



Designation: E213 – 14<sup>ε1</sup>

## Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing<sup>1</sup>

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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Order of references corrected editorially in March 2015.

### 1. Scope\*

1.1 This practice<sup>2</sup> 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 angle beam immersion techniques. 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. 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 The values stated in inch-pound units are to be regarded as standard. The SI equivalents are in parentheses and may be approximate.

<sup>1</sup> 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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<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Practice SE-213 in the Code.

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

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>3</sup>

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 Ultrasonic Testing Using Electromagnetic Acoustic Transducer (EMAT) Techniques

#### 2.2 ASNT Documents:

Recommended Practice SNT-TC-1A for Nondestructive Testing Personnel Qualification and Certification<sup>4</sup>

ANSI/ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel<sup>4</sup>

#### 2.3 ISO Standards:

ISO 9712 Non-destructive Testing— Qualification and Certification of NDT Personnel<sup>5</sup>

#### 2.4 Aerospace Industries Association Document:

NAS 410 Certification and Qualification of Nondestructive Testing Personnel<sup>6</sup>

### 3. Terminology

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

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> Available from American Society for Nondestructive Testing, Inc., 1711 Arlingate Lane, Columbus, OH 43228.

<sup>5</sup> Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, <http://www.iso.org>.

<sup>6</sup> Available from Aerospace Industries Association of America, Inc., 1250 Eye St. NW, Washington D.C. 20005.

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

#### 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 are items that must be decided upon by the using party or parties.

- 6.1.1 Size and type of pipe or tubing to be examined,
- 6.1.2 Additional scanning for transverse discontinuities,
- 6.1.3 Items that affect examination coverage may also be specified such as scan overlap, pulse density and maximum search unit size.
- 6.1.4 The stage(s) in the manufacturing process at which the material will be examined,
- 6.1.5 Surface condition,
- 6.1.6 Maximum time interval between equipment standardization checks, if different from that described in 13.2 and the tolerance to be applied to a standardization 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 Criteria for reportable and rejectable indications (acceptance criteria),
- 6.1.10 Reexamination of repaired/reworked items, if required or permitted, shall be specified in the contractual agreement.
- 6.1.11 Requirements for permanent records of the response from each tube, if applicable,
- 6.1.12 Contents of examination report,
- 6.1.13 Operator qualifications and certification, if required,

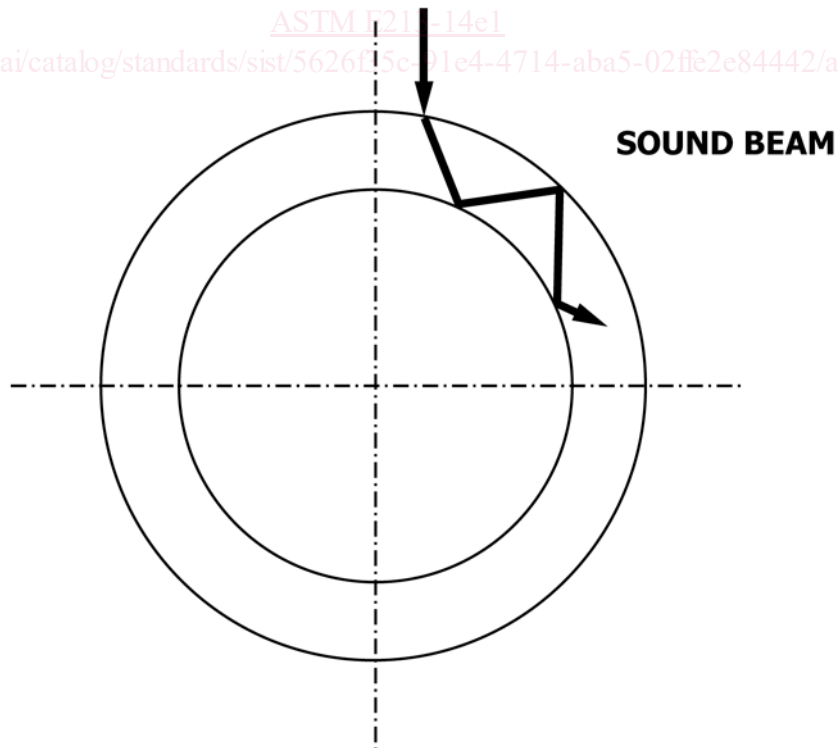


FIG. 1 Circumferential Propagation of Sound in a Pipe or Tube Wall

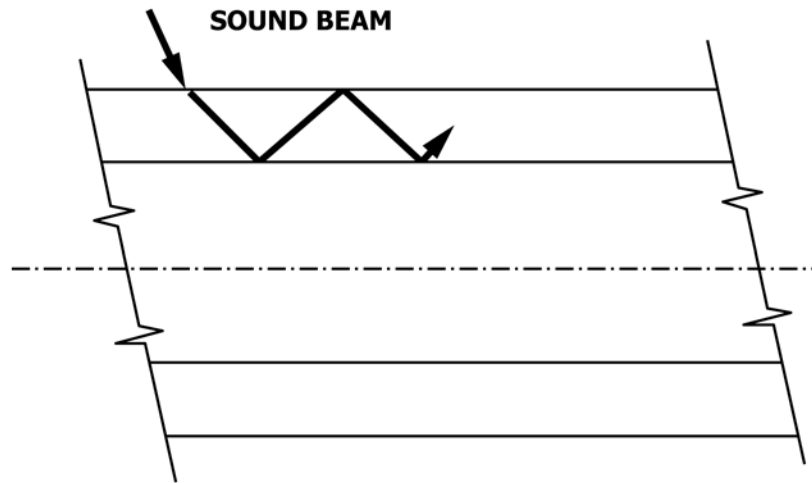


FIG. 2 Axial Propagation of Sound in a Pipe or Tube Wall

6.1.14 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.

6.1.15 Level of personnel qualification. (See 7.1)

## 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.

## 8. Surface Condition

8.1 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.

## 9. Apparatus

9.1 Instruments shall be of the pulse echo type and shall be capable of detecting the reference notches of the types described in Section 11 to the extent required in the standardization procedure described in Section 12. 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 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.

9.1.1 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.

9.2 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.

9.2.1 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 Reference 1).

9.3 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.

## 10. Couplant

10.1 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 should 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.

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

**11. Reference Standards**

11.1 A reference standard of a convenient length 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.

11.2 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.

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

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

11.5 The notch dimensions, which are length, depth, and width (and for V-notches, the included angle) must be decided upon by the using party or parties. 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.

11.5.1 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  $\pm 0.0005$  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. 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  $\pm 0.001$  in. (0.025 mm), or + 10, - 15 % of the specified depth, whichever is greater.

11.5.2 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 intercepting beam width to notch length.

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

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

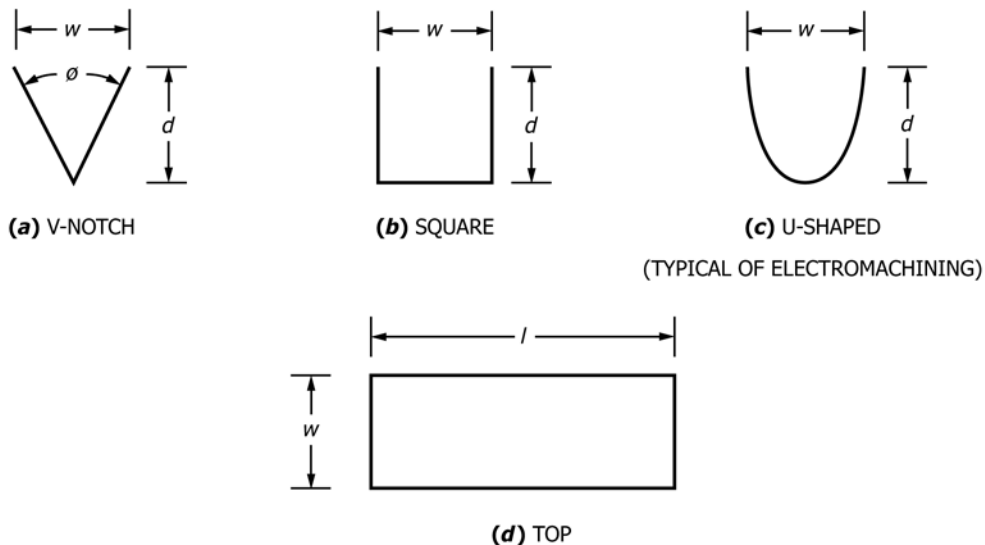


FIG. 3 Common Notch Shapes

## 12. Standardization of Apparatus

12.1 *Static Standardization*—Using the reference standard specified in Section 11, 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 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.

12.2 *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  $\pm 10\%$ . Axial scanning with circumferential indexing may be used to provide equivalent coverage.

12.3 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.

## 13. Procedure

13.1 Examine the pipe or tubing with the ultrasonic 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.

NOTE 8—If a requirement exists for both longitudinal and transverse notches the following three options are available:

- (a) Each pipe or tube is passed through a single-channel examination station four times, twice in each direction,
- (b) Each pipe or tube is passed through a two-channel examination station twice, once in each direction, or
- (c) Each pipe or tube is passed through a four-channel examination station once.

13.2 *Standardization Checks*—Periodically check the dynamic standardization of the equipment by passing the reference standard through the examination system in accordance with 12.2. 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 and 12.2 any time the equipment fails to produce the signal amplitudes or other conditions for rejection within the tolerances agreed

upon with the contracting agency. 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.

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

13.3 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, 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.

13.4 Do not make any equipment adjustments, during examination, unless the complete standardization procedure described in Section 12 is performed after any such adjustment.

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

NOTE 9—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.

## 14. Interpretation of Results

14.1 All indications that are equal to or greater than the rejection level established during standardization as described in Section 12, using the agreed upon reference indicators described in 11.5, 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.

14.2 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 13.2.

NOTE 10—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 11—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.

## 15. Documentation

15.1 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.

15.2 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 pipe or tube examined. This may be in the form of a strip chart recording or computerized data of the ultrasonic instrument output during the examination. 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:

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

15.2.2 Identification of the examination equipment and accessories.

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

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

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

15.2.6 Examination results.

## 16. Keywords

16.1 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 References

(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).

A1.3.3 The focal length of a focused immersion search unit should equal the pipe or tube radius plus a convenient water path length so that it may be focused on the pipe or tube centerline (See (4)).

A1.3.4 The angle of the central beam of the search unit, with respect to a perpendicular to the tangent to the surface at the point of beam incidence, shall be adjusted to produce a suitable refraction angle in the pipe or tube wall to provide complete coverage of the pipe or tube wall thickness (See (1)). A refraction angle of 45 degrees is typically used when examining pipe or tubes with a diameter-to-wall thickness ratio of no less than about 10 to 1. For many materials a 45 degree refraction angle may be achieved with a beam incidence angle of about 18 to 19 degrees. This may be achieved in the immersion method by parallel offsetting the beam centerline from a perpendicular to a tangent of the surface by a distance equal to 1/6 of the outside diameter of the pipe or tube. This is often a convenient initial adjustment during system standardization.