Designation: E2580 – 12

Standard Practice for Ultrasonic Testing of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications[1]

This standard is issued under the fixed designation E2580; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice establishes two procedures for ultrasonic testing (UT) of flat panel composites and flat sandwich core panels (parallel surfaces). Typical as-fabricated lay-ups include uniaxial, cross ply and angle ply laminates; as well as honeycomb sandwich core materials. These procedures can be used throughout the life cycle of the materials; product and process design optimization, on line process control, after manufacture inspection, and in service inspection. Contact methods such as angle-beam techniques using shear waves, or surface-beam techniques using Lamb waves, are not discussed.

1.2 Ultrasonic testing is a common sub surface method for detection of laminar oriented discontinuities. Two techniques can be considered based on panel surface accessibility; pulse echo for one sided and through transmission (bubblers/squirters) for two sided. As used in this practice, both require the use of a pulsed straight-beam ultrasonic longitudinal wave followed by observing indications of either the reflected (pulse-echo) or received (through transmission) wave. The general types of anomalies detected by both techniques include foreign materials, delamination, disbond/un-bond, fiber debonding, inclusions, porosity, and voids.

1.3 This practice provides two ultrasonic test procedures. Each has its own merits and requirements for inspection and shall be selected as agreed upon in a contractual document.

1.3.1 *Test Procedure A, Pulse Echo (non-contacting and contacting),* is at a minimum a single transducer transmitting and receiving a longitudinal wave in the range of 0.5 to 20 MHz (see Fig. 1). This procedure requires access to only one side of the specimen. This procedure can be conducted by automated or manual means. Automated and manual test results may be imaged or recorded.

1.3.2 *Test Procedure B, Through Transmission,* is a combination of two transducers. One transmits a longitudinal wave and the other receives the longitudinal wave in the range of 0.5 MHz to 20 MHz (see Fig. 2). This procedure requires access to both sides of the specimen. This procedure is automated and the examination results are recorded.

1.4 This practice does not specify accept-reject criteria.

1.5 *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:*[2]

C274 Terminology of Structural Sandwich Constructions

D3878 Terminology for Composite Materials

D5687/D5687M Guide for Preparation of Flat Composite Panels with Processing Guidelines for Specimen Preparation

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

E543 Specification for Agencies Performing Nondestructive Testing

E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases

E1316 Terminology for Nondestructive Examinations

E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases

E1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases

2.2 *SAE Standards:*[3]

ARP 5605 Solid Composite Laminate NDI Reference Standards, Issued 2001-09

ARP 5606 Composite Honeycomb NDI Reference Standards, Issued 2001-09

[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.

Current edition approved June 15, 2012. Published July 2012. Originally approved in 2007. Last previous edition approved in 2007 as E2580 - 07. DOI: 10.1520/E2580-12.

[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 Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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

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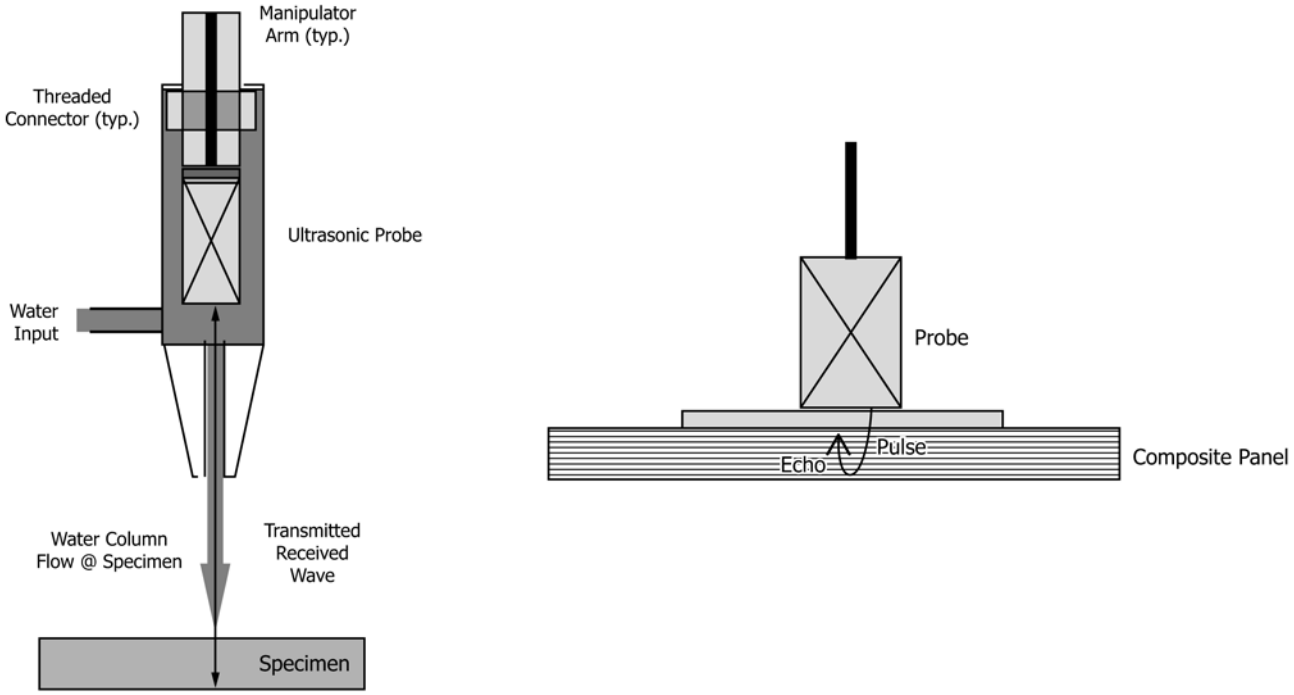

FIG. 1 Test Procedure A, Pulse Echo Apparatus Set-up

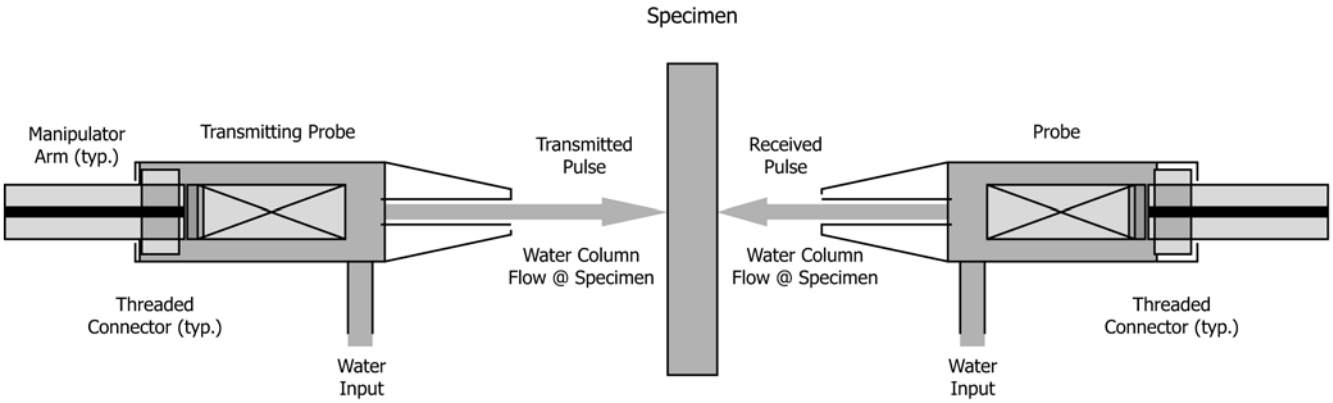

FIG. 2 Test Procedure B, Through Transmission Apparatus Set-up

2.3 *AIA Standard:*[4]

NAS-410 Nondestructive Testing Certification of Personnel

2.4 *ASNT Standards:*[5]

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ANSI/ASNT CP-189 Standard for Qualification and Certification or Nondestructive Testing Personnel

3. Terminology

3.1 *Definitions*—Terminology in accordance with Terminologies C274, E1316, and D3878 shall be used where applicable.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *flat panel composite, n*—any fiber reinforced composite lay-up consisting of laminate (plies) with one or more

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

orientations with respect to some reference direction that are consolidated by press or autoclave to yield a two-dimensionally flat article of finite thickness.

3.2.2 *sandwich core material, n*—a structural panel made up of two relatively thin outer skins of composite laminate or other material, such as metal or wood, separated by and bonded to a relatively thick lightweight inner core such as honeycomb, open and close cell foam, wave formed material, bonded composite tubes, or naturally occurring material such as balsa wood.

4. Summary of Practice

4.1 This practice describes two procedures for detecting anomalies in flat panel composite and flat sandwich core panels using ultrasonic longitudinal waves coupled by either contact (Procedure A) or bubbler/squirter (Procedure B). Equipment, reference blocks, examination and evaluation procedures, and documentation are described in detail.

5. Significance and Use

5.1 This practice is intended primarily for the testing of flat panel composites and sandwich core panels to an acceptance criteria most typically specified in a purchase order or other contractual document.

5.2 *Basis of Application*—There are areas in this practice that require agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization.

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, NAS-410, or 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 *Surface Preparation*—The pre-examination surface preparation criteria shall be in accordance with 8.4, unless otherwise specified.

6.5 *Timing of Examination*—The timing of examination shall be in accordance with 8.2 and 8.3, unless otherwise specified.

6.6 *Extent of Examination*—The extent of examination shall be in accordance with 8.5 unless otherwise specified.

6.7 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with 14.1 unless otherwise specified. Since acceptance criteria (for example, for reference radiographs) are not specified in this standard, they shall be specified in the contractual agreement.

6.8 *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 and Materials

7.1 *Equipment*

7.1.1 *Operation*—Test equipment shall be capable of providing uniform, repeatable, and controlled operation.

7.1.2 *Electronic Equipment*—The electronic equipment should be capable of producing and processing electronic signals at frequencies in the range of search unit frequencies being used.

7.1.3 *Search Unit(s)*—The search unit(s) selected should be compatible with the electronic equipment being used and with the material to be inspected. The search unit should match the intended squirter(s) or contact. Only straight-beam (longitudinal) search units, with flat or focused acoustic lenses, should be used.

7.1.4 *Alarm*—The alarm or threshold level should be adjustable to allow triggering at any commonly required level of indication amplitude. Alarms are not required on systems that record amplitude recordings.

7.1.5 *Alarm Gate Synchronization*—In the pulse echo mode ensure that the alarm gate tracks the inspection area. The gate should lock on the first interface pulse from the test piece rather than on the initial pulse from the system. In the through transmission mode the alarm gate should be wide enough to cover any negative or positive movement (left to right) in the horizontal plane.

7.1.6 *Manipulating Equipment* should be provided to adequately support the search tube(s) and allow angular adjustment in two mutually perpendicular planes. The search unit manipulator shall be capable of providing the adjustments necessary to properly position the search unit during testing. The scanning and indexing apparatus should have sufficient structural rigidity to provide support for the manipulator and should allow smooth, accurate positioning of the search unit. The scanning apparatus should be sufficiently rigid to keep search unit backlash to within tolerances as specified in the contractual agreement.

7.1.7 *Tank or Gantry System*—The tank or gantry system should permit accurate positioning of the search unit, reference standards, and part or material to be examined.

7.1.8 *Squirter*—The squirter equipment shall be capable of supplying a laminar flow of coupling fluid from the transducer to the part being tested at all angles used.

7.1.9 *Scan-Record*—The recording shall not exhibit backlash or hysteresis that would hinder detection or evaluation of discontinuities.

7.1.10 *Composite Reference Blocks*—For the applicable testing system the responses from reference block and part shall be similar to the extent that standardization of the testing system can be accomplished and demonstrated to provide a known and acceptable detection level in the part. Reference

blocks contain either structural anomalies or foreign inclusions. Structural anomalies are those that are known to be possible during the life cycle of the material. Debonding during manufacturing or delamination during in-service may be represented by the block. Foreign inclusions most commonly encountered during manufacturing are used in the reference blocks.

7.1.11 *Transfer Cutouts*—When non-contact through-transmission is used transfer cutouts may be used in lieu of reference blocks when agreed upon contractually. The size of the transfer cutouts shall be agreed contractually. The transfer cutouts must provide sufficient attenuation to simulate voids or unbonds in the part. Transfer cutouts shall be attached to the part and be placed to cover changes in part configuration and alignment.

7.2 *Materials:*

7.2.1 *Flat Panel Specimens*—Processing guidelines that facilitate fabrication of flat panel composite specimens made from unidirectional tape or using orthogonal weave patterns are found in Guide D5687/D5687M. For specimen preparation using other processing techniques, for example, pultrusion, filament winding and resin transfer molding, processing guidelines are not available and shall be agreed upon by the using parties.

7.2.2 *Sandwich Core Specimens*—Processing guidelines for fabrication of sandwich construction specimens are diverse and shall be agreed upon by the using parties.

7.2.3 *Transfer Cutouts*—Transfer cutouts shall be made of two layers of lead foil tape cut to size.

7.2.4 *Couplants*—Immersion and contact couplants shall provide intimate coupling between search unit and part; shall be compatible with the part; and shall be easily removed from the part using an applicable cleaning process.

8. General Requirements

8.1 In-process testing of flat panel composite or honeycomb structure shall be conducted using automated equipment capable of electronically recording the test output or manual contact during indication evaluation. There shall be a direct correlation of the electronic recording and the tested specimen. Transducer frequency shall be determined by the material's apparent attenuation and the required acceptance criteria. Scan increment shall be set to provide three ultrasonic signal violations from the standard at the specified threshold level.

8.2 In-service testing shall be conducted using manual contact techniques, these tests are for the determination of suspected areas of damage. Testing shall be conducted using a reference standard. This reference standard shall be of the same configuration as the test specimen or as agreed upon contractually. This reference standard shall be acoustically similar and contain simulated or actual discontinuities.

8.3 In-process testing of flat panel composites shall be for the detection of foreign materials, delaminations, voids and porosity. In-process testing of honeycomb structures shall be for the detection of non-bonds between the face sheets and core. In-service testing of flat panel composites shall be for the detection of damage such as delaminations. In-service testing of honeycomb structure shall be for unbond between the face sheet and core.

8.4 *Material Condition*—Perform ultrasonic testing of parts or materials that possess a clean and smooth surface.

8.5 *Coverage*—In all examinations, perform scanning to locate discontinuities that are oriented parallel with the entry surface. The index increment shall be such that the target simulated anomaly registers three times at a contractually agreed upon threshold.

8.6 *Ultrasonic Frequency*—For a particular test select the frequency based on the material being inspected and of the anticipated type of discontinuities.

8.7 *Evaluation*—Evaluate each discontinuity to determine its type, size, location and conformance to the applicable accept/reject criteria. Specific discontinuity evaluation procedures shall be agreed upon contractually.

8.8 *Technique Record*—For each part inspected, a technique record shall be completed for each discontinuity detection scan and indication evaluation set-up used. The technique record shall identify the part, the area or zone, or bond-line of the part being inspected, the inspector, the inspection procedure, and the equipment used. The record shall include cross-sectional sketches as necessary to show part coverage. The technique record shall note instrument control settings such that the test can be repeated.

TEST PROCEDURES

9. Procedure A

9.1 Test procedure A (Pulse-Echo) is a single transducer transmitting and receiving a longitudinal wave in the range of 0.5 MHz to 20 MHz (see Fig. 1). This procedure can be automated or manual. The test results may be recorded. This procedure requires access to one side of the specimen.

9.1.1 Select the ultrasonic transducer based on the specific requirements of the material, discontinuity size, resolution, and life cycle requirements.

9.1.2 Select the reference block based on the objective of the test. Step wedge blocks may be useful for ply count and de-bond or delamination. Flat bottom holes may be useful to determine the size of a given discontinuity at a known ply or material thickness.

9.1.3 Select the frequency based on the acoustic properties of the material and the testing sensitivity required. The frequency should provide a discontinuity to parent material signal ratio of 3 to 1.

9.2 *Pulse-Echo Testing Application*

9.2.1 *Non-Contact Testing*

9.2.1.1 Set up part and reference so the entry surface is level with the scanning bridge.

9.2.1.2 Use the largest diameter nozzle and shortest free water column possible. For inspection adjust the water flow to eliminate bubbles and entrapped air while providing a sufficiently smooth laminar flow.

9.2.1.3 Normalize beam-to-surface of part.

9.2.1.4 Check for an adequate and consistent signal by taking cursory scans of the part.

9.2.2 *Contact Testing*

9.2.2.1 Clean surface of part and apply the contact couplant that provides the most consistent signal. Select a probe that provides at least a 3:1 signal to noise response from reference standard and provides proper indication sizing capabilities.

9.3 *Standardize the System*

9.3.1 Standardize the system using the contractually agreed upon reference blocks.

9.3.2 Establish the front and back surface signal positions on the base line of the ultrasonic display.

9.3.3 Position the search unit over the reference discontinuity representing the smallest size unacceptable discontinuity nearest to the depth zone being inspected. If the entire thickness is being inspected, set up on the reference discontinuity nearest the back surface.

9.3.4 Adjust instrument controls to obtain at least an 80 % full scale response from the reference discontinuity.

9.3.5 Adjust instrument controls, as necessary, to minimize the spread of front surface signals and to maximize the signal-to-noise ratio while maintaining the required response from the reference discontinuity.

9.3.6 Move the search unit away from the discontinuity to a discontinuity-free area of the reference block, and note the response from the back surface. When the response is greater than 80 % adjust to 80 % and note the difference. This gain difference will be used to adjust for attenuation differences between the reference block and part.

9.3.7 Record the reference block. Using an automated system, record an image and document the responses. Using manual system, document the amplitude responses from each reference block reflector.

9.4 *Scan the Part*

9.4.1 Index the scan such that an overlap of ¼ of the water column diameter (squirter) or transducer diameter (contact) as appropriate.

9.4.2 Scanning speed should not exceed automated system response time or manual visual detection.

9.4.3 Mark all indications for evaluation.

9.5 *Anomaly Evaluation*

9.5.1 Evaluate all anomalies marked during testing.

9.5.2 Compare size of anomaly to size of reference discontinuity located at a similar material depth of the anomaly.

9.5.3 Using linear settings only, standardize the testing system on the applicable reference discontinuity and size the reference discontinuity at the ½ amplitude (-6db) drop points.

9.5.4 Adjust the ultrasonic test system to compensate for attenuation differences.

9.5.5 Evaluate each anomaly in accordance with contractual requirements.

10. Procedure B

10.1 Test procedure B (Through Transmission) uses two transducers. One transmits a longitudinal wave and the other receives the longitudinal wave in the range of 0.5 to 20 MHz (see Fig. 2). This method is automated and the examination results are recorded. This procedure requires access to both sides of the test specimen.

10.1.1 Parts shall be sealed to protect against entrance and entrapment of water. Part shall not be immersed in water at any time. Verify surfaces (both front and back) are free from contaminants that would negatively affect the test.

10.1.2 Adjust squirter spacing to accommodate part and reference block. Free water columns should be kept to a minimum.

10.1.3 Water columns must be normal to the surface of laminate structure and parallel to cell walls of honeycomb core.

10.1.4 Adjust water flow from squirters until a smooth laminar flow, free of spirals is obtained. Position squirters so that the fan at the intersection of the two opposing water streams is uniform and at right angles to the line of flow.

10.1.5 Check for an adequate and consistent signal by taking a cursory scan over the part.

10.2 *Standardize the System*

10.2.1 Position the water columns over a good area of the agreed upon reference block. Adjust sensitivity to provide a 100 % first received signal pattern. Adjust the sensitivity control for a 100 % signal.

10.2.2 Gate the first received signal.

10.2.3 Scan reference block to include good area and reference discontinuity.

10.3 *Scan the Part*

10.3.1 Position the squirters over part and verify gate position used on the reference block is consistent.

10.3.2 When multiple scans are required to cover the area being tested, identify the perimeter of the test areas on the test results. Each scan should be traceable to the scan instructions for the part.

10.3.3 Tapered parts should be zoned and inspected by individual zones in order to maintain a 100 % received signal.

10.3.4 Record all indications.

10.4 *Evaluate Indications*

10.4.1 Eliminate indications found to originate from physical features of the part from further evaluations.

10.4.2 Review indications held for evaluation. The indications should be verified using the contractually agreed upon technique(s).

11. Safety and Hazards

11.1 Precautions must be taken to preclude the possibility of electrical shock when performing ultrasonic testing.

12. Report

12.1 To ensure material traceability, essential information about the composite material, reinforcement, matrix, preform,

prepreg, process method, and part information shall be recorded as described in Guide E1309. Additional information may be necessary when individual constituents that make up the composite material being tested are considered independently. For example, for identification of reinforcements in terms of class, subclass, chemical family, form, dimensional parameters, and dimensional distribution, Guide E1471 should be consulted.

12.2 To ensure test validity, including reproducibility and repeatability, essential information about the test method, specimen preparation, specimen geometry, specimen conditioning, test equipment, transducer (if applicable), test environment, loading (if applicable), raw and normalized data, and statistical analysis (if applicable) shall be recorded as described in Guide E1434.

13. Calibration and Standardization

13.1 UT provides indications that are of no value unless interpretations are made. Interpretations are often dependent on calibration and standardization that must be performed either before, during, or after each test.

13.2 Specific provisions for design and production of a solid composite laminate physical reference standard that can accommodate UT interrogation of a full array of glass and carbon fiber laminates found on aerospace components can be found in SAE ARP 5605.

13.3 Specific provisions for design and production of a composite honeycomb physical reference standard that can accommodate UT interrogation of a broad range of nonmetallic composite honeycomb structures found on aircraft can be found in SAE ARP 5606.

14. Quality Assurance Provisions

14.1 *System Performance*—As a minimum requirement, system performance should be verified in accordance with the following schedule (if mutually agreed upon, more stringent or frequent checks may be specified): (*1*) Gain settings, distance amplitude relationships, and alarm trigger levels should be checked after any interruption of power, change of operating personnel, replacement of a system component, or adjustment of any electrical or mechanical control which cannot be returned exactly to its previous position and (*2*) verification should also be made at such interim periods as are needed to assure that any material previously inspected can be recovered and re-inspected.

14.2 *Wetting Agent Control*—When wetting agent solution is used check the agent concentration in the solutions after initial solution makeup and at 90-day intervals. Wetting agents are used to de-aerate the couplant and enhance adherence of the couplant to the material and search unit.

15. Documentation

15.1 Document all specific examination requirements, procedural details, and results for a particular examination in written contractual agreements, procedures, and reports.

15.2 *Contractual Agreement*—Specific examination requirements for a particular examination item should include at least the following requirements:

15.2.1 Positioning backlash,
15.2.2 Reference standards,
15.2.3 Reference reflectors,
15.2.4 Water path variation,
15.2.5 Transfer technique,
15.2.6 Coverage,
15.2.7 Evaluation of discontinuities,
15.2.8 Personnel qualifications, and
15.2.9 System performance.

15.3 *Written Procedure and Report*—Ultrasonic examinations performed in accordance with this practice should be detailed in a written procedure. This should identify the type of ultrasonic equipment, test methods, reference standards, search unit type(s), style, and frequency, method of reporting indications, and all other instructions that pertain to the actual examination. Procedures should be sufficiently detailed so that another qualified operator could duplicate the examination and obtain equivalent information. The list of specified data required for the completed record and the report of an examination should be agreed upon between the supplier and the purchaser. As a minimum, the following items should be documented either in the written procedure or report:

15.3.1 Specific part number and configuration tested, stage of fabrication, surface finish, and surface preparation methods;

15.3.2 Manufacturer, model number, and serial numbers of all instrumentation. This includes any recording equipment and alarm equipment;

15.3.3 Type, serial number and size of search unit(s). Include frequency, transducer element material (or model number), description of focal length, or search unit stand-off attachments;

15.3.4 Description of manipulating and scanning equipment and special fixtures;

15.3.5 Couplant and wetting agent solutions;

15.3.6 Scanning plan. Describe the surface(s) from which the examinations were performed and the ultrasonic beam paths used;

15.3.7 Method of applying transfer and amount of transfer applied;

15.3.8 Acceptance classes, reference standards, water paths, scan-index determination, and distance-amplitude correction; and

15.3.9 Evaluation procedure.

16. Precision and Bias

16.1 *Precision*—It is not practical to specify the precision of this practice since the result will depend on the conditions selected and the practices chosen for evaluation.

16.2 *Bias*—The procedure in this practice has no bias because the test conditions are defined only in terms of this practice.

17. Keywords

17.1 aerospace composites; fiber-reinforced polymer matrix composites; flat panel composites; honeycomb core; laminates; nondestructive evaluation (NDE); nondestructive inspection

(NDI); nondestructive testing (NDT); polymeric matrix composites (PMC); sandwich core materials; ultrasonic testing (UT); ultrasound

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E2580 - 07) that may impact the use of this standard. (June 15, 2012)

(1) Section 6: Basis of Application has been added.
(2) Subsection 7.2: Deleted and placed in subsection 6.3
(3) Subsection 13.1: Deleted and placed in subsection 6.2.

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