



Designation: E2700 – 20

Standard Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays¹

This standard is issued under the fixed designation E2700; 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 ultrasonic techniques for examining welds using phased array ultrasonic methods (see [Note 1](#) and [Note 2](#)).

1.2 This practice uses angle beams, either in S-scan or E-scan modes, primarily for butt welds and Tee welds. Alternative welding techniques, such as solid state bonding (for example, friction stir welding) and fusion welding (for example, electron beam welding) can be examined using this practice, provided adequate coverage and techniques are documented and approved. Practices for specific geometries such as spot welds are not included. The practice is intended to be used on thicknesses of 9 to 200 mm. Greater and lesser thicknesses may be examined using this practice if the technique can be demonstrated to provide adequate detection on mockups of the same wall thickness and geometry.

1.2.1 Extreme caution should be used when attempting to size indications using phased array. It is likely that without proper procedures, indications can be oversized due to beam divergence, multiple virtual probes returning signals from the same indication, etc. For more guidance, see [12.4](#).

1.3 *Units*—The values stated in SI units are to be regarded as standard.

NOTE 1—This practice is based on experience with ferrous and aluminum alloys. Other metallic materials can be examined using this practice, provided reference standards can be developed to demonstrate that the particular material and weld can be successfully penetrated by an ultrasonic beam.

NOTE 2—For additional pertinent information, see ASME BPVC Section V, Article 4, Guide [E2491](#), Practice [E317](#), and Practice [E587](#).

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

1.5 *This international standard was developed in accordance with internationally recognized principles on standard-*

ization 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:²

- [E164 Practice for Contact Ultrasonic Testing of Weldments](#)
- [E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments](#)
- [E543 Specification for Agencies Performing Nondestructive Testing](#)
- [E587 Practice for Ultrasonic Angle-Beam Contact Testing](#)
- [E1316 Terminology for Nondestructive Examinations](#)
- [E2192 Guide for Planar Flaw Height Sizing by Ultrasonics](#)
- [E2491 Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems](#)

2.2 ASME Standard:³

- [ASME BPVC Section V, Article 4](#)

2.3 ISO Standards:⁴

- [ISO 2400 Reference Block for the Calibration of Equipment for Ultrasonic Examination](#)
- [ISO 9712 Nondestructive Testing—Qualification and Certification of NDT Personnel](#)
- [ISO 19675 Nondestructive Testing—Ultrasonic Testing—Specification for a Calibration Block for Phased Array Testing \(PAUT\)](#)

2.4 ASNT Documents:⁵

- [SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing](#)
- [ANSI/ASNT CP-189 Standard for Qualification and Certification of NDT 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 referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁵ Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

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

2.5 AIA Standard: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 This practice provides procedural guidance for both manual and mechanized scanning of welds using phased array systems, including a discussion of general requirements for standardization of range, angular and depth sensitivity and reference blocks for same; coupling considerations; examination procedures, including development of scan plans for common butt and tee weld configurations; basic indication evaluation; and reporting requirements.

5. Significance and Use

5.1 Phased array ultrasonic testing (PAUT) is an advanced examination technique used for enhanced flaw detection, sizing, and imaging as compared to conventional UT employing single-element transducers. PAUT utilizes multi-element (array) probes in which groups of elements are pulsed with pre-calculated time delays (“focal laws”) for each element (“phasing”). The resulting constructive and destructive interference allows for electronic steering, shaping, and focusing of the sound beam.

5.2 Though primarily a method of generating and receiving ultrasound, phased arrays are also a method of scanning and imaging. The two basic types of scans are the Linear or Electronic scan (E-Scan) and the Sectorial or Azimuthal scan (S-Scan). In the E-Scan, which emulates a manual scan, multiple sound beams are created at the same refracted angle. The beam is electronically translated along the active axis of the array by sequentially adding an element on one end and dropping an element off the other end of the active group of elements within the probe, with time multiplexing coordinated by the instrument’s on-board processor. In the S-Scan, which is unique to phased arrays, the sound beam is electronically swept through a range of user-defined angles by sequentially changing the time delays applied to each element. Because the beam angle is no longer solely dependent upon the wedge angle, more complete data can be obtained and more complex geometries can be examined versus conventional UT. With their distinct features and capabilities, phased arrays require special set-ups and standardization, as addressed by this practice. Commercial software permits the operator to easily make set ups without detailed knowledge of the phasing requirements.

5.3 Phased arrays can be used in different ways: manual or encoded linear scanning; and different displays or combinations of displays. In manual scanning, the dominant display will be an S-scan with associated A-scans. S-scans have the

advantage over E-scans in that all the specified examination angles can be covered at the same time.

5.4 The main advantages of using phased arrays for ultrasonic weld examinations are:

5.4.1 Increased control of beam characteristics, including capability for focusing and steering the beam;

5.4.2 Faster scanning and increased probability of detection due to multiple lines/angles acquired and displayed in a single pass;

5.4.3 Increased ability to examine complex geometries and areas with limited access;

5.4.4 Better imaging from the true depth S-scan;

5.4.5 Digital data storage capability, which is intended to enable auditing, archiving, and off-line post-processing, re-processing, and comparison of data from different examinations;

5.4.6 Rapid and reproducible set-ups with electronic instruments.

6. Basis of Application

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

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

6.2.1 In addition, there should also be training or knowledge and experience related to phased array equipment and techniques. Personnel performing examinations to this standard should list the qualifying credentials in the examination report.

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 *Procedures and Techniques*—The procedures and techniques to be used shall be as specified in the contractual agreement. Guide E2491 recommends methods of assessing performance characteristics of phased array probes and systems.

6.5 *Surface Preparation*—The pre-examination surface preparation criteria shall be in accordance with 9.1, unless otherwise specified.

6.6 *Timing of Examination*—The timing of examination shall be determined by the contracting parties and in accordance with the stage of manufacture or in-service conditions.

6.7 *Extent of Examination*—The extent of examination shall be suitable to examine the volume of the weld plus the heat affected zone, unless otherwise specified.

6.8 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with

⁶ Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, <http://www.aia-aerospace.org>.

13.1, unless otherwise specified. Since acceptance criteria are not specified in this standard, they shall be specified in the contractual agreement.

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

7. Equipment

7.1 Phased Array Instruments:

7.1.1 The ultrasonic phased array instrument shall be a pulse echo type with multiple independent pulser/receiver channels equipped with a standardized dB gain or attenuation control stepped in increments of 1 dB minimum. The system shall be capable of generating and displaying both B-scan and S-scan images (ideally C-Scan image capability should also be available), which can be stored and recalled for subsequent review.

7.1.2 The phased array system shall have on-board focal law generation software that permits direct modification to ultrasonic beam characteristics. Specific delay calculations may be performed by the system itself or imported from external calculations.

7.1.3 The phased array system shall have a means of data storage for archiving scan data. An external storage device, flash card, or USB memory stick can be used for data storage. A remote portable PC connected to the instrument may also be used for this purpose. If instruments do not inherently store A-scan data, such as some manual instruments, the final image only may be recorded.

7.1.4 The phased array system shall be standardized for amplitude and height linearity in accordance with Guide E2491 annually, at a minimum.

7.1.5 The instrument shall be capable of pulsing and receiving at nominal frequencies of 1 MHz to 10 MHz. For special applications, higher frequencies can be used, but may require special instrumentation with appropriate digitization capability.

7.1.6 The instrument shall be capable of digitization of A-scans at a minimum of five times the nominal frequency of the probe used. Amplitude shall be digitized at a resolution of at least 8-bit (that is, 256 levels).

7.1.7 The instrument shall be capable of equalizing the amplitude response from a target at a fixed sound path for each angle used in the technique (angle corrected gain (ACG)), thereby providing compensation for wedge attenuation variation and echo-transmittance.

7.1.8 The instrument shall also be equipped with facilities to equalize amplitudes of signals across the time-base (time-corrected gain (TCG)).

7.2 Phased Array Probes:

7.2.1 The application requirements will dictate the design, including number of elements, element dimensions, and pitch, of the phased array probe used.

7.2.2 The probe selected shall not have more elements than the number of elements addressable by the pulser-receivers available in the phased array instrument being used.

7.2.3 Phased array probes used for weld examination may be of 1D, 1.5D, or 2D design. For manual scanning techniques,

1D arrays or dual arrays configured with side-by-side transmitter-receiver arrays (as in Transmit-Receive Longitudinal wave probes) are recommended. For 2D arrays, standardization should be performed at all skewed angles.

7.2.4 Phased array probes may be used with a removable or integral wedge, delay-line, or in an immersion or localized bubbler system mode. In some cases, a phased array probe may be used without a refracting wedge or delay-line (that is, just a hard wear-face surface).

7.2.5 When refracting wedges are used to assist beam steering, the natural incident angle of the wedge shall be selected such that the angular sweep range of the examination technique used does not exceed the manufacturer's recommended limits for the probe and mode (compression or transverse) used; this will minimize spurious indications/interference due to grating lobes.

7.2.6 Refracting wedges used on curved surfaces shall require contouring to match the surface curvature if the curvature causes a gap between the wedge and examination surface exceeding 0.5 mm at any point.

8. Standardization

8.1 General:

8.1.1 A baseline assessment of probe element activity shall be made in accordance with Annex A3 of Guide E2491.

8.1.2 Standardization shall include the complete ultrasonic phased array system and shall be performed prior to use of the system in the thickness range under examination.

8.1.3 Standardization on reference block(s) shall be performed from the surface (clad or unclad; convex or concave) corresponding to the surface of the component from which the examination will be performed.

8.1.4 The same couplant to be used during the examination shall be used for standardization.

8.1.5 The same contact wedges or immersion/bubbler systems used during the examination shall be used for standardization.

8.1.6 The same focal law(s) used in standardization shall be used for examination.

8.1.7 Any control which affects instrument amplitude response (for example, pulse-duration, filters, averaging, etc.) shall be in the same position for standardization and examination.

8.1.8 Any control which affects instrument linearity (for example, clipping, reject, suppression) shall not be used.

8.2 Reference Blocks:

8.2.1 Reference blocks shall be made of the same material as the test piece or an acoustically similar material acceptable to the customer.

8.2.2 Reference standards for sensitivity-amplitude standardization should be designed so that sensitivity does not vary with beam angle when angle beam examination is used. Sensitivity amplitude reference standards that accomplish this are side-drilled holes parallel to the major surfaces of the plate and perpendicular to the sound path, flat-bottomed holes drilled at the examination angle, and equal-radius reflectors. Surface notches may be used under some circumstances but are not generally recommended.