each search unit shall be marked with a method to identify the manufacturer's name, search unit type, exit point, incident beam angle or refracted beam angle for a specific wedge/steel velocity ratio, frequency, and crystal size.[8]

7.4.2 The search unit array design shall be specific to the project where the examination is to be performed.

7.4.3 All search units shall be contoured to match the curvature of the pipe surface.

7.5 *Reference Standards*—Reference standards shall be used to establish sensitivity and qualify the examination system for field examination and to monitor the system's performance on

[8] For phased array and EMAT probes, not all of the listed items may be applicable.

an ongoing basis. Reference standards shall be manufactured from a section of unflawed project-specific line pipe supplied by the contracting agency. The contracting agency will provide the contractor with details of project-specific weld geometries and the reference reflectors required in specific areas. The contractor shall then provide a reference standard design that must be submitted to the contracting agency for approval before manufacturing. No design changes to the reference standard shall be made without prior approval of the contracting agency. Annex A3 provides an example of a typical reference standard.

7.6 *Ultrasonic Examination Procedure*—The contractor shall provide a procedure that will provide examination criteria for the ultrasonic examination of the weld in a single pass. It must allow for characteristic Hi/Lo fit-ups (edge misalignment), weld shrinkage and be pipe-size specific. Procedures submitted will allow zonal flaw characterization that permits use of the contracting agency's engineering critical assessment acceptance criteria. It shall include but not be limited to describing the following requirements:

7.6.1 The mechanized variable speed scanner mountable on mechanical welding bands or other tracking mechanism,

7.6.2 The encoder capable of accurately indicating any flaw location about the girth weld,

7.6.3 Independently loaded ultrasonic search units mounted in an array that provides independent examination of the weld from both sides,

7.6.4 Provisions for adjusting and maintaining the alignment of these search units,

7.6.5 Provisions for recording the continuity of the coupling,

7.6.6 Provisions for ensuring the mechanical reliability of the equipment,

7.6.7 A technique summary stating beam angles, wave types, search unit frequencies, beam sizes and profiles with sketches for each geometry to be examined,

7.6.8 Record analog or digital signals from the multi-channels to a common distance of rotation,

7.6.9 Provide permanent copy of the scans in an easily interpretable format to meet archival and audit needs,

7.6.10 Provide construction and accuracy details of the reference standard,

7.6.11 Provide the standardization procedures to be used in the field, and

7.6.12 Standardization checks shall be established and verified on a time or weld cycle defined by the contracting agency. System performance between standardization checks shall be continually monitored for degradation.

8. Ultrasonic Examination Set-Up

8.1 *Search Unit Positioning and Primary Reference Sensitivity*—The system shall be optimized for field examination using the reference standard. Each search unit shall be positioned at its operating distance from the simulated weld centerline on the reference standard and adjusted to provide a peak signal from its target reference reflector in the search unit's examination zone. The peak signal response shall be adjusted to 80 % full-screen height (FSH) for each channel. The gain level determined for each search unit shall be the primary reference.

8.2 *Gate Settings:*

8.2.1 *Fusion-Zone Search Units*—Using the reference standard, each detection gate shall be set to cover a sound path distance that starts at least 3 mm (0.12 in.) before the weld preparation and ends at least 1 mm (0.04 in.) past the weld centerline. The gate start position with respect to the weld preparation and gate length for each channel shall be recorded in the procedure.

8.2.2 *Porosity Detection Search Units (Fill Region)*—Porosity provides a weak and characteristically different reflected signal compared to specular reflection from nonfusion discontinuities. Dedicated channels using B-scan or mapping type presentations are recommended for detecting and characterizing porosity and other volumetric flaws. One of the fusion-zone search units can be used for porosity detection or (an) extra search unit(s) may be added to the array. Using the reference standard, each mapping gate should be set to cover a sound path distance which starts at least 1 mm (0.04 in.) before the weld preparation and long enough to encompass the weld bevel on the opposite side of the weld centerline. For test piece thickness greater than about 12 mm (0.5 in.), beam characteristics may require the use of more than one search unit for porosity detection in the fill regions. Scanning sensitivity should be typically 8 to 14 dB over that required to achieve an 80 % FSH signal from a flat-bottom hole (FBH) typically 1.5 to 2.0 mm (0.060 to 0.080 in.) diameter, but should not be so great as to cause interfering electrical or geometric noise that could be misinterpreted.

8.2.3 *Porosity Detection Search Units (Root Region)*—Using the reference standard each detection gate shall be set to cover a sound path distance which starts at least 1 mm (0.04 in.) before the weld preparation and long enough to ensure coverage of the weld root area. Fusion-zone search units in the lowest examination zone(s) can be used for porosity detection in the root region or (an) extra search unit(s) may be added to the array. Scanning sensitivity requirements for porosity detection in the root region shall be adequate to ensure detection of porosity in this region. Scanning sensitivity should be typically 4 to 14dB over that required to achieve an 80 % FSH signal from a FBH typically 1.5 to 2.0 mm (0.060 to 0.080 in.) diameter but should not be so great as to cause interfering electrical or geometric noise that could be misinterpreted.

8.3 *Evaluation Threshold*—The evaluation threshold for each detection channel shall be typically 20 % of full screen height or greater for fusion zones. All signals above this amplitude will be evaluated in accordance with the contracting agency's acceptance criteria. Porosity detection channels may use a threshold for evaluation or patterns in mapping type channels and transit time may be used to characterize porosity.

8.4 *Recording Set-Up*—Channel output signals shall be arranged on the recording display in a manner that allows the weld to be presented symmetrically on either side of the weld centerline. In addition, delays shall be applied to the signals from each search unit to compensate for the various circumferential positions relative to the circumferential zero point.

Details of the delays applied and the chart arrangement shall be recorded in the procedure.

8.5 *Circumferential Scanning Velocity*—For asynchronous system, the circumferential scanning velocity V_c shall be determined by:

$$V_c \leq W_c \times \frac{PRF}{3} \quad (1)$$

where: W_c is the narrowest -6dB beam width at the appropriate operating distance(s) of the all search units and PRF is the effective pulse repetition frequency per search unit.

For synchronous systems, the sample interval shall be 1 mm (0.04 in.) regardless of travel speed.

9. Dynamic Standardization

9.1 *Detection Channels:*

9.2 With the system optimized the reference standard shall be scanned at the same speed at which the examination will be performed. The analog or digital recording shall indicate signals, 80 % FSH, from each reference reflector recorded in their correct position assigned on the display. The circumferential positional accuracy of the recorded reflectors relative to each other should be within typically ±2 mm (0.080 in.), and with respect to the zero start they should be within typically ±1 cm (0.4 in.).

9.3 Acceptability of a system to produce a standardization chart or record will be based on its ability to discriminate examination zones typical of those described in Fig. 1. This will be demonstrated by signals from adjacent zones being at least 6 dB and not more than 14 dB lower than from the zone for which a search unit channel is standardized for. Failure to ensure the 6 to 14 dB separation between zones may be unacceptable and could require repositioning of the search unit or a complete search unit replacement. Actual dB separation requirements may be stipulated by the contracting agency.

9.4 *Coupling Monitor Channels*—A method shall be employed to determine that constant coupling is achieved during examinations. An examination of the test piece with its surface wiped dry (lack of couplant) shall produce a record showing an absence of the couplant recording signal.

10. Field Examination

10.1 *Weld Identification*—Each weld shall be identified by a unique number, a "0" mark and arrow, designating start point and direction of travel. The mark shall not interfere with scanning.

10.2 *Surface Condition*—A10 cm (4.0 in.) wide scanning area on each side of the weld shall be clear of weld spatter and other conditions which may interfere with the movement of the search units, the coupling liquid, or the transmission of acoustic energy into the material. Any surface condition such as geometry, coating, etc., impeding the ultrasonic examination shall be noted for corrective action prior to scanning.

10.3 *Time of Inspection*—Unless otherwise detailed in the contract, examination may begin anytime after welding and when the surface temperature is low enough to allow the application of couplant.

10.4 *Reference Line*—Prior to welding the Contractor should scribe a reference line on the pipe surface at a distance of 40 mm (1.60 in.) ± 0.5 mm (0.020 in.) from the centerline of the weld preparation, on the examination band side. The reference line shall be used to ensure that the search unit array is adjusted to the same distance from the centerline as to duplicate the reference standard. The tolerance to ideal positioning should not exceed ±0.5 mm (0.020 in.).

10.5 *System Performance:*

10.5.1 *Sensitivity Verification*—The reference standard shall be used to verify scanning sensitivity at the start of each shift and thereafter at intervals not exceeding 2 h or ten welds, whichever comes first, and at the conclusion of each shift or at intervals defined by the contracting agency. Hardcopy records for each reference standard scan should be included sequentially with the weld examination data. During production weld examination, at the contracting agency's discretion, the system may be operated at a higher gain to ensure detection of flaws and to compensate for differences in coupling efficiencies between the reference standard and the production pipe. Whereas for initial standardization, the channels should indicate 80 % FSH, a satisfactory standardization during production may indicate values from 70 to 99 % FSH. Standardization outside of this range should require restandardization of the system (see 10.7.1).

10.5.2 *Circumferential Position Accuracy Verification*—The positional accuracy of the chart distance markers shall be verified prior to commencement of the project and verified monthly. The scanner shall travel from the zero position with the scanning frame and the pipe zero position coincident. At the ¼, ½ and ¾ positions, the index marks on the scanning frame and pipe shall be aligned. The chart shall then be compared to circumferential distance measured with a tape measure placed on the outer surface of the pipe; chart accuracy should typically be ±1 cm (0.4 in.), or better, over the circumference.

10.5.3 *Temperature Differentials and Control*—Where temperature differences between reference standard's surface, search unit wedge material and examination surface cause shifts in refracted angle which result in the system not being able to provide the required zonal discrimination, a means of regulating the temperature of the reference standard or search unit wedge material, or both, shall be employed.

10.5.4 *Weld Zone Identification*—The system shall be capable of identifying all discontinuities identified in Fig. 1 or those defined in API 1104 and clearly identifying the specific zone in which they are located.

10.6 *Scanning Sensitivity*—Scanning shall be at least at primary reference sensitivity for fusion-zone channels and at the added gain setting for porosity detection channels as described in 8.2.2 and 8.2.3.

10.7 *Re-Examination:*

10.7.1 *Sensitivity*—If standardization during production weld examination indicates one or more channels with values outside the range defined by the contracting agency, the data from the welds scanned since the last acceptable standardization shall be evaluated to determine if the examination was acceptable or if the weld must be re-examined. The contracting agency shall provide a written procedure for the evaluation of suspect welds and define requirements for re-examination.

10.7.2 *Coupling Monitoring*—An area with lack of coupling as indicated by the absence of a coupling monitor signal over a circumferential distance exceeding the minimum allowable flaw length, should be re-examined.

10.7.3 Scanning speed will be limited by mechanical ability to maintain acoustic coupling and by the system's electronic ability to ensure full waveforms are captured without missing data points. Missing data exceeding 5 % of the scan lines to be collected, or two or more adjacent data lines being missed shall require re-examination.

11. Report

11.1 *Weld Examination Chart*—The examination data produced as a permanent record shall consist of a complete strip-chart type hardcopy showing the reference point, the direction of scanning, date and time of examination, and the name of the operator. The examination zone identified in each channel shall also be recorded. Alternate archival record formats may be approved by the contracting agency. For B-scan data, depending on noise level, colors for mapping can be selected down to 3 to 5 % FSH to aid in characterizing flaws. Colors used shall provide a rapid means of identifying areas of concern. Colors on monitor displays and colors or gray scales used on printouts should be selected to provide useful information to the operator. However, in addition the hardcopy should contain sufficient resolution and contrast so that the rationale for flaw evaluations can be easily seen by the contracting agency's representative.

11.2 *Time of Report*—For examination during production welding ultrasonic examination of the weld should be carried out as soon as possible after the weld has been completed. The entire examination of a weld, including ultrasonic examination, evaluation and production of the weld examination record should not take longer than the weld production cycle. Evaluation of a weld and the associated weld examination data should be completed prior to commencement of the subsequent weld.

12. Standards of Acceptability

12.1 Standards of acceptability are to be established by the contracting agency. These may be based on workmanship or Engineering Critical Assessment (ECA) calculations. Examples of ECA determined acceptance criteria are shown in Tables 1 and 2 (see Note 1).

NOTE 1—Values in Table 1 and Table 2 are provided in only metric (Table 1) or inch pound (Table 2), as they are actual industry examples. Each is derived from different calculations and only the units of calculation are used in the table.

13. Keywords

13.1 contact focused search units; girth welds; mechanized ultrasonics

TABLE 1 Mechanized Girth Weld Acceptance Criteria[A,B,C]

Table 1 Note A: Based on Appendix K of CSA-Z662.
Table 1 Note B: This table is an example only. It is used here to illustrate how zonal discrimination can be applied to acceptance criteria. Acceptable lengths are based on calculations derived from destructive testing for a specific material.

Feature	Depth Assumed for Analysis	Acceptable Length for Wall Thickness <12.5 mm	Acceptable Length for Wall Thickness >15 mm
External Undercut/Low Cap	0.5 mm — 1.0 mm	250	335
External Undercut/Low Cap	1.1 mm — 2.5 mm	100	195
Surface Porosity/Pinholes	2.5 mm	25	25
External Weld Reinforcement	>2.5 mm (height)	None Allowed	
Lack of Fusion in one Fill Pass	2.5 mm	100	195
Lack of Fusion or porosity in Multiple Fill Passes	up to 5.8 mm	25	25
Lack of Fusion in Hot Pass: Both Zones	3.8 mm	65	120
Lack of Fusion in Hot Pass: One Zone	1.9 mm	100	200
Lack of Fusion or porosity in Root Pass	2 mm	100	200
Lack of Fusion in Both Root and Hot pass/Burn Through	5.8 mm	25	25
Lack of Cross Penetration	1 mm	250	335
Spherical Porosity	1 mm	250	335
Piping Porosity	Unacceptable if piping porosity continues through 3 or more passes.		

[A] External undercut, low cap, cap porosity and excessive external weld reinforcement may be assessed by visual examination.
[B] Flaw interaction should be considered in defining the effective flaw length. See API 1104 Appendix A for examples of flaw interaction.
[C] All welding procedures assessed in accordance with this criteria should be qualified according to the appropriate governing standard, for example CSA Z662, Appendix K or API 1104.

TABLE 2 Example Acceptance Criteria based on API 1104—Appendix A

Table 2 Note A: Parameters:
Pipe diameter– 30.0 in.
Wall thickness– 0.577 in.
Crack tip opening displacement attained– 0.01 in.
Maximum applied strain– 0.002 (100 % yield) (inches per inch)
Examination error– 0.05 in. (depth measurements)

Flaw Type	Depth Range	Acceptable Length
Planar Surface flaws	0.000 in. to 0.144 in. 0.145 in. to 0.289 in.	12.00 in. 2.31 in.
Planar buried flaws	0.000 in. to 0.144 in. 0.145 in. to 0.289 in.	12.00 in. 2.31 in.
Porosity (Table A-1)	0.144 in.	0.14 in.
Slag (Table A-1)	0.144 in.	2.31 in.
Unrepaired Burnthrough (Table A-1)	0.144 in.	1.15 in.
Arc Burns	0.063 in.	0.31 in.

ANNEXES

(Mandatory Information)

A1. DETERMINING ACOUSTIC VELOCITY IN PIPE STEELS

A1.1 *General* :

A1.1.1 The procedure defined in this annex covers the methods that may be used to determine acoustic velocity of shear waves in line pipe steels.

A1.1.2 Line pipe used in oil and natural gas transmission pipelines is generally made of various grades of steel. The rolling processes used by various manufacturers orientates the acicular grains with their long axis parallel to the direction of rolling. Size of grains as well as exact details of chemistry and stresses resulting from the rolling to shape (long-seam or spiral-seam pipe) allows for variations in acoustic velocities from manufacturer to manufacturer. In addition, the variation in grain characteristics and stress with respect to direction of propagation causes acoustic velocity variations with resultant changes in the refracted angle of the sound in the steel.

A1.1.3 Examination of welds in line pipe steel by ultrasonic methods invariably uses refracted sound beams. Since the acoustic velocity ratio between the incident material and refracting material determines the angle of refraction it is essential to know the velocity of the two media. This is especially critical where focused beams are used for zonal discrimination.

A1.2 *Equipment* :

A1.2.1 To carry out the examinations the following equipment is recommended:

A1.2.1.1 Micrometer or vernier caliper,

A1.2.1.2 Contact SH (horizontally polarized) shear wave search unit (5 MHz, 6 mm to 10 mm diameter),

A1.2.1.3 Coupling fluid for SH shear waves (honey or other non-Newtonian viscous fluids), and

A1.2.1.4 Ultrasonic pulser-receiver with receiver with a -6dB bandwidth typically from 1 MHz to 10 MHz and a CRT type display capable of displaying received RF signals and capable of at least 10 nanosecond resolution.

A1.3 *Specimen Preparation*:

A1.3.1 Steel used in line pipe is anisotropic, therefore measurements made must specify the direction of sound beam propagation. A minimum of three readings shall be made for each plane in which examination will be done.

A1.3.1.1 A specimen is cut from a section of pipe to be examined and the corresponding results are specific for a particular pipe diameter, wall thickness and manufacturer. Specimen dimensions should be a minimum of 50 by 50 mm (2 by 2 in.); however, larger sections may be preferred for handling and machining.

A1.3.2 A minimum of two parallel surfaces are machined for the plane to be evaluated; one pair of surfaces is made in the radial direction (perpendicular to the outer surface) and the other pair made 20° from the perpendicular to the outer surface. Additional pairs of parallel surfaces may be machined at other angles in the plane to be evaluated if more data points are desired.

A1.3.3 The machined surfaces should be smooth to a 20-µm finish or better. Minimum width of the specimen surface to be measured should be 20 mm and the minimum thickness between the parallel surfaces to be measured should be 10 mm. Vertical extent of the test surface will be limited by the pipe wall thickness.

A1.4 *Procedure* :

A1.4.1 Using the micrometer or vernier caliper measure the thickness of the steel specimen between the machined parallel faces.

A1.4.2 Assemble the ultrasonic pulser/receiver, SH shear wave search unit and oscilloscope as illustrated in Fig. A1.1 using honey or other acceptable couplant (see A1.2.1) to acoustically couple the search unit to the specimen. Exert sufficient pressure on the search unit to obtain a clearly defined back reflection and one multiple. Pivot the search unit on the test surface and observe there may be two closely spaced signals at the back reflection and multiple; this is due to birefringence. This birefringence results from the anisotropic nature of the material. The velocity varies according to the relative direction of the shear-wave polarization and the microstructure of the material. Adjust the oscilloscope and read the interval of time between the faster of the two back reflection signals and the faster of the two first frontwall multiple signals. An example of the birefringent signal is shown in Fig. A1.2.

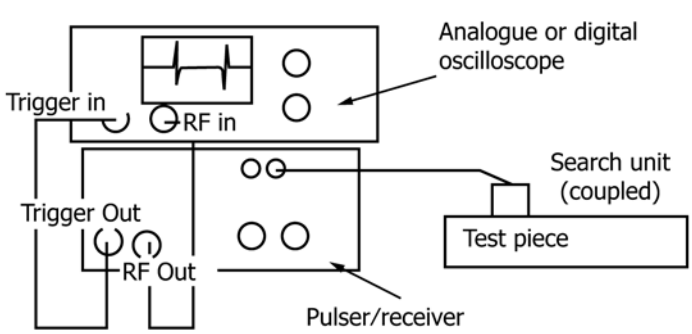


FIG. A1.1 Example of Equipment Setup

A1.4.3 Record the time interval measured.

A1.4.4 In addition to the two measurements made from the machined surfaces (axial and angled velocities), make a third reading from the outer surface for radial velocity. This will require a thickness reading of the pipe wall at the point of search unit contact using the micrometer or vernier caliper. The configuration shown for the test sample in Fig. A1.1 is for radial velocity determination. The slots shown in the specimen in Fig. A1.3 are for measurements that would be made for girth weld examinations. If long seam welds were to be examined it would be necessary to make measurements in the circumferential plane, in that case the axial velocity would be replaced by the circumferential velocity and the angled velocity would be taken at 20° from the perpendicular but in the circumferential plane.

A1.4.5 Determine the acoustic velocities of the three directions assessed using the equation:

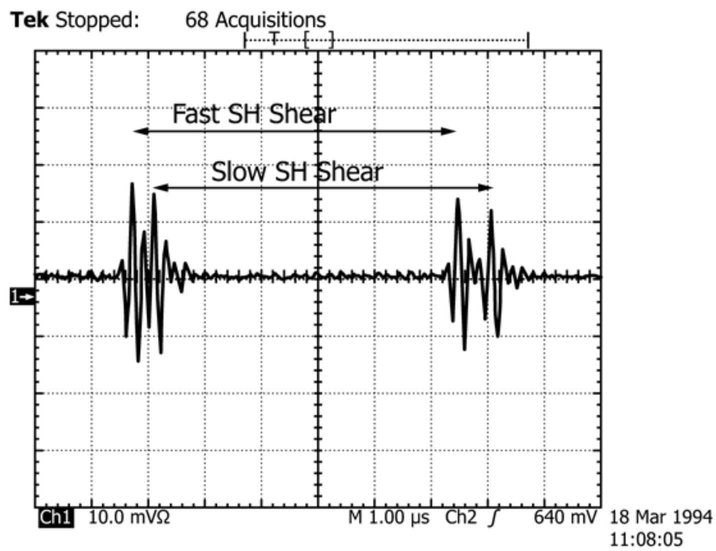
$$V = \frac{2d}{t} \tag{A1.1}$$

where:

V = velocity,
d = sample thickness (physically measured), and
t = time interval (measured by pulse-echo).

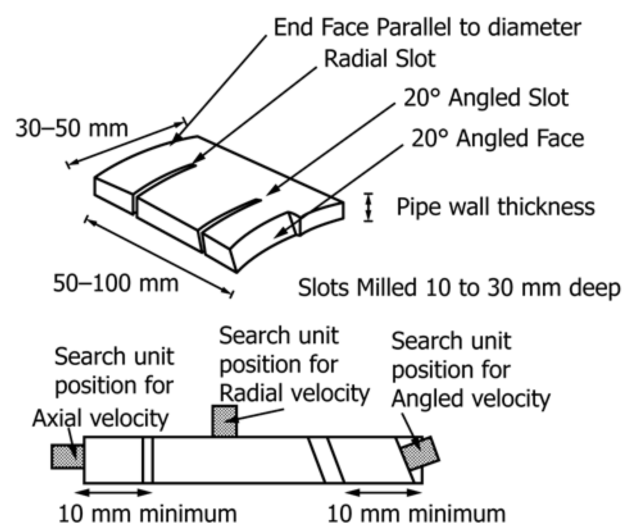
A1.5 *Tolerances* —In order that the error in velocity determination be not greater than ±20 m/s (780 in./s), thickness measurements of the samples must be accurate to ±0.1 mm (0.004 in.) and time measurements must be accurate to ± 25 ns.

A1.6 *Recording and Plotting*—Values for the velocities determined can be tabulated and graphed. By plotting velocities on a two-dimensional polar graph for a single plane, velocities at angles other than those made directly can be estimated. The effect of temperature on velocity can be significant under extreme examination conditions, therefore the temperature at which these readings have been made should also be recorded.



Backwall and first multiple displayed (initial pulse delayed off screen)

FIG. A1.2 Example of Time Interval Measured in Birefringent Material



Slot width not important

FIG. A1.3 Steel Specimen

A2. TYPICAL SEARCH UNIT CONFIGURATION

A2.1 Fig. A2.1 illustrates a typical configuration for search unit array placement on a girth weld. Motion is facilitated using mechanized carrier on a welding band which keeps the search unit exit points at fixed distances from the weld centerline.

A2.2 Fig. A2.2 illustrates an example of beam configurations used to examine a weld in a single pass. The weld bevel illustrated is used in an Automatic Gas Metal Arc Welding (GMAW) process. The six zones identified would be typical of a pipe wall thickness of 12.6 mm (0.496 in.). Search unit placement is symmetric about the weld centerline. Only search units used on one side of the weld are illustrated.

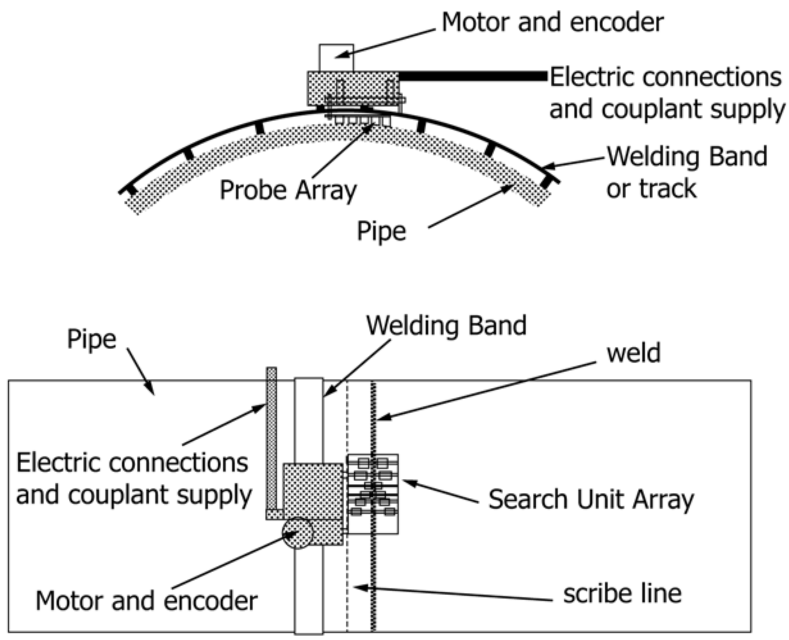


FIG. A2.1 Typical Search Unit Configuration

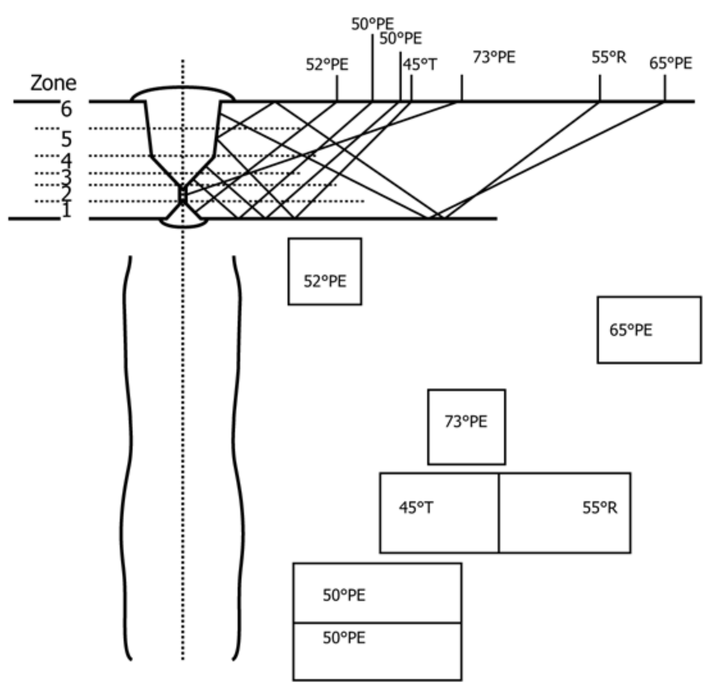


FIG. A2.2 Example of Beam Configurations

A3. MINIMUM REQUIREMENTS FOR REFERENCE STANDARDS

A3.1 *Instrument Standardization*—A reference standard shall be constructed and used to standardize the system and demonstrate proper positioning and performance of the scanning apparatus.

A3.2 *Material* :

A3.2.1 Material used shall be taken from pipe of the same manufacturer, diameter, thickness, and seam type as that to be examined.

A3.2.2 Acoustic velocity shall be determined using SH shear waves for specific angles cut from the same pipe material to be used (see Annex A1).

A3.3 *Dimensions* —Overall dimensions of the reference standard and its actual shape shall be determined by the size of the search unit array and block support structure. The standard (and its mounting) shall provide sufficient surface area to permit the entire search unit array to traverse the target area of the reference standard during dynamic standardization scanning. The standard and mounting should be equipped with a permanently mounted welding band to allow the array to be correctly positioned and moved during dynamic standardization scanning.

A3.4 *Identification* —All standards shall be permanently identified using hard stamps. Information recorded for each reference standard shall include; manufacturer, diameter, wall thickness, acoustic velocity and serial number. The serial number shall be used to trace recorded information with regards to acoustic velocities, manufacturer and target information.

A3.5 *Targets* :

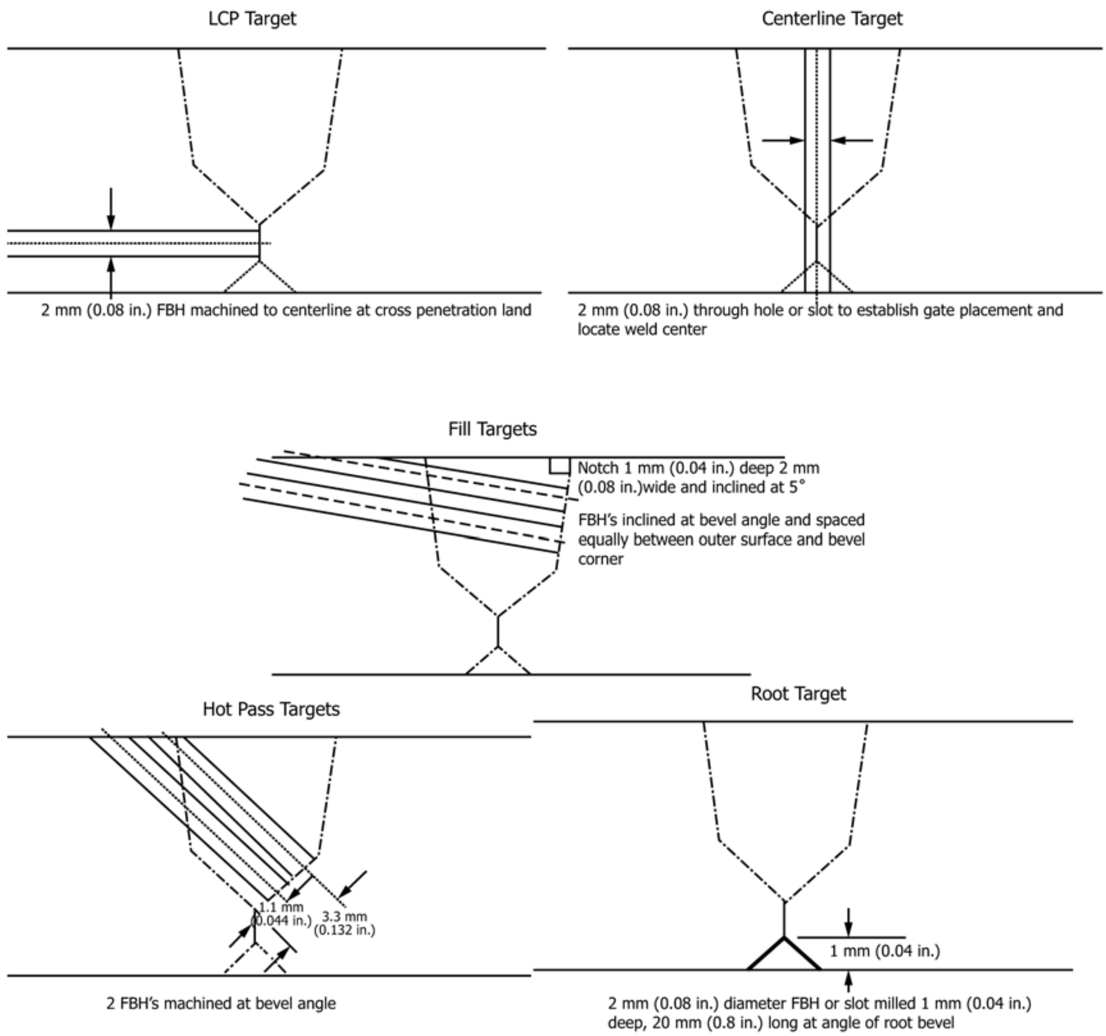
A3.5.1 Targets shall be arranged to allow zonal discrimination based on both weld profile and number of fill passes. (See Fig. A3.1).

A3.5.2 Primary reference targets for fusion areas should be typically 2 to 3 mm (0.08 to 0.12 in.) diameter flat-bottom holes (FBH).

A3.5.3 Square slots 1 mm (0.04 in.) deep and 2 mm (0.080 in.) wide should be machined typically 1 to 2 cm (0.4 to 0.8 in.) long on the design fusion line to indicate locations where undercut or surface breaking non-fusion would occur on the pipe outer surface. Slots may also be used for the root fusion zone. Root slots should be typically 1 to 2 cm (0.4 to 0.8 in.) long and their depth and angular configuration should be identical to the root bevel used in the weld process being examined.

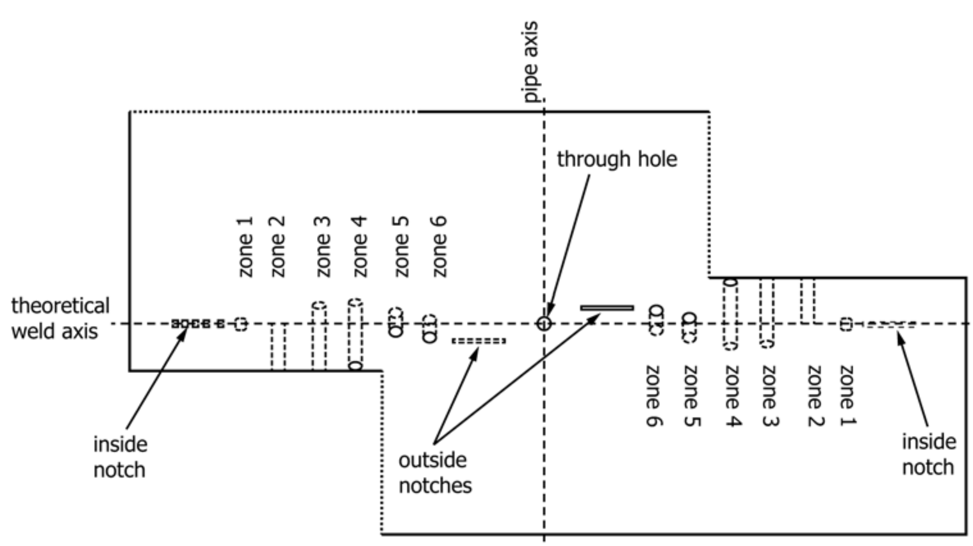
A3.5.4 A centerline through hole, 2 mm (0.08 in.) diameter, should be drilled to verify detectability of centerline flaws and to ensure gate length is sufficient to cover 1 mm (0.04 in.) past the weld centerline.

A3.6 Lateral positioning of the targets shall be such as to allow for independent signals. The beam of each search unit shall pass across the target without any part of the beam encountering adjacent targets during the time the primary target is in the beam. (See Fig. A3.2).



NOTE 1—Fig. A3.1 uses a weld bevel configuration typical of the automatic gas metal arc welding process to illustrate the minimum number of targets for a more complex weld bevel geometry.

FIG. A3.1 Illustrations of Targets



NOTE 1—Fig. A3.2 illustrates placement of holes and slots relative to the weld centerline for a six-zoned weld similar to the configuration used in Fig. A3.1.

FIG. A3.2 Illustrations of Target Layout on Reference Standard Pipe Section

A3.7 The contractor may add other targets to the above minimum required in A3.5 provided they do not interfere with the required targets.

A3.8 *Tolerances* —Tolerances of targets should be as follows:

Hole diameters	±0.2 mm (0.008 in.)
Slot lengths	±1.0 mm (0.040 in.)
Slot depths	±0.2 mm (0.008 in.)
All pertinent angles	±1°
Center position of all targets	±0.2 mm (0.008 in.)

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E1961 - 11) that may impact the use of this standard. (June 1, 2016)

(1) Added ISO 9712 to 2.7 and subsection 5.2.1.
(2) Corrected subsection 8.2.2, to use "specular" in place of "perpendicular."
(3) Addressed re-examination criteria for missing data lines in subsection 10.7.3.
(4) Renumbered notes in Table 1 from "Note 1" and Note 2" to "Table 1 Note A" and "Table 1 Note B."
(5) Renumbered note in Table 2 from "Note 1" to "Table 2 Note A."