Designation: ~~E213 – 20~~ E213 – 22

Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing[1]

This standard is issued under the fixed designation E213; 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[2] covers a procedure for detecting discontinuities in metal pipe and tubing during a volumetric examination using ultrasonic methods. Specific techniques of the ultrasonic method to which this practice applies include pulse-reflection techniques, both contact and non-contact (for example, as described in Guide E1774 and Practice E1816), and angle beam immersion techniques, both conventional and phased array. Artificial reflectors consisting of longitudinal, and, when specified by the using party or parties, transverse reference notches placed on the surfaces of a reference standard are employed as the primary means of standardizing the ultrasonic system.

1.2 This practice is intended for use with tubular products having outside diameters approximately ½ in. (12.7 mm) and larger, provided that the examination parameters comply with and satisfy the requirements of Section ~~12~~11. These procedures have been successful with smaller sizes. These may be specified upon contractual agreement between the using parties. These procedures are intended to ensure that proper beam angles and beam shapes are used to provide full volume coverage of pipes and tubes, including those with low ratios of outside diameter-to-wall thickness, and to avoid spurious signal responses when examining small-diameter, thin-wall tubes.

1.3 The procedure in Annex A1 is applicable to pipe and tubing used in nuclear and other special and safety applications. The procedure in Annex A2 may be used to determine the helical scan pitch.

1.4 This practice does not establish acceptance criteria; they must be specified by the using party or parties.

1.5 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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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 ASME Boiler and Pressure Vessel Code applications, see related Practice SE-213 in the Code.

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]
E543 Specification for Agencies Performing Nondestructive Testing
E1065 Practice for Evaluating Characteristics of Ultrasonic Search Units
E1316 Terminology for Nondestructive Examinations
E1774 Guide for Electromagnetic Acoustic Transducers (EMATs)
E1816 Practice for Measuring thickness by Pulse-Echo Electromagnetic Acoustic Transducer (EMAT) Methods
2.2 *ASNT Documents:*[4]
Recommended Practice SNT-TC-1A for Nondestructive Testing Personnel Qualification and Certification
ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel
2.3 *ISO Standard:*[5]
ISO 9712 Non-destructive Testing— Qualification and Certification of NDT Personnel
2.4 *AIA Document:*[6]
NAS 410 Certification and Qualification of Nondestructive Testing Personnel

3. Terminology

3.1 *Definitions*—For definitions of terms used in this practice, see Terminology E1316.

4. Summary of Practice

4.1 A pulsed ultrasonic angle beam by means of non-contact, surface contact, or immersion method shall be used. Fig. 1 illustrates the characteristic ultrasonic angle beam entry into the wall of a pipe or tube in the circumferential direction to detect longitudinal discontinuities using a single search unit. Fig. 2 illustrates the characteristic angle beam ultrasound entry into the wall of a pipe or tube in the axial direction to search for transverse discontinuities using a single search unit.

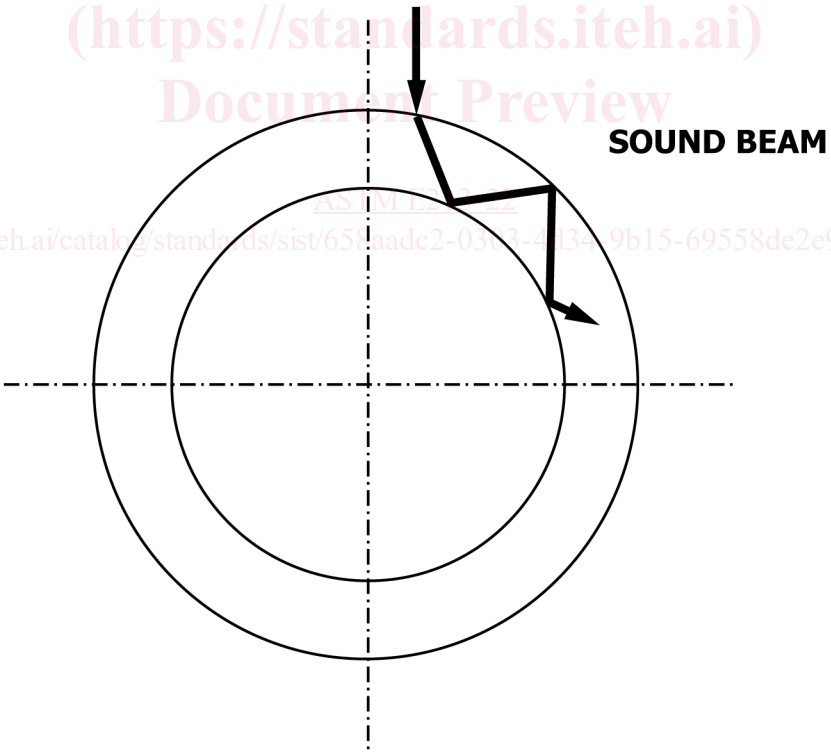


FIG. 1 Circumferential Propagation of Sound in a Pipe or Tube Wall

[3] 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.
[4] Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, http://www.asnt.org.
[5] 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.
[6] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

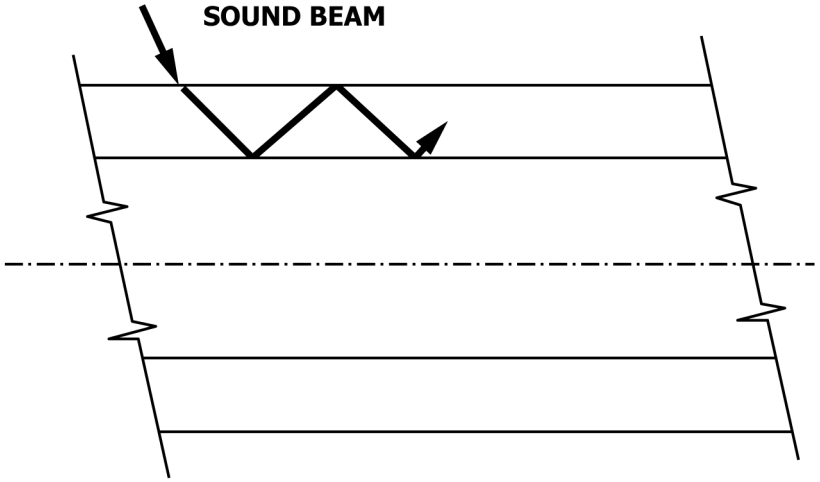


FIG. 2 Axial Propagation of Sound in a Pipe or Tube Wall

NOTE 1—The immersion method may include tanks, wheel search units, or systems that use streams or columns of liquid to couple the ultrasonic energy from the search unit to the material.

4.2 To ensure detection of discontinuities that may not provide a favorable response from one side, scanning shall be performed in both circumferential directions for longitudinal discontinuities and when an axial scan is specified by the using party or parties, in both axial directions for transverse discontinuities.

4.3 For efficient examination of large quantities of material, multiple search units and instruments may be used simultaneously to perform scanning in the required directions. Multiple search units may be employed for "interlaced" scanning in each required direction to enable higher examination rates to be achieved through higher allowable scan index or "pitch."

5. Significance and Use

5.1 The purpose of this practice is to outline a procedure for detecting and locating significant discontinuities such as pits, voids, inclusions, cracks, splits, etc., by the ultrasonic pulse-reflection method.

6. Basis of Application

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

6.2 If specified in the contractual agreement, personnel performing examinations to this practice shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT-CP-189, SNT-TC-1A, ISO 9712, NAS 410, 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.

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

6.4 Size and type of pipe or tubing to be examined.

6.5 *Procedures and Techniques*—The ~~following are items that must be decided upon by the using party or parties.~~procedures and techniques to be utilized shall be as specified in the contractual agreement and should include:

6.5.1 ~~Size and type of pipe or tubing to be examined.~~Type, dimension, location, and number of reference reflectors to be placed in the reference standard,

6.5.2 ~~Additional scanning for transverse discontinuities.~~Method(s) for measuring side versus side acoustic response of reference notches and tolerance limits,

6.5.3 Items that affect examination coverage may also be specified such as scan overlap, examination frequency, pulse density, and maximum search unit ~~size.~~size,

6.5.4 ~~The stage(s) in the manufacturing process at which the material will be examined.~~Sound beam orientation and number of beams used,

6.5.5 ~~Surface condition.~~Number of dead elements within a phased array virtual probe,

6.5.6 Procedure and use of distance amplitude compensation, and

6.5.7 Maximum time interval between equipment standardization checks, if different from that described in ~~13.2~~12.2, and the tolerance to be applied to a standardization ~~check.~~check,

~~6.1.7 Type, dimensions, location, method of manufacture, and number of artificial reflectors to be placed on the reference standard.~~

~~6.1.8 Method(s) for measuring dimensions of artificial reflectors and tolerance limits if different than specified in Section 11.~~

~~6.1.9 Method(s) for measuring side versus side acoustic response of reference notches and tolerance limits.~~

~~6.1.10 Criteria for reportable and rejectable indications (acceptance criteria).~~

~~6.1.11 Reexamination of repaired/reworked items, if required or permitted, shall be specified in the contractual agreement.~~

~~6.1.12 Requirements for permanent records of the response from each tube, if applicable.~~

~~6.1.13 Contents of examination report.~~

~~6.1.14 Operator qualifications and certification, if required.~~

~~6.1.15 Qualification of Nondestructive Agencies. If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in Specification E543. The applicable edition of Specification E543 shall be specified in the contractual agreement.~~

~~6.1.16 Level of personnel qualification. (See 7.1.)~~

6.6 The stage(s) in the manufacturing process at which the material will be examined.

6.7 *Surface Preparation*—The pre-examination surface preparation if additional requirements are necessary beyond what is specified in Section 7.

6.8 *Reporting*

6.8.1 Criteria for reportable and rejectable indications (acceptance criteria), and

6.8.2 Requirements for permanent records of the response from each tube, if applicable.

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

~~7. Personnel Qualification~~

~~7.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in accordance with a nationally recognized NDT personnel qualification practice or standard such as ANSI/ASNT CP-189, SNT-TC-1A, ISO~~

~~9712, NAS 410, 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.~~

7. Surface Condition

7.1 All surfaces shall be clean and free of scale, dirt, grease, paint, or other foreign material that could interfere with interpretation of examination results. The methods used for cleaning and preparing the surfaces for ultrasonic examination shall not be detrimental to the base metal or the surface finish. Excessive surface roughness or scratches can produce signals that interfere with the examination.

8. Apparatus

8.1 Instruments shall be of the pulse echo type and shall be capable of detecting the reference notches of the types described in Section ~~11~~10 to the extent required in the standardization procedure described in Section ~~12~~11. An independent channel (or channels) of instrumentation shall be employed to individually monitor the responses from the longitudinal and, when required, transverse oriented search units. The instrument pulse repetition rate per channel shall be capable of being adjusted to a sufficiently high value to ensure notch detection at the scanning rate employed. The instrument shall be capable of this pulse repetition rate without false indications due to spurious reflections or interference from other instruments and search units being used for simultaneous examinations in other directions or along other scan paths.

8.1.1 The frequency and bandwidth of the instrument and search unit shall be capable of being selected to produce a satisfactory signal-to-noise ratio for the detection of the required notches as compared to background "noise" response from irregularities such as grain boundaries and surface roughness.

8.2 Search unit frequency shall be selected to produce a desirable "signal-to-noise" ratio (S/N), from the material to be examined, at the specified sensitivity. A S/N value of at least 3 to 1 is usually considered to be minimum. A higher minimum value is desirable and may be specified by the contracting agency.

8.2.1 Select a search unit size, frequency, and refracted angle (or corresponding parameters for non-contact techniques) to produce an approximate 45 degrees beam-center shear wave in the tube or pipe wall. For material with an outside diameter-to-thickness ratio less than 7, a lower refracted angle (or corresponding parameters for non-contact techniques) must be used to ensure intersection with the inside surface. This does not ensure detection of midwall discontinuities (See Ref (**1**)).[7]

8.2.2 *Phased Array Transducers: Linear or Non-Linear Arrays*—Each virtual probe in the array shall meet the applicable requirements of a search unit as defined in 8.2.1. Virtual probe responses within an array shall be normalized to each other for a defined beam profile.

8.2.3 For contact systems, the curvature of the contact mechanism should match the tube outside diameter.

8.3 The positions of all conveyor and drive mechanisms must be set to support and feed the material to be examined in a stable manner and at the desired scan "pitch" (helix). For small tubes, support mechanisms must be used in the examination station to prevent any transverse motion with respect to the search unit beam during scanning. If larger material that is not straight is to be examined, the search units may have to be supported in a "follower" mechanism to compensate for this.

9. Couplant

9.1 For piezoelectric-based search units (non-contact techniques do not require couplant), a couplant such as water, oil, or glycerin, capable of conducting ultrasonic vibrations between the search unit and the pipe or tube being examined shall be used. Rust inhibitors, softeners, and wetting agents may be added to the couplant. The couplant liquid with all the additives shall not be detrimental to the surface condition of the pipe or tube, and shall wet the surface of the material to provide adequate coupling efficiency. To prevent spurious signals or loss of sensitivity, or both, care must be taken to avoid the presence of air bubbles in the couplant. For contact, squirter, or wheel-type systems, the equipment may use ultrasonic or other means/techniques to monitor the coupling to ensure uninterrupted examination.

NOTE 2—In the contact method, some couplants result in better ultrasonic transmission when the tubing is precoated several hours before the examination.

[7] The boldface numbers in parentheses refer to the list of references at the end of this standard.

10. Reference Standards

10.1 A reference standard of a convenient length (see A1.4) shall be prepared from a length of pipe or tube of the same nominal diameter, wall thickness, material, surface finish, and acoustical properties as the material to be examined. The reference pipe or tube shall be free of discontinuities or other conditions producing indications that can interfere with detection of the reference notches.

10.2 Longitudinal and, when required by the contracting agency, transverse reference notches shall be placed on both the outside and inside surfaces of the reference standard to ensure satisfactory examination sensitivity near each of these boundaries.

10.3 Reference notches shall be separated sufficiently (circumferentially or axially, or both) to preclude interference and interpretation difficulties.

10.4 All upset metal, burrs, etc., adjacent to the reference notches shall be removed.

10.5 The notch dimensions and tolerances, which are length, depth, and width (and for V-notches, the included angle) must be decided upon by the using party or parties, unless specified otherwise by the product specification. Fig. 3 illustrates the common notch configurations and the dimensions to be measured (Note 3). Reflection amplitudes from V-, square-, and U-shaped notches of comparable dimensions may vary widely depending on the angle, frequency, and vibrational mode of the interrogating sound beam.

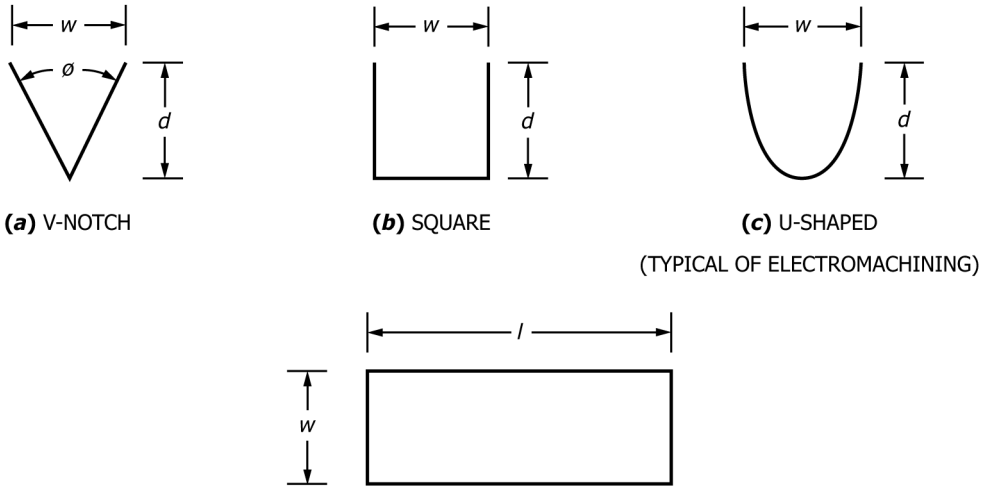
NOTE 3—In Fig. 3 (*a*), (*b*), and (*d*), the sharp corners are for ease of illustration. It is recognized that in normal machining practice, a radius will be generated.

10.5.1 The notch depth shall be an average measured from the circular tubing surface to the maximum and minimum penetration of the notch. Measurements may be made by optical, replicating, or other agreed upon techniques. Unless specified otherwise by the using party or parties, the notch depth shall be within ±0.0005 in. (0.013 mm) of the specified value for notches 0.005 in. (0.13 mm) or less in depth, and within + 10, – 15 % of the specified value for notches over 0.005 in. in depth. At the option of the testing agency, shallower notches may be used to provide a more stringent examination.

NOTE 4—For as-rolled or scaly pipe or tube surfaces, it may be necessary to modify ~~11.5.1~~10.5.1. Two acceptable modifications are listed below. Modification (*a*) is preferred; however, modification (*b*) may be used unless otherwise specified.

(*a*) The circular pipe or tube surface may be smoothed or prepared in the notch area, or

(*b*) The notch depth shall be within ±0.002 in. (0.051 mm), or + 10, – 15 % of the specified depth, whichever is greater.



(*a*) V-NOTCH **(*b*)** SQUARE **(*c*)** U-SHAPED

(TYPICAL OF ELECTROMACHINING)

(*d*) TOP

FIG. 3 Common Notch Shapes

10.5.2 When notch tolerances are specified by the using party or parties, tolerances may often include only negative values with zero positive deviation allowed so that sensitivity is never reduced below a specified minimum value. The use of smaller notches by the examination agency is permissible, provided that concurrence is obtained from the contracting agency.

NOTE 5—The amplitude of indications obtained from reference notches may not be linearly proportional to notch depth. This depends upon the transducer beam profile as well as the intercepting beam width to notch length.

10.5.3 The width of the notches shall be as small as practical, but should not exceed twice the depth.

10.6 Other types and orientations of reference reflectors may be specified by the using party or parties.

11. Standardization of Apparatus

11.1 *Static Standardization*—Using the reference standard specified in Section ~~11~~10, adjust the equipment to produce clearly identifiable indications from both the inner and outer surface notches. The response from the inner and outer surface notches should be as nearly equal as possible. Use the lesser of the two responses to establish the rejection level. On large diameter or heavy wall pipe and tubing, if the inner and outer surface notch amplitude cannot be made equal because of material soundpath distance and inside diameter curvature, a separate rejection level or gain may be established for the inner and outer surface notches.

NOTE 6—*Distance-Amplitude Correction*— A method of compensating for the reduction in ultrasonic signal amplitude as a function of material sound-path distance may be employed. Details of the procedures used to establish and apply the distance-amplitude correction (DAC) curve shall be established by the using party or parties.

11.2 *Dynamic Standardization*—Standardize the equipment under dynamic conditions that simulate the production examination. The pipe or tubing to be examined and the search unit assembly shall have a rotating translating motion relative to each other such that a helical scan path will be described on the outer surface of the pipe or tube. Maintain the speed of rotation and translation constant within ±10 %. Axial scanning with circumferential indexing may be used to provide equivalent coverage.

11.3 The pitch of the feed helix shall be small enough to ensure at least 100 % coverage at the examination distance and sensitivity established during standardization. Coverage shall be based upon the maximum effective size of the search unit, the pulse density for each instrument channel, and the helix.

12. Procedure

12.1 Examine the pipe or tubing with the ultrasound transmitted in both circumferential directions for longitudinal discontinuities and, when specified, in both axial directions for transverse discontinuities, under identical conditions used for equipment standardization (see Note 7).

NOTE 7—Identical conditions include all instrument settings, mechanical motions, search unit position and alignment relative to the pipe or tube, liquid couplant, and any other factors that affect the performance of the examination.

12.2 *Standardization Checks*—Periodically check the dynamic standardization of the equipment by passing the reference standard through the examination system in accordance with ~~12.2~~11.2. Make these checks prior to any examination run, prior to equipment shutdown after an examination run, and at least every four hours during continuous equipment operation. Restandardize the equipment in accordance with ~~12.1~~11.1 and ~~12.2~~11.2 any time the equipment fails to produce the signal amplitudes or other conditions for rejection within the tolerances agreed upon with the contracting agency or the product manufacturer's procedure. In the event that the equipment does not meet this requirement, reexamine all pipe or tubing examined since the last acceptable standardization after restandardization has been accomplished.

12.2.1 When required by the purchaser, more specific restandardization criteria may be specified.

12.3 For many tubular sizes and examination arrangements, there will be a reflection from the entry surface of the pipe or tube. This signal may be observed, but not gated for evaluation purposes, as a supplement to the required checking of the reference standard to provide increased assurance that the equipment is functioning properly. If such a signal does not exist, make more frequent equipment standardization checks.