Designation: 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 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.*

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

[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.

[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.

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

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.

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 procedures and techniques to be utilized shall be as specified in the contractual agreement and should include:

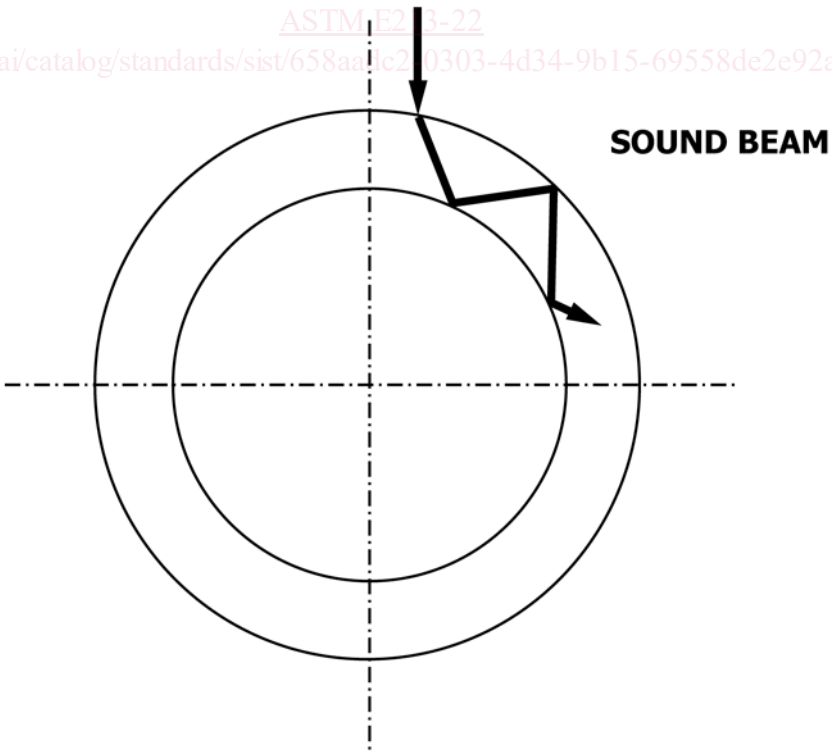


FIG. 1 Circumferential Propagation of Sound in a Pipe or Tube Wall

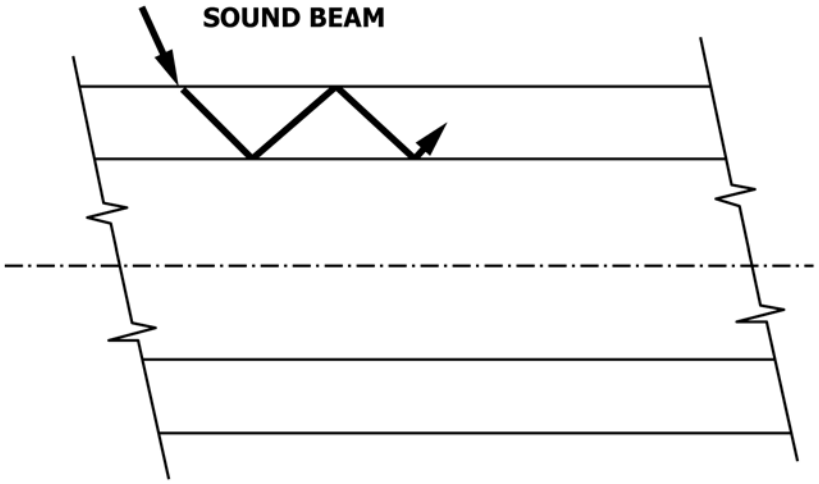


FIG. 2 Axial Propagation of Sound in a Pipe or Tube Wall

6.5.1 Type, dimension, location, and number of reference reflectors to be placed in the reference standard,

6.5.2 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,

6.5.4 Sound beam orientation and number of beams used,

6.5.5 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 12.2, and the tolerance to be applied to a standardization check,

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. 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 10 to the extent required in the standardization procedure described in Section 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.

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

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

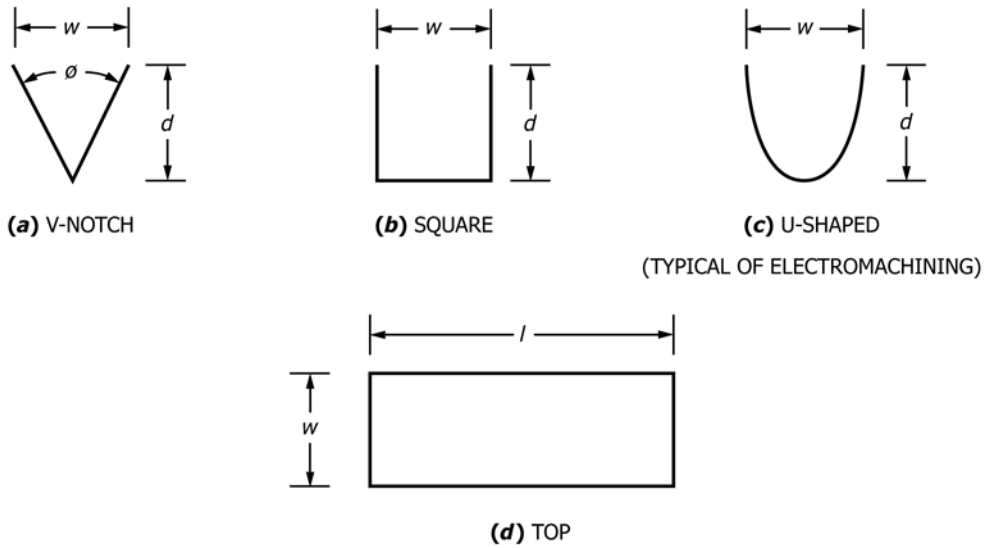


FIG. 3 Common Notch Shapes

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 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.

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 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 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 11.1 and 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.

12.4 Do not make any equipment adjustments, during examination, unless the complete standardization procedure described in Section 11 is performed after any such adjustment.

12.5 The examination shall be applied to 100 % of the pipe or tubing unless otherwise specified.

NOTE 8—Some traversing mechanisms do not allow examination of pipe or tube ends. When this condition exists, clearly indicate the extent of this effect, per tube, in the examination report.

13. Interpretation of Results

13.1 All indications that are equal to or greater than the rejection level established during standardization as described in Section 11, using the agreed upon reference indicators described in 10.5, shall be considered as representing defects and may be cause for rejection of the pipe or tube. Alternatively, the using party or parties may specify specific acceptance criteria or other means (manual or semi-automated techniques) to further evaluate the indication to determine its acceptability.

13.2 If, upon further examination of the pipe or tube, no rejectable indications are detected, the material shall be considered as having passed the ultrasonic examination, except as noted in 12.2.

NOTE 9—Rejected pipe or tubes may be reworked in a manner acceptable to the purchaser. If, upon ultrasonic reexamination of the reworked pipe or tube, no rejectable indications are detected, the material should be considered as having passed the ultrasonic examination.

NOTE 10—Care should be exercised to ensure that reworking a pipe or tube does not change its acceptability with respect to other requirements of the material specification such as wall thickness, ovality, surface finish, length, and the like.

14. Documentation

14.1 When a report is required, it shall contain such information as is mutually considered adequate to document that the examination of the pipe or tubes supplied meets the requirements of this practice, and any modifications specified in the contractual agreement.

14.2 When a "third party" examination is required, as might be performed by an independent examination facility, and to the extent specified in the contractual agreement, a permanent record containing objective evidence of the examination results shall be obtained for each pipe or tube examined. It shall contain recordings of all standardizations and standardization checks and should be annotated to provide a positive correlation between examination record for each reject pipe or tube and the corresponding pipe or tube. The supplier shall maintain a report of the examination on file. When requested by the customer, a report of the examination shall be submitted to the customer. The report shall include at least the following information:

14.2.1 Identification of the material by type, size, lot, heat treatment, and any other pertinent information.

14.2.2 Identification of the examination equipment and accessories.

14.2.3 Details of the examination technique, including examination speed, examination frequency, and end effects if any.

14.2.4 Description of the reference standard, including the actual (measured) dimensions of the artificial reference reflectors.

14.2.5 Description of the distance-amplitude correction procedure, if used.

14.2.6 Examination results.

15. Keywords

15.1 angle beam; nondestructive examination; pipe; tubing; ultrasonic examination

ANNEXES

(Mandatory Information)

A1. EXAMINATION OF PIPE AND TUBING FOR SPECIAL AND SAFETY APPLICATIONS

A1.1 Introduction—When the end use of pipe or tubing depends critically upon freedom from discontinuities over a certain maximum size, certain additional ultrasonic examination procedures are required to assure that the required quality standards are met. The immersion method is almost always required for examining tubes for these uses. In some instances, such as field examination or where part contact with water is undesirable, the contact method, or non-contact technique, for instance as described in Guide E1774, may be employed.

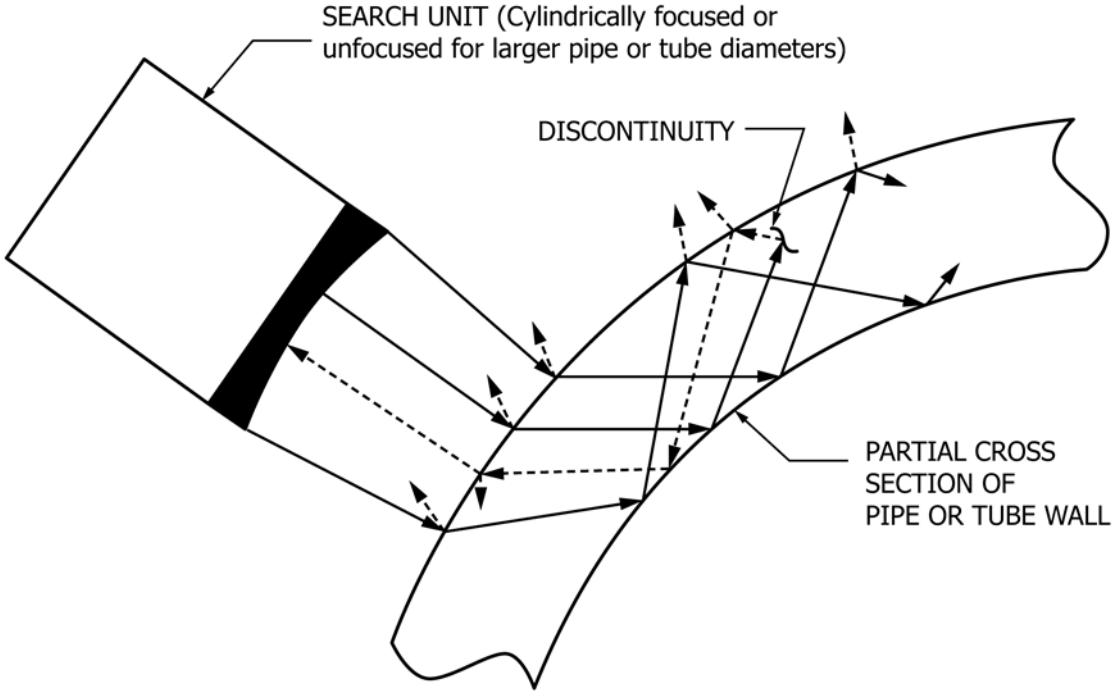
A1.1.1 This practice is intended for use with tubular products of any diameter and wall thickness, provided that proper procedures, as described herein, are followed. These procedures are intended to ensure that proper refraction angles and beam shapes are used to provide full volume coverage of pipes 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.

A1.2 Summary of Practice—Pulsed ultrasonic angle beams by either the surface contact or immersion method shall be used. Fig. A1.1 illustrates characteristic angle beam ultrasound entry into the wall of a pipe or tube in the circumferential direction to detect longitudinal defects and in the axial direction to detect transverse defects, when required. The incident and refracted beams in these cases are pictured as being generated by a cylindrically focused immersion search unit. In pipes and tubes with diameters several times larger than the length of a contact search unit, the general beam shapes are approximately the same.

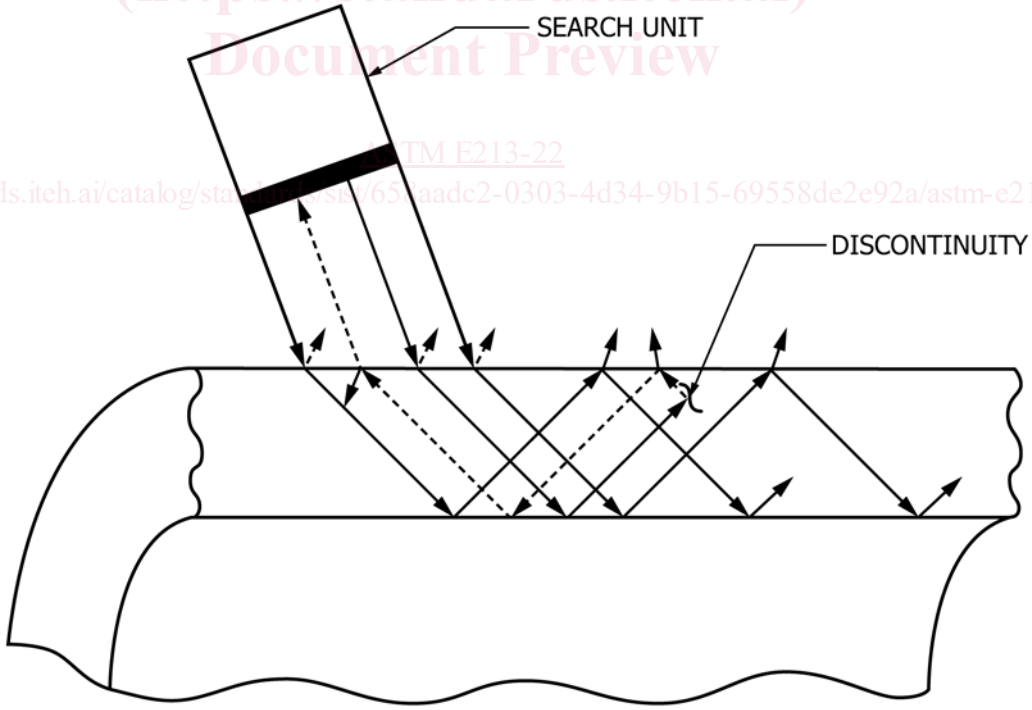
A1.3 Additional Apparatus Requirements

A1.3.1 Although contact search units may be used for small quantity and field examinations of pipes and tubes, cylindrically (line) focused immersion search units are preferred for critical examinations and for larger quantities (See Refs (**2**), (**3**), and (**4**)). Search unit element size and focused beam length shall be suitable for achieving reliable detection of defects equivalent in size to the reference notches at the scanning pitch or index used. When examination of heavy-wall pipes and tubes is required, the focal length, refraction angle, and included beam angle of focused search units shall be suitable for complete through-wall coverage (See (**1**)).

A1.3.2 The beam length of the search unit in the wall material must be either longer or shorter than the length of longitudinal notches in the reference standard, by an amount that is no less than the "pitch" (linear advance per revolution) of the helical scan path (see A2.1). This is necessary to ensure detection of discontinuities that are as long as the notches in spite of their random locations with respect to the scan path, (See Annex A2).



(a) Circumferential Scan to Search for Axial (Longitudinal) Discontinuities



(b) Axial Scan to Search for Circumferential (Transverse) Discontinuities

FIG. A1.1 Beam Propagation in Pipe or Tube Walls