Designation: E3370 – 23

Standard Practice for Matrix Array Ultrasonic Testing of Composites, Sandwich Core Constructions, and Metals[1]

This standard is issued under the fixed designation E3370; 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 covers procedures for matrix array ultrasonic testing (MAUT) of monolithic composites, composite sandwich constructions, and metallic test articles. These procedures can be used throughout the life cycle of a part during product and process design optimization, on line process control, post-manufacturing inspection, and in-service inspection.

1.2 In general, ultrasonic testing is a common volumetric method for detection of embedded or subsurface discontinuities. This practice includes general requirements and procedures which may be used for detecting flaws and for making a relative or approximate evaluation of the size of discontinuities and part anomalies. The types of flaws or discontinuities detected include interply delaminations, foreign object debris (FOD), inclusions, disbond/un-bond, fiber debonding, fiber fracture, porosity, voids, impact damage, thickness variation, and corrosion.

1.3 Typical test articles include monolithic composite layups such as uniaxial, cross ply and angle ply laminates, sandwich constructions, bonded structures, and filament windings, as well as forged, wrought and cast metallic parts. Two techniques can be considered based on accessibility of the inspection surface: namely, pulse echo inspection for one-sided access and through-transmission for two-sided access. 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.

1.4 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.

1.4.1 *Test Procedure A, Pulse Echo (non-contacting and contacting)* is at a minimum a single matrix array transducer transmitting and receiving longitudinal waves in the range of 0.5 MHz 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 analyzed in real time or recorded and analyzed later.

1.4.2 *Test Procedure B, Through Transmission (non-contacting and contacting)* 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. Typically, the signal transmitting and signal receiving transducers are perpendicularly aligned with each other. This is normally achieved using a yoke transducer holder arrangement, which attaches the two transducers to a single point but deploys them on opposite sides of the structure. Through transmission inspections are also permitted without the use of a yoke transducer holder. This is due to the capacity for improved manual alignment via the matrix array transducers, whereby the live C-scan display enables visual confirmation of accurate alignment, and facilitates re-alignment if needed. This procedure can be conducted by automated or manual means. Automated and manual test results may be imaged or recorded.

1.5 Other contact methods such as angle-beam techniques using shear waves to characterize welds, or surface-beam techniques using Lamb waves to detect impact damage in composite panel structures are not covered.

1.6 This practice does not specify accept-reject criteria.

1.7 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.8 *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.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[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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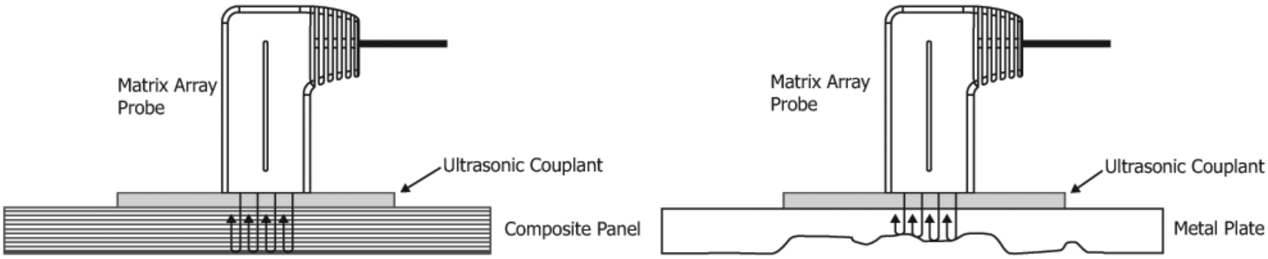

FIG. 1 Test Procedure A, Pulse Echo Apparatus Set-up for a Composite Panel (Left) and Metal Plate (Right) Using One-sided Access

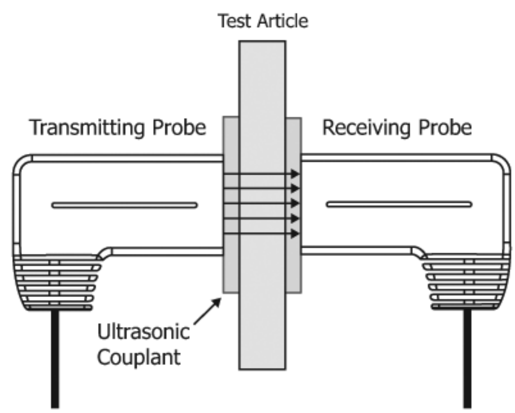

FIG. 2 Test Procedure B, Through Transmission Apparatus Set-up using Two-sided Access

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]

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

E127 Practice for Fabrication and Control of Flat Bottomed Hole Ultrasonic Standard Reference Blocks

E494 Practice for Measuring Ultrasonic Velocity in Materials by Comparative Pulse-Echo Method

E543 Specification for Agencies Performing Nondestructive Testing

E797/E797M Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method

E1001 Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves

E1434 Guide for Recording Mechanical Test Data of Fiber-Reinforced Composite Materials in Databases (Withdrawn 2015)[3]

E1901 Guide for Detection and Evaluation of Discontinuities by Contact Pulse-Echo Straight-Beam Ultrasonic Methods

E1316 Terminology for Nondestructive Examinations

E2375 Practice for Ultrasonic Testing of Wrought Products

E2491 Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems

E2580 Practice for Ultrasonic Testing of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications

2.2 *SAE Standards:*[4]

ARP 5605 Solid Composite Laminate NDI Reference Standards

ARP 5606 Composite Honeycomb NDI Reference Standards

ARP 5089 Composite Repair NDT/NDI Handbook

2.3 *AIA Standard:*[5]

NAS-410 NAS Certification & Qualification of Nondestructive Test Personnel

[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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[5] Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, http://www.aia-aerospace.org.

2.4 *ASNT Documents:*[6]

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

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

Nondestructive Testing Handbook, Ultrasonic Testing, 2nd Edition, Vol. 7

2.5 *ISO Standard:*[7]

ISO 9712 NDT–Qualification and Certification of NDT Personnel in the Applicable Product Sector "Aerospace"

2.6 *European Committee for Standardization Document:*[8]

EN 4179 Aerospace Series - Qualification and Approval of Personnel for Non-destructive Testing

2.7 *FAA Circular Advisory:*[9]

AC-65-31B Training, Qualification, and Certification of Nondestructive Inspection Personnel

2.8 *MIL Document:*[10]

MIL-HDBK-1823 Nondestructive Evaluation System Reliability Assessment

3. Terminology

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

3.2 *Definitions of Terms Not Specific to This Standard:*

3.2.1 *defect, n*—see Terminology E1316.

3.2.2 *delamination, n*—see Terminology D3878.

3.2.3 *disbond, n*—see Terminology D3878.

3.2.4 *distance amplitude correction (DAC), n*—see Terminology E1316.

3.2.5 *flaw, n*—see Terminology E1316.

3.2.6 *matrix array transducers, n*—these transducers have an active area divided in two dimensions in different elements. This division can, for example, be in the form of a checkerboard, or sectored rings. Matrix array transducers may either be phased or nonphased. Nonphased matrix array transducers tend not to have discrete piezoelectric elements that pulse and receive individually. They instead achieve a matrix array aperture by either using a crossed electrode architecture or by pulsing from a large single crystal and receiving on a separate two-dimensional array. Due to this architecture, matrix array transducers may not allow beam steering. They are thus typically used for straight beam applications such as inspection of composites and corrosion mapping. Such nonphased matrix array transducers use live C-scan displays, highlighting the inspection region directly beneath the transducers.

3.2.6.1 *Discussion*—For the purpose of this practice, the matrix array transducers used are nonphased.

3.2.7 *phased array transducer, n*—see Terminology E1316.

3.2.8 *pulse echo method, n*—see Terminology E1316.

3.2.9 *sandwich construction, n*—see Terminology D3878.

3.2.10 *through transmission technique, n*—see Terminology E1316.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *flat panel composite, n*—any fiber reinforced composite lay-up consisting of laminate (plies) with one or more orientations with respect to some reference direction that are consolidated by press or autoclave to yield a two-dimensionally flat article of finite thickness.

3.3.2 *time-corrected gain (TCG), n*—time-corrected gain is a method of compensating for a reduction in signal amplitude with increasing range from reflectors of equal area. This is achieved by increasing the system gain with time so that the signals appear of equal amplitude. TCG achieves the same objective as a DAC.

3.3.2.1 *Discussion*—Calibration using TCG is required to ensure that indications have uniform amplitude with depth and position.

4. Summary of Practice

4.1 This practice describes two procedures for detecting bulk defects in monolithic composites, composite sandwich constructions, and metallic parts using ultrasonic longitudinal waves emitted from a two-dimensional matrix array transducer and coupled by contact. Equipment, reference blocks, examination procedures, data evaluation procedures, and documentation are described in detail

4.2 This practice focuses on the advantages and limitations of two-dimensional matrix arrays. Characteristics of phased array transducers such as linear, annular, and "rho-theta" are not discussed.

5. Significance and Use

5.1 The procedures described in this practice have proven utility in the inspecting (*1*) monolithic polymer matrix composites (laminates) for bulk defects, (*2*) metals for corrosion during the service life of the part of interest, (*3*) thickness checks, (*4*) adhesive bonding of metals, composites, and sandwich core constructions, (*5*) coatings, and (*6*) composite filament windings. Both unpressurized, and with suitable precautions, pressurized materials and components are inspected.

5.2 This practice provides guidelines for the application of longitudinal wave examination to the detection and quantitative evaluation of damage, discontinuities, and thickness variations in materials.

5.3 This practice is intended primarily for the testing of parts to acceptance criteria most typically specified in a purchase order or other contractual document, and for testing of parts in-service to detect and evaluate damage.

5.4 MAUT search units provide near-surface resolution and detection of small discontinuities comparable to phased array

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

[7] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[8] Available from CEN-CENELEC Management Centre, Rue de la Science 23, B-1040 Brussels.

[9] Available from U.S. Department of Transportation Federal Aviation Administration 800 Independence Ave SW, Washington, DC 20591.

[10] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

transducers. They may or may not be capable of beam steering. The advantage of MAUT for straight-beam longitudinal wave inspections is the ability to provide real-time C-scan data, which facilitates data interpretation and shortens inspection time. Depending on inspection needs, data can be displayed as A-, B- or C-scans, or three-dimensional renderings. Toggling between pulse-echo and through transmission ultrasonic (TTU) modes without having to use another system or changing transducers is also possible.

5.5 The MAUT technique has proven utility in the inspection of multi-ply carbon-fiber reinforced laminates used in primary aircraft structures.[11]

5.6 For ultrasonic testing of laminate composites and sandwich core materials using conventional UT equipment consult Practice E2580. Consult Practice E114 for ultrasonic testing of materials by the pulse-echo method using straightbeam longitudinal waves introduced by a piezoelectric element (transducer) with diameters of 3.2 mm to 28.6 mm (⅛ in. to 1⅛ in.) in contact with the material being examined and usually presented in an A-scan display.

5.7 This practice is directed towards the evaluation of discontinuities detectable at normal beam incidence. If discontinuities or material integrity at other orientations are of concern such as through cracks and welds, alternate scanning techniques are required.

[11] The Boeing Company, *787 Nondestructive Test Manual Part 4 – Ultrasonic*, Dec. 30, 2015, P.O. Box 3707, Seattle, Washington 98124.

5.8 *Test Procedure A, Pulse Echo*—Pulsed energy is transmitted into materials, travels in a direction normal to the contact surface, and is reflected back to the search unit by discontinuity or boundary interfaces, which are parallel or near parallel to the contacted surface. These echoes return to the search unit, where they are converted from mechanical to electrical energy and are amplified by a receiver. The amplified echoes (signals) are displayed as A-, B- or C-scans, or three-dimensional renderings. Types of information that may be obtained from the pulsed-echo straight-beam practice are (*1*) apparent discontinuity size, (*2*) depth location of discontinuities, (*3*) material properties such as velocity of sound in the material, and similarly, the thickness of a material, and (*4*) the extent of bond and unbond (or fusion and lack of fusion) between two ultrasonic conducting materials if geometry and materials permit. In addition to detecting volumetric discontinuities such as delaminations (Fig. 3), ultrasonic thickness measurements can be made with MAUT search units in pulse-echo mode on basic shapes and products of many materials, and on precision machined parts, to determine wall thinning in process equipment caused by corrosion and erosion (Fig. 4).

5.9 *Test Procedure B, Through Transmission*—In TTU, a transducer on one side of a part transmits an ultrasonic pulse to an aligned receiving transducer on the other side (Fig. 2). Alignment between the two transducers is often accomplished by automation. Attenuation or absence of the pulse coming to the receiving transducer indicates the presence of a defect. Advantages of TTU over pulse-echo include less attenuation of

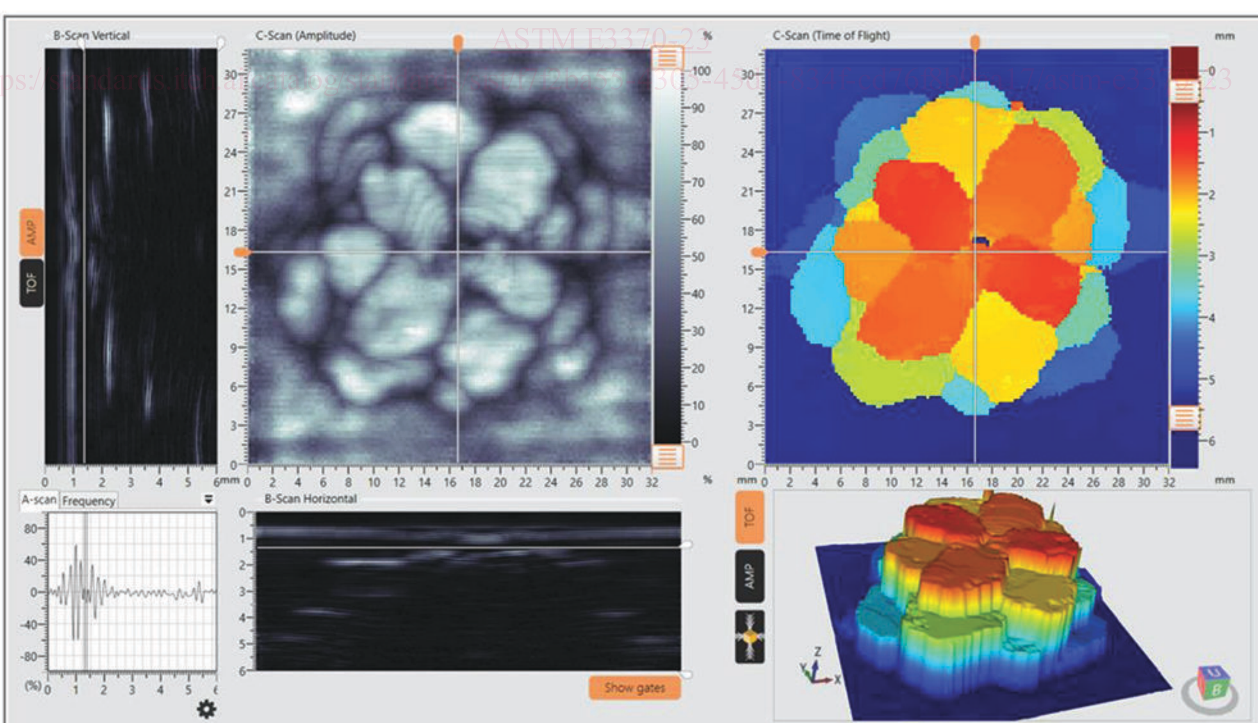

FIG. 3 Detection of Delamination in Flat Panel Carbon-fiber Reinforced Composite Using Matrix Array Ultrasonic Testing Showing Typical A-, B- and C-Scans and A Three-dimensional Rendering (Pulse-Echo Method)

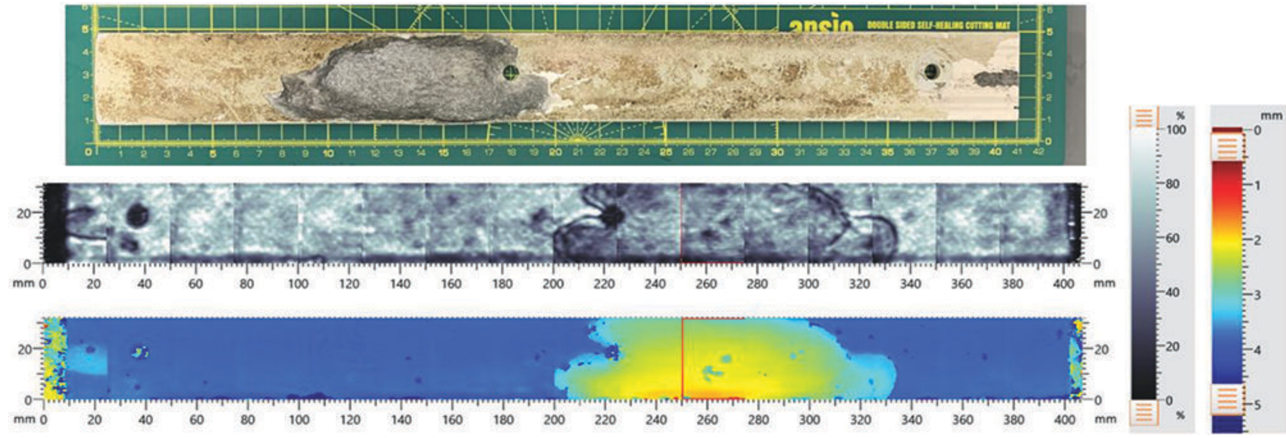

FIG. 4 Detection of Wall Thinning Corrosion in 3.5 mm Thick Aluminum Plate Using Matrix Array Ultrasonic Testing (Pulse-Echo Method)

sound energy, absence of transducer ringing, and less of an effect of defect orientation on transmitted signal. However, two-sided access is necessary, and like pulse-echo, vertical defects such as through cracks are difficult to detect. Applications include inspection of plate and bar stock after manufacturing, and detection of disbonds in materials with high attenuation properties that hinder sound propagation, such as multiple bond layers, honeycomb cores (Fig. 5), and foam cores.

5.10 This practice does not discuss nonlinear resonant ultrasonic spectroscopy, ultrasonic spectral analysis, use of angle beams, transverse waves, and guided waves that can be used to assist in bond characterization in composites or sandwich constructions.[12] Air coupled ultrasonic inspection using MAUT search units to detect skin-to-core disbonds in sandwich constructions is also not discussed.

6. Basis of Application

6.1 *Timing of Examination*—The timing of examination shall be in accordance with 9.1 and 9.2 in this practice, unless specified otherwise.

6.2 *Extent of Examination*—The extent of examination (coverage) shall be in accordance with 9.4 in this practice, unless specified otherwise.

6.3 *Reporting Criteria/Acceptance Criteria*—Reporting criteria for the examination results shall be in accordance with 9.8 and Section 12, unless otherwise specified. Since acceptance criteria (for example, for reference sonograms) are not specified in this practice, they shall be specified in the contractual agreement.

6.4 *Reexamination of Repaired/Reworked Items*—Reexamination of repaired/reworked items is not addressed in this practice and if required shall be specified in the contractual agreement. For guidance to assist inspectors on where to inspect repaired composite and metal bonded parts on the aircraft, to understand the capabilities of current NDT methods,

[12] Hsu, D. K., Bossi, R. H., and Roach, D. P., *Bond Testing, Part 2. Bond Testing Methods, Chapter 14*, American Society of Nondestructive Testing, 2014.

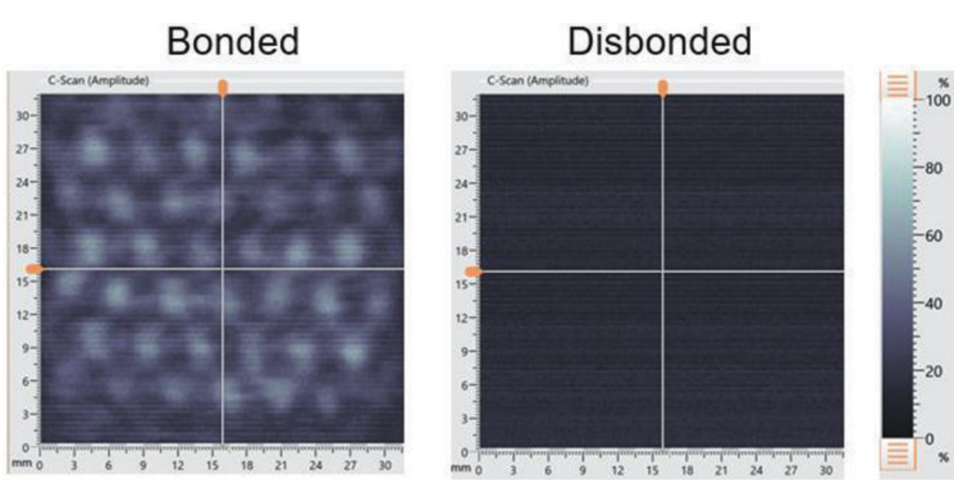

FIG. 5 Detection of Disbond in A Sandwich Construction Consisting of A Graphite Fiber Reinforced Facesheet and An Aluminum Honeycomb Core Using Matrix Array Ultrasonic Testing (Through-Transmission Mode)

and to aid interpretation of inspection results, consult ARP 5089. ARP 5089 does not override any instructions that may be issued within a manufacturer's or operator's published documentation.

6.5 *Probability of Detection (POD)*—Detailed instruction for assessing the reliability of NDT data using POD with composite, sandwich core and metallic test articles is beyond the scope of this practice. More detailed instruction for assessing the capability of an NDT method by determining the POD as a function of flaw size can be found in MIL-HDBK-1823. Specific performance of NDT methods applied to composite laminate and composite honeycomb structures can be found elsewhere.[13]

7. Quality Assurance Provisions

7.1 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.

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

7.3 *Personnel Qualification*—If specified in the contractual agreement, personnel performing examinations to this practice 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, ISO 9712, FAA CA-65-31B 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.

7.4 *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.

7.5 *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 and distance amplitude relationships 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 reinspected. To evaluate performance characteristics of phased array transducers consisting of a series of individually wired elements that are activated separately using a programmable time delay pattern, and where it is possible to vary the beam angle, focal distance, or beam dimensions, consult Practice E2491.

7.6 *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 deaerate the couplant and enhance adherence of the couplant to the material and search unit. The ability of the wetting agents used as a couplant should be verified during normal system calibration activities carried out just prior to conducting an inspection.

8. Apparatus and Materials

8.1 *Apparatus*

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

8.1.2 *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. The equipment and its display should be capable of meeting the minimum equipment requirements to be completed by filling in Table 1 in Practice E1001 and are applicable only for the frequencies required for the inspection. Also, the equipment, including the search unit, should be capable of producing echo amplitudes of at least 60 %, of full scale, with the noise level no greater than 20 %, from the appropriate reference reflector at a material distance equal to the thickness of the part to be inspected. Alternatively, if these conditions can be met at one half the part thickness, the part may be inspected from both sides.

8.1.3 *General Considerations for Search Unit(s)*—The search unit(s) selected should be compatible with the electronic equipment being used and with the material to be inspected. MAUT search units can be used for both examination and evaluation provided their ultrasonic element density is sufficient in each axis to adequately detect and evaluate indications as required. The assembly of transducer, holder, wearface, and electrical connector comprise the search unit. Select a suitable search unit size and frequency after consideration of the acoustic characteristics of material to be examined, the geometry of the production item, and the minimum size and type of discontinuity to be detected. The higher the frequency selected, the higher the resolving capability accompanied with a decrease in penetrating power; conversely, the lower the frequency used, the greater the penetrating power with decreasing resolving capability. Factors limiting the use of higher frequencies are the equipment and the material properties. The limiting use of lower frequencies is the loss in sensitivity level for the examination. Various types of straight-beam search units are available offering advantages for specific applications.

NOTE 1—While the use of squirters is allowed, their use is not specifically addressed in this practice aside from levying a requirement that the search unit should match the intended squirter(s) if used.

8.1.4 *Search Unit(s) for Thickness Measurements*—If a thickness readout instrument has the capability to read thin sections, a highly damped, high-frequency search unit is generally used. High-frequency (10 MHz or higher) delay line search units are generally required for thicknesses less than about 0.6 mm (0.025 in.). In general, composites will require lower frequency search units compared to metals. Low frequency (0.5 MHz to 1.5 MHz) search units are generally

[13] Roach, D, Rice, T., "A Quantitative Assessment of Advanced Nondestructive Inspection Techniques for Detecting Flaws in Composite Laminate Aircraft Structures," U.S. Dept. of Transportation Report DOT/FAA/TC-15/4, March, 2016.

required for composite thicknesses greater than about 25 mm (1.0 in.). The optimum frequency will depend on the inherent attenuation of the material and also its quality. High porosity level composites, especially those manufactured using out-of autoclave processes, will require lower search unit frequencies. Measurements of materials at high temperatures require search units specially designed for the application.

8.1.5 *Manipulating Equipment* should be provided during automated inspections to adequately support the search unit(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.

NOTE 2—Matrix array search units used in TTU mode (Procedure B) can be used in contact without the requirement for a manipulating equipment, because the matrix array and corresponding software display allow manual alignment adjustments to be made. However, manipulating equipment can also be used instead of this as required.

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

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

8.1.8 *Curved Surfaces*—Reference blocks with flat surfaces may be used for establishing gain settings for examinations on test surfaces with radii of curvature 100 mm to 130 mm (4 in. to 5 in.) or greater. For test surfaces with radii of curvature less than 100 mm to 130 mm, reference blocks with the same nominal curvature should be used, unless otherwise agreed upon between the supplier and the purchaser. Additional details on curved surface reference blocks are discussed in subsection 7.3.3 in Practice E2375.

8.1.9 *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 disbonds in the part. Transfer cutouts shall be attached to the part and be placed to cover changes in part configuration and alignment. Transfer cutouts shall be made of two layers of lead foil tape cut to size.

8.2 *Materials:*

8.2.1 *Material Condition*—In accordance with Guide E1901, unless otherwise agreed upon, the surface finish of the article under examination shall not exceed 6.4 µm (250 µin.) rms and shall be free from waviness that may affect the examination. Ultrasonic examination should be performed in the simplest configuration possible and after all operations that may cause a discontinuity. If surface roughness and part geometry are within the tolerance specified in the contractual agreement, MAUT is performed on the part or material before machining. Surfaces may already be sufficiently free of roughness and waviness to permit a uniform examination over the required areas. When it is determined that surface roughness precludes adequate detection and evaluation of subsurface discontinuities or anomalies, areas in question can be smoothed by machining, grinding, or other means before the examination is performed. For brittle or friable materials or materials prone to fraying, care should be taken to avoid generating surface or near-surface cracks or crumbling or fraying of the surface by the smoothing operation. During examination and evaluation, ensure that the entry surface and back surface are free of loose scale, paint, dirt, machining or grinding particles or other loose foreign matter. Tightly adhering paint, scale, or coatings do not necessarily need to be removed for examining if they present uniform attenuation characteristics. If needed, surfaces may be ground, sanded, wire brushed, scraped, or otherwise prepared for examining purposes.

8.2.2 *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.

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

8.2.4 *Metallic Specimens*—Processing guidelines for fabrication of metallic specimens are diverse and shall be agreed upon by the using parties.

8.2.5 *Couplants*—A couplant, usually a liquid or semi-liquid, shall provide intimate coupling between search unit and part. Couplants shall be compatible with the part and shall be easily removed from the part using an applicable cleaning process. Typical couplants include water, cellulose gel, oil, and grease. The couplant used in the standardization should be used for the examination. The couplant should be selected so that its viscosity is appropriate for the surface finish of the part being examined. For example, parts with a rough surface finish generally require a high viscosity couplant. For details on suggested oil couplant viscosities and precautions when performing examinations at high temperatures or over large areas, consult Section 6 and Table 1 in Practice E114, and subsection 7.2 in Guide E1901.

8.2.5.1 For composite test articles, the coupling agent shall not dissolve, swell, or have any adverse effect on the composite matrix resin, bondline adhesive, or other materials present in the composite or sandwich construction.

8.2.5.2 For metallic test articles, a suitable corrosion inhibiting agent, or a wetting agent, or both, shall be added to the water, if necessary. Glycerin (pure), silicones, and graphite greases shall not be used as couplants, unless specifically permitted by the cognizant engineering organization. Any inhibiting and wetting agents including mixing concentrations shall have been previously determined to be compatible with the materials to be examined.