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Standard Test Method for Ultrasonic Inspection of Aluminum-Alloy Plate for Pressure Vessels[1]

This standard is issued under the fixed designation B548; 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 test method covers pulse-echo ultrasonic inspection of aluminum-alloy plate of thickness equal to or greater than 0.500 in. (12.7 mm) for use in the fabrication of pressure vessels. The ultrasonic test is employed to detect gross internal discontinuities oriented in a direction parallel to the rolled surface such as cracks, ruptures, and laminations, and to provide assurance that only plate that is free from rejectable discontinuities is accepted for delivery.

1.2 The inspection method and acceptance criteria included in this standard shall be limited to plate of the following aluminum alloys: 1060, 1100, 3003, Alclad 3003, 3004, Alclad 3004, 5050, 5052, 5083, 5086, 5154, 5254, 5454, 5456, 5652, 6061, and Alclad 6061.

1.3 This test method applies only to ultrasonic tests using pulsed longitudinal waves which are transmitted and received by a search unit containing either a single crystal or a combination of electrically interconnected multiple crystals. Ultrasonic tests employing either the through-transmission or the angle-beam techniques are not included.

1.4 This test method shall be used when ultrasonic inspection as prescribed herein is required by the contract, purchase order, or referenced plate specification.

~~1.5The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.~~

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

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E214 Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves

E317 Practice for Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Instruments and Systems without the Use of Electronic Measurement Instruments

2.3 *Other Standards:*

ASNT Recommended Practice for Nondestructive Testing Personnel Qualification and Certification—Ultrasonic Testing Method—SNT-TC-1A[3]

3. Summary of Method

3.1 The plate is inspected ultrasonically by scanning one rolled surface with a beam of pulsed longitudinal waves which is oriented in a direction perpendicular to the entry surface of the plate. The ultrasound is transmitted into the plate either by the direct contact, immersion, or liquid-column coupling method. During the scan, an indication representing the first back reflection is observed on the A-scan screen of the test instrument.

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[1] This test method is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is ~~under~~ the ~~jurisdiction~~ direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

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

3.2 When the test system sensitivity level is appropriately adjusted, a discontinuity is detected during the scan by noting an isolated indication associated with a loss of the first back reflection indication. The apparent size of the discontinuity is determined by measuring the total area in the scanned entry surface of the plate where the isolated indication and the loss of back reflection persist. The estimated discontinuity size and location are then compared with suitable acceptance criteria.

NOTE 1—Additional information describing ultrasonic tests by the direct contact method and by the immersion method is available in Practices E114 ~~and E214E114E214~~and E214.

4. Significance and Use

4.1 A number of factors such as the condition of the entry and back surfaces of the plate, the inclination of the ultrasonic beam with respect to the entry surface, and the performance characteristics of the test system may cause either a reduction of isolated indications or a substantial loss of back reflection and thereby could seriously impair the reliability of the test procedure outlined in this standard.

4.2 Accurate evaluations of discontinuity size also may be limited significantly by variations in beam characteristics which exist in most search units. For this reason, discontinuity size as determined by the test procedure outlined in this method is regarded as "apparent" or "estimated" in recognition of the limited quantitative value of the measurement.

4.3 Because a large number of interacting variables in a test system can adversely influence the results of an ultrasonic test, the actual quantitative effects of detected discontinuities upon the mechanical properties of the inspected plate are difficult to establish. Consequently, this ultrasonic inspection method is not applicable as an exclusive indicator of the ultimate quality and performance of pressure vessels but provides a reliable control of plate quality to avoid failure during the forming process for fabrication of vessels.

5. Apparatus

5.1 *Test Instrument*—Any electronic device that produces pulsed longitudinal waves and displays ultrasonic reflections on an A-scan indicator when used with an appropriate search unit is satisfactory. The instrument shall provide stable, linear amplification of received pulses at a selected test frequency and shall be free from significant interface signal interference at the required sensitivity level.

5.2 *Search Unit*—The search unit recommended for this standard is the flat nonfocusing type, and contains a piezoelectric crystal which generates and receives longitudinal waves at the rated frequency when connected to the test instrument through a suitable coaxial cable. A dual-crystal search unit containing both a transmitting and a receiving crystal in one container may be used provided the test instrument will accommodate two-crystal operation and the resulting pulse-echo test is equivalent to that obtained with a search unit containing a single-crystal.

5.2.1 The total effective area of the crystal or combination of crystals in the search unit used for initial scanning shall not be less than 0.4 in.^{2}(2.6 cm^2) nor greater than 3.0 in.^{2}(19.4 cm^2).

5.2.2 The effective diameter of the round search unit used to evaluate discontinuity size shall not exceed 0.75 in. (19 mm).

NOTE 2—For control purposes, the performance characteristics of the test instrument and search unit may be established in accordance with procedures outlined in Practice E317.

5.3 *Tank*—For tests by the immersion method, any container is satisfactory that will facilitate the accurate, stable positioning of both the search unit and the plate to be inspected.

5.4 *Scanning Apparatus*—During the inspection procedure, the search unit is supported by any one of the following devices. The scanning apparatus shall permit measurement of both the scan distance and the index distance within ±0.1 in. (±2 mm).

5.4.1 *Manipulator and Bridge*—When a manipulator is used in tests by the immersion method, the manipulator shall adequately support a search tube containing a search unit and shall provide fine adjustment of angle within 1° in two vertical planes that are perpendicular to each other. The bridge shall be of sufficient strength to provide rigid support for the manipulator and shall allow smooth, accurate positioning of the search unit. Special search unit supporting fixtures may be used provided they meet the requirements prescribed for a manipulator and bridge.

5.4.2 *Liquid Coupling Nozzle*—For tests by the liquid-column coupling method, the nozzle is usually positioned manually and shall be capable of containing the couplant while rigidly supporting the search unit with its active surface immersed in the couplant. The couplant distance shall be maintained so that the second couplant reflection is to the right of the first back reflection on the instrument cathode ray tube (CRT). The couplant path shall not vary more than ±¼ in. (6.4 mm) during calibration, initial scanning, and discontinuity evaluation. The recommended minimum inside dimension of the nozzle is 1.0 in. (25 mm) greater than the maximum dimension of the crystal surface in the search unit. Provisions also should be included for adjustment of search unit inclination within 1° in two vertical planes that are perpendicular to each other.

NOTE 3—Nozzles containing either sealed or unsealed openings may be used for inspecting plate provided the test results obtained with either device are equivalent to those obtained by the immersion method.

5.4.3 *Contact Scanning Unit*—During tests by the contact method, the search unit usually is supported and positioned manually on the entry surface of the inspected plate. However, special fixtures for contact scanning may be employed provided their use ensures conformance to the requirements in this specification.

5.5 *Couplant*—Clean, deaerated water at room temperature is the recommended couplant for tests either by the immersion

method or by the liquid-column coupling technique. Inhibitors or wetting agents or both may be used. For tests by the contact method, the recommended couplant is clean, light-grade oil.

NOTE 4—Other coupling liquids may be employed for inspecting plate provided their use does not adversely affect test results.

6. Personnel Requirements

6.1 The testing operator performing the ultrasonic examination prescribed in this standard shall be qualified and certified to at least a Level I—Ultrasonic Testing in accordance with the ASNT Recommended Practice SNT-TC-1A.

6.2 The required documentation supporting qualification and certification of ultrasonic testing operators shall be established by the certifying agency and shall be available upon request by the purchaser.

7. Condition of Plate

7.1 The entry and back surfaces of the inspected plate shall be sufficiently clean, smooth, and flat to maintain a first back reflection amplitude greater than 50 % of the initial standardization amplitude while scanning an area in the plate that does not contain significant isolated ultrasonic discontinuities.

7.2 The inspected plate shall be at room temperature during the test.

8. Procedure

8.1 *Preferred Method*—The ultrasonic test may be performed by either the liquid column coupling, the direct contact, or the immersion methods. However, the immersion method is preferred.

8.1.1 Maintain the couplant distance so that the second couplant reflection is to the right of the first back reflection on the instrument's A-scan display. The couplant path shall not vary more than ±¼ in. (6.4 mm) during calibration, initial scanning, and discontinuity evaluation.

8.2 *Test Frequency*—When using any of the three methods listed in 8.1, the recommended test frequency is 5.0 MHz. Other test frequencies between 2.0 MHz and 10.0 MHz may be employed when necessary to minimize possible adverse effects of plate thickness, microstructure, and test system characteristics upon test results and thereby maintain a clean, easily interpreted A-scan screen pattern throughout the inspection.

8.3 *Sensitivity Standardization*—Standardize the sensitivity level of the test system operating at the selected frequency by adjusting the instrument gain control to obtain a first back reflection amplitude of 75 ± 5 % of the vertical limit exhibited by the A-scan indicator when the search unit is positioned over an area free from significant discontinuities in the plate to be inspected. During tests by either the immersion method or the liquid column coupling method, adjust the angular alignment of the search unit to obtain a maximum number of back reflections before the final sensitivity level is established.

8.4 *Scanning*—With no further adjustments of the instrument gain controls, locate the search unit over one corner of the plate to be inspected so that the edge of the crystal in the search unit is about 1 in. (25 mm) from either edge of the plate.

8.4.1 Subsequent to checking the angular alignment of the search unit with respect to the rolled entry surface to ensure a maximum first back reflection, proceed to scan the plate continuously by moving the search unit at a constant scanning rate (see 8.6) from the initial starting position to the opposite edge in a direction perpendicular to the predominant rolling direction of the plate.

8.4.2 During the scan, note the occurrence of isolated discontinuity indications and monitor the amplitude of the first back reflection by continuously observing the A-scan indicator screen.

NOTE 5—Auxiliary monitoring devices may be employed in the test system to enhance detection reliability during the scan.

8.5 *Scan Index*—When the initial scan is completed, move the search unit over a predetermined scan index distance in a direction parallel to the predominant rolling direction of the plate and proceed with a second scan along a line parallel to the initial scanning direction while observing the test pattern on the A-scan indicator screen. Calculate the scan index distance as follows:

$$\text{Scan index distance (in.)}, S_i = 0.8 + 0.7\,D_s \quad (1)$$

$$\text{Scan index distance (mm)}, S_i = 20 + 0.7\,D_s \quad (2)$$

where:

D_s = actual crystal diameter.

8.5.1 Continue the inspection by constantly observing the test pattern on the A-scan indicator while successively scanning the plate at a constant scanning rate in a direction perpendicular to the predominant rolling direction of the plate and indexing the search unit through the index distance calculated in 8.5.

8.5.2 During the inspection procedure, check the test system sensitivity standardization periodically by noting the amplitude of the first back reflection when the search unit is repositioned over the reference area of the plate and by adjusting the instrument gain control as required to maintain the sensitivity standardization specified previously in 8.3.

8.6 *Scanning Rate*—When the screen pattern on the A-scan indicator is monitored visually by the test operator during the inspection, the scanning rate shall not be greater than 12 in./s (305 mm/s).

NOTE 6—Scanning rates greater than 12 in./s (305 mm/s) may be employed if auxiliary monitoring apparatus is used to maintain adequate detection reliability.