Designation: E 2223 – 02

Standard Practice for Examination of Seamless, Gas-Filled, Steel Pressure Vessels Using Angle Beam Ultrasonics[1]

This standard is issued under the fixed designation E 2223; 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 describes a contact angle-beam shear wave ultrasonic technique to detect and locate the circumferential position of longitudinally oriented discontinuities and to compare the amplitude of the indication from such discontinuities to that of a specified reference notch. This practice does not address examination of the vessel ends. The basic principles of contact angle-beam examination can be found in Practice E 587. Application to pipe and tubing, including the use of notches for standardization, is described in Practice E 213.

1.2 This practice is appropriate for the ultrasonic examination of cylindrical sections of gas-filled, seamless, steel pressure vessels such as those used for the storage and transportation of pressurized gasses. It is applicable to both isolated vessels and those in assemblies.

1.3 The practice is intended to be used following an Acoustic Emission (AE) examination of stacked seamless gaseous pressure vessels (with limited surface scanning area) described in Test Method E 1419.

1.4 This practice does not establish acceptance criteria. These are determined by the reference notch dimensions, which must be specified by the using parties.

NOTE 1—Background information relating to the technical requirements of this practice can be found in the references sited in Test Method E 1419, Appendix X1.

1.5 Dimensional values stated in in-pound units are regarded as standard; SI equivalents, in parentheses may be approximate.

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:*

E 213 Practice for Ultrasonic Examination of Metal Pipe and Tubing[2]

E 543 Practice for Agencies Performing Nondestructive Testing[2]

E 587 Practice for Ultrasonic Angle-Beam Examination by the Contact Method[2]

E 1316 Terminology for Nondestructive Examinations[2]

E 1419 Test Method for Examination of Seamless, Gas-Filled, Pressure Vessels Using Acoustic Emission[2]

2.2 *ASNT Documents:*

Recommended Practice SNT-TC-1A for Personnel Qualification and Certification[3]

ANSI/ASNT-CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel[3]

2.3 *AIA Document:*

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

3. Terminology

3.1 Terminology relating to this practice for angle-beam shear wave ultrasonic examination is defined in Terminology E 1316.

4. Summary of Methodology

4.1 An ultrasonic pulse-echo contact angle-beam, shear wave technique with the beam directed circumferentially is used to locate surface breaking discontinuities in the cylindrical wall of a pressure vessel. The amplitude of the reflected signal from the discontinuity is compared to that of a known reference notch. Scanning is performed in both clockwise and counter clockwise directions to detect and confirm the position of the discontinuity identified in the AE examination report.

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

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[2] *Annual Book of ASTM Standards*, Vol 03.03.

[3] Available from the American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518.

[4] Available from Aerospace Industries Association of America, Inc., 1250 Eye St., NW, Washington, DC 20005..

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5. Significance and Use

5.1 The purpose of this practice is to provide a procedure for locating, detecting and estimating the relevance of longitudinally oriented crack-like discontinuities which have been previously indicated by AE examination.

5.2 This practice may be used for a pressure vessel that is situated in such a way as to limit access to the vessel's wall. Typical examples include tube trailers and gas tube railroad cars. Since the pressure vessels are stacked horizontally in a frame, with limited space between them, the circumferential location of a discontinuity may be a distance away from the search unit (several skip distances).

5.3 This practice has been shown to be effective for cylinders between 9 in. (229 mm) and 24 in. (610 mm) in diameter and wall thicknesses between ¼ in. (6.4 mm) to 1 in. (26 mm) with discontinuities that are oriented longitudinally in pressure vessel sidewall.

5.4 To be reliably detected by the procedure in this practice, a significant part of the reflecting surface must be transverse to the beam direction.

5.5 Evaluation of possible discontinuity in the end faces indicated by AE is not covered by this practice.

6. Basis of Application

6.1 *Personnel Qualification*

6.1.1 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, NAS-410, or a similar document and certified by the employer or certifying agency, as applicable. The standard used and its applicable revision shall be specified by the regulatory authority, or stated in the contractual agreement, or both.

6.1.2 *Additional Personnel Training*

6.1.2.1 Personnel performing this type of examination shall have additional training in the following topics.

6.1.3 Construction and manufacturing techniques for seamless steel pressure vessels.

6.1.4 Familiarity with the types of discontinuities that may occur in this type of pressure vessels.

6.2 *Qualification of Nondestructive Agencies*

6.2.1 If specified in the contractual agreement, NDT agencies shall be qualified and evaluated as described in the applicable Sections 5 through 9 of Practice E 543. The applicable edition shall be specified by the regulatory authority, or stated in the contractual agreement, or both.

6.3 *Extent of Examination*

6.3.1 The extent of the examination shall be in accordance with the procedures in Sections 9 and 10 unless otherwise specified.

6.3.2 The reference notch dimensions shall be specified by the regulatory authority, or stated in the contractual agreement, or both.

6.4 *Reporting Criteria*

6.4.1 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 defined in accordance with Section 8 and by the regulatory authority or stated in the contractual agreement.

6.5 *Reexamination of Repaired/Reworked Items*

6.5.1 Reexamination of repaired/reworked items is not addressed in this standard and if required shall be specified by the regulatory authority, or stated in the contractual agreement, or both.

7. Apparatus

7.1 Ultrasonic pulse-echo instrumentation shall have a minimum capacity of examining at center frequencies from 2¼ to 5 MHz. The instrument, search units and related equipment shall be cable of displaying the peak amplitude of the indication from the reference notch in the standardization ring, as described in Section 8, and locating its circumferential position over the full sweep range required for coverage of the vessel to be examined.

7.1.1 Each search unit used for this technique shall have the appropriate frequency and refracted angle for the material and geometry of the pressure vessel that is being examined. The frequency and angle of the search unit is selected during standardization and is related to diameter, wall thickness and the type of steel used for the vessel and corresponding standardization rings.

7.1.1.1 The angle and frequency of the search unit to be used shall be determined by using different search units on a reference ring that represents the examination piece. A search unit which can satisfactorily detect and display the indication from the notch in the reference ring at the maximum distance to be used during the examination shall be selected for setting up the Distance Amplitude Correction (DAC) curve for examination in accordance with 9.3.

7.1.1.2 Select search units for evaluation from those having frequencies 2 ¼ and 5 MHz with refracted angles of 45° to 75° in steel, and in available commercial sizes. Those producing the required sensitivity and DAC response on the appropriate reference ring are acceptable. These search units have generally been found satisfactory for the examination of the type of vessels specified in 5.3.

7.1.1.3 The search unit shall be comprised of a transducer mounted on a plastic wedge that is designed to have continuous acoustic coupling between search unit and the pressure vessel wall.

NOTE 2—This is usually accomplished with a wedge that is radiused to match the cylinder diameter.

7.2 Couplant for this practice shall be a liquid that is used between the ultrasonic search unit and examination piece to remove the air and transmit ultrasonic waves. Water is a preferred couplant. Other couplant such as oil or glycerin may be used. Couplant shall be the same for both standardization and actual examination. Care shall be taken to ensure that the couplant does not freeze when the examination is conducted at low temperatures.

8. Standardizing Ring with Reference Notches

8.1 The reference ring shall be fabricated from the same type of pressure vessel that is being examined. That is,

reference ring must have the same diameter, wall thickness, material, heat treatment, and surface condition as the vessel to be examined.

8.1.1 Reference notches will be placed into both internal and external surfaces of the reference ring, see Fig. 1. The preferred notch fabrication method is by the EDM process.

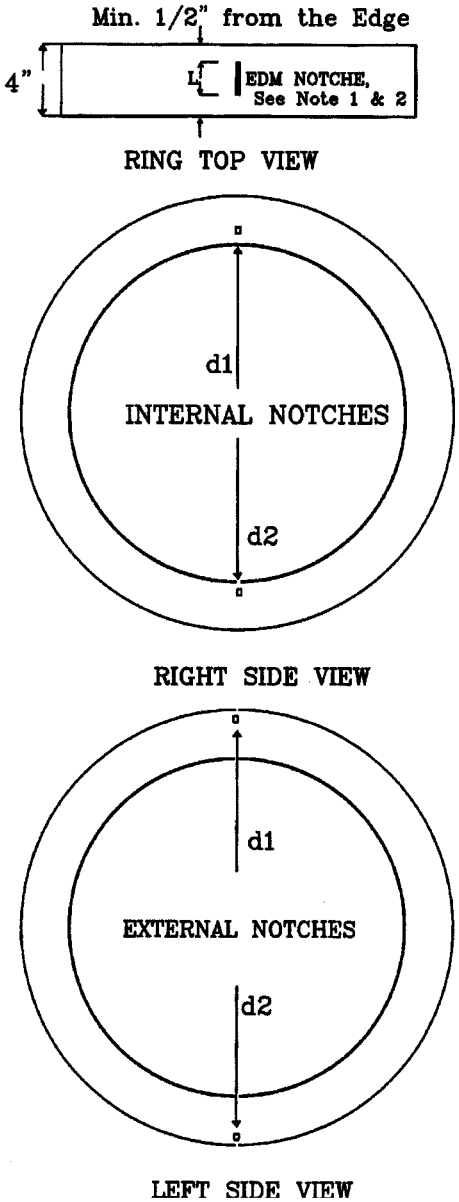
8.1.2 The inner surface and outer surface notches may be placed into a single reference ring. However, where practical, separate rings may be used, see Fig. 1.

8.1.3 Notch dimensions must be specified by the using parties for each type and size of vessel.

9. Standardization Procedure

9.1 The instrument sweep shall be adjusted to encompass the sound path to be used during the examination.

9.2 Place couplant and search unit on the outside surface of the standardization ring and adjust the gain (sensitivity) and location of the search unit until the indication from the internal



Note1: Internal and external notches shall be adjacent to each other but not at the same circumferential position.
Note2: d1&d2 are typical depths, d2=4d1, L is a typical length, approx. 1 in. and W is the width <0.006 in.
Note3: Notches must not extend to within 1/2 in. of the ring's edge.
Note4: 1 in. = 25.4 mm.
Note5: Drawings are not to Scale.

FIG. 1 Example of Standardizing Ring with Reference Notches

notch is identified. Temperature of the reference ring during standardization should be the same as the temperature of the pressure vessel that is being examined.

9.3 The search unit is located at a close distance (half-skip distance) from the designated internal notch on the surface of the reference ring. Increase the gain until the signal is maximized at 80% of the full screen height as shown in Fig. 2.

9.3.1 Without adjusting the gain, obtain three additional indications from the notch with the search unit located at 90-, 120- and 180-degree positions around the ring's circumference by moving the search unit on the ring, away from each notch. It may be necessary to increase the horizontal display range control on the instrument. The minimum signal height should not be below 10 % full screen height.

9.3.2 The position and maximum peak of each indication at 90-, 120- and 180-degree positions is marked on the display screen. A DAC curve is constructed by connecting the signal peaks. Fig. 2 illustrates a typical DAC curve display for two internal notches with different depths.

9.3.3 Since the skip distances vary with vessel geometry, a separate DAC shall be produced for each type of pressure vessel. The last point of the DAC curve shall be at a known distance on the reference ring (not be less than ½ the circumference of the ring).

9.3.4 The same procedure shall be used to generate DAC curves for internal and external notches.

9.3.5 Some ultrasonic instrumentation may have the capability to provide electronic compensation such as time-varied gain (TVG/STC), digitized storage and display of Distance Amplitude (D-A) response curve or Distance Amplitude Gate functions (DAG). Application of these functions may require modification of the prescribed procedures. Refer to the Manufacturers operational instructions.

10. Examination Procedure

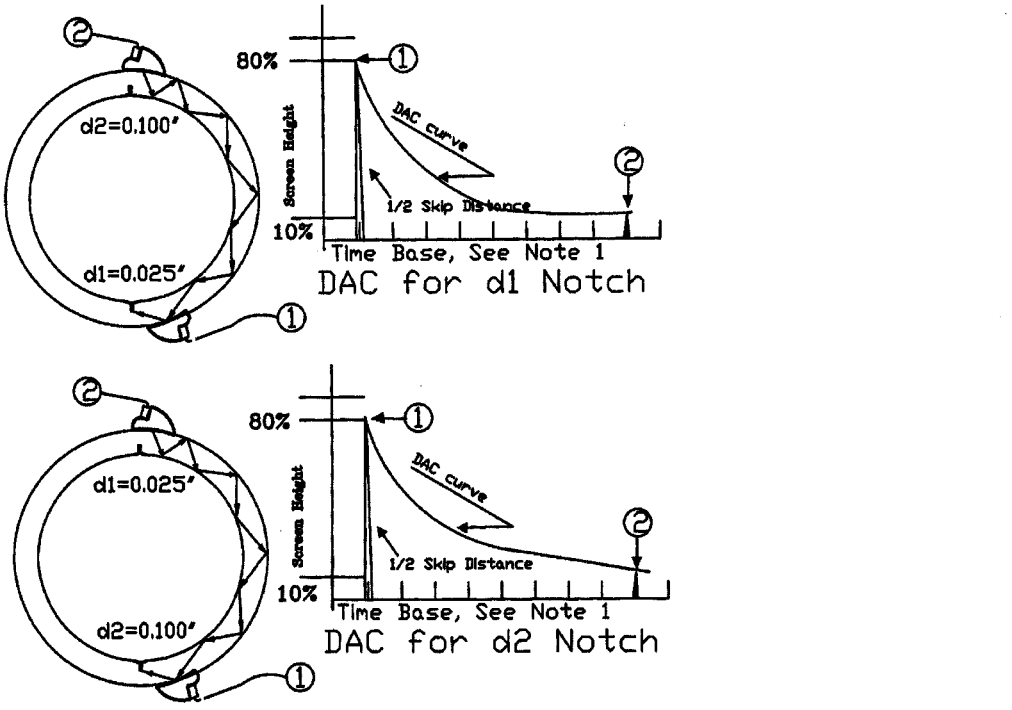
10.1 Since this procedure usually follows acoustic emission (AE) testing, the ultrasonic examination is applied to those locations on the pressure vessel that produced locatable AE events. Prior to ultrasonic examination, the position of the source of each AE indication shall be clearly marked on the vessel. If space is available, the recommended scanning area is 12 in. (30 cm) each side of the position of the AE indication. Ultrasonic examination shall be performed at service pressure.

NOTE 3—At service pressure, it is probable that the wall of the pressure vessel is strained and discontinuity surfaces are separated. In this condition, the amplitude of the reflected ultrasonic signal is at its maximum, making the indication easier to detect.

10.1.1 Prior to scanning, the gain shall be increased by 6 dB over reference to increase examination sensitivity. Prior to evaluating and reporting the indication, gain must be returned to the same value used during standardization.

10.1.2 Circumferential scanning shall be performed in both clockwise (CW) and counter clockwise (CCW) directions to ensure adequate coverage of the marked location.

10.1.3 For difficult to reach locations on pressure vessels which are stacked in the middle row, the search unit may be



Note1: Time base shall be sufficient in length to display at leaset 1/2 of the cylinder's circumferance.

Note2: Drawings of sound paths do not represent the actual number of skip distances.

Note3: Drawings are not to Scale.

FIG. 2 Distance Amplitude Correction Curves (DAC) of a Typical DOT 3AAX Tube with Internal Surface Notches, Similar Procedure Will Be for External Surface Notches

mounted at the end of an extension rod. If an extension rod is used for examination, standardization shall be under the same condition.

10.1.4 Any detected discontinuity showing an amplitude that exceeds the DAC curve should be considered a potential for rejection. After the discontinuity has been located, it shall be evaluated by scanning in at least two directions. The signal amplitude as well as the circumferential and longitudinal position of the discontinuity shall be recorded. The pressure vessel containing the rejectable discontinuity may require removal from the stack to allow access to the discontinuity location.

10.1.5 In the event of discontinuity location, the lateral search unit motion between the -6 dB amplitude positions shall be recorded as the length of discontinuity.

10.2 When a removal of a pressure vessel from service is indicated, another approved examination technique, such as reflected tip-diffraction, may be used to more accurately evaluate the discontinuity (depth, length and orientation). Guidelines for the application of these techniques are beyond the scope of this practice.

11. Report

11.1 The NDT agency shall provide an examination report that includes the following information.

11.1.1 Identification and dimensions of the Pressure Vessel. Serial Number and location as appropriate

11.1.2 Date and Results of the AE examination including the longitudinal and circumferential locations of the AE indications.

11.1.3 Date of the examination and name of the examiner.

11.1.4 Examination data as follows:

11.1.4.1 Reference gain (sensitivity).

11.1.4.2 Indication signal amplitude.

11.1.4.3 Circumferential and longitudinal locations of the indication.

11.1.4.4 Lateral search unit movement between -6 dB points.

12. Keywords

12.1 acoustic emission; angle-beam; contact examination; couplant; crack detection; gas-filled pressure vessels; nondestructive testing; reference notches; seamless steel pressure vessels; standardizing ring; ultrasonic examination

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