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Designation: E 1736 – 00

Standard Practice for Acousto-Ultrasonic Assessment of Filament-Wound Pressure Vessels[1]

This standard is issued under the fixed designation E 1736; 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 a procedure for acousto-ultrasonic (AU) assessment of filament-wound pressure vessels. Guidelines are given for the detection of defect states and flaw populations that arise during materials processing or manufacturing or upon exposure to aggressive service environments. Although this practice describes an automated scanning mode, similar results can be obtained with a manual scanning mode.

1.2 This procedure recommends technical details and rules for the reliable and reproducible AU detection of defect states and flaw populations. The AU procedure described herein can be a basis for assessing the serviceability of filament-wound pressure vessels.

1.3 The objective of the AU method is primarily the assessment of defect states and diffuse flaw populations that influence the mechanical strength and ultimate reliability of filament-wound pressure vessels. The AU approach and probe configuration are designed specifically to determine composite properties in lateral rather than through-the-thickness directions.[2]

1.4 The AU method is not for flaw detection in the conventional sense. The AU method is most useful for materials characterization, as explained in Guide E 1495, which gives the rationale and basic technology for the AU method. Flaws and discontinuities such as large voids, disbonds, or extended lack of contact of interfaces can be found by other nondestructive examination (NDE) methods such as immersion pulse-echo ultrasonics.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 1001 Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves[3]

E 1067 Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels[3]

E 1316 Terminology for Nondestructive Examinations[3]

E 1495 Guide for Acousto-Ultrasonic Assessment of Composites, Laminates, and Bonded Joints[3]

2.2 *ASNT Standards:*[4]

ANSI/ASNT CP-189 Personnel Qualification and Certification in Nondestructive Testing

ASNT SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

2.3 *Military Standards:*[5]

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification

NAS-410 Certification and Qualification of Nondestructive Test Personnel

3. Terminology

3.1 *Definitions*—Relevant terminology and nomenclature are defined in Terminology E 1316 and Guide E 1495.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *composite shell*—a multilayer filament-winding that comprises a second shell that reinforces the inner shell. The composite shell consists of continuous fibers, impregnated with a matrix material, wound around the inner shell, and cured in place. An example is the Kevlar®-epoxy filament-wound spherical shell shown in Fig. 1. The number of layers, fiber orientation, and composite shell thickness may vary from point to point (Fig. 2). The examination and assessment of the composite shell are the objectives of this practice.

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

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[2] Vary, A., "Acousto-Ultrasonics," *Nondestructive Testing of Fibre-Reinforced Plastics Composites*, Vol 2, J. Summerscales, ed., Elsevier Science Publishers Ltd., Barking, Essex, England, 1990, Chapter 1, pp. 1–54.

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

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

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

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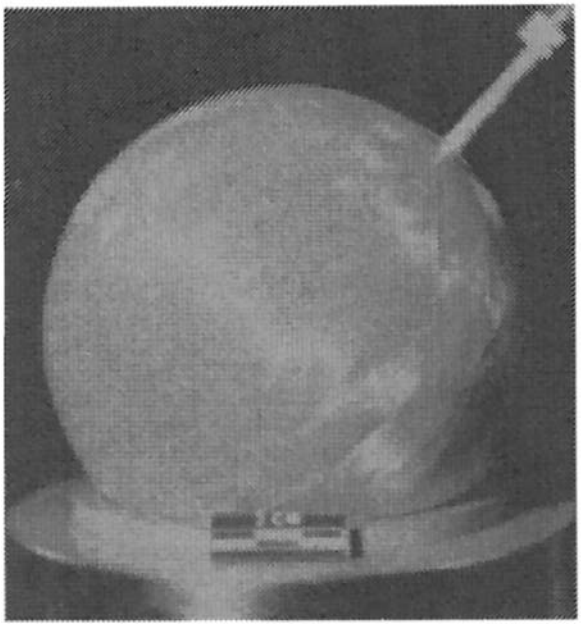

FIG. 1 Kevlar®-Epoxy Filament-Wound Shell

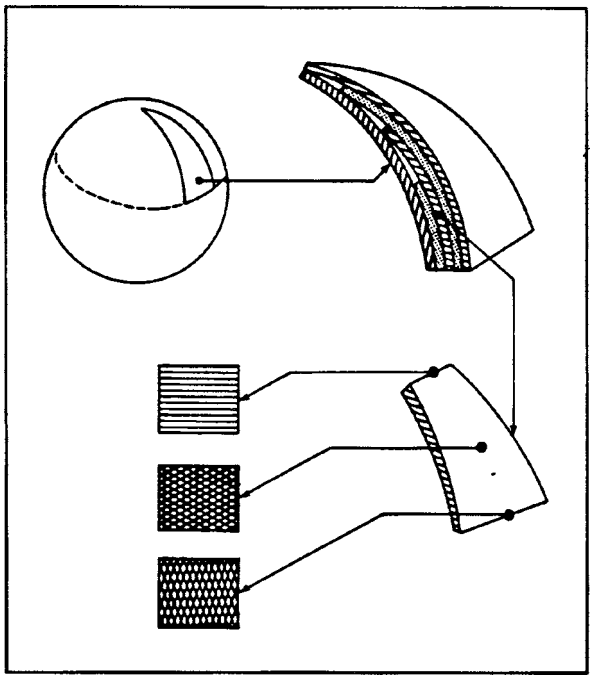

FIG. 2 Representation of Filament-Wound Composite Shell Layers Showing Typical Thicknesses and Layering Variations

3.2.2 *filament-wound pressure vessel*—an inner shell overwrapped with composite layers that form a *composite shell*. The inner shell or liner may consist of an impervious metallic or nonmetallic material. The vessel may be cylindrical or spheroidal and will have at least one penetration with valve attachments for introducing and holding pressurized liquids or gases.

4. Significance and Use

4.1 The AU method should be considered for vessels that are proven to be free of major flaws or discontinuities as determined by conventional techniques. The AU method may be used for detecting major flaws if other methods are deemed impractical. It is important to use methods such as immersion pulse-echo ultrasonics (Practice E 1001) and acoustic emission (Practice E 1067) to ascertain the presence of major flaws before proceeding with AU.

4.2 The AU method is intended almost exclusively for materials characterization by assessing the collective effects of dispersed defects and subcritical flaw populations. These are material aberrations that influence AU measurements and also underlie mechanical property variations, dynamic load response, and impact and fracture resistance.[6]

4.3 The AU method can be used to evaluate laminate quality using access to only one surface, the usual constraint imposed by closed pressure vessels. For best results, the AU probes must be fixtured to maintain the probe orientation at normal incidence to the curved surface of the vessel. Given these constraints, this practice describes a procedure for automated AU scanning using water squirters to assess the serviceability and reliability of filament-wound pressure vessels.[7]

5. Limitations

5.1 The AU method possesses the limitations common to all ultrasonic methods that attempt to measure either absolute or relative attenuation. When instrument settings and probe configurations are optimized for AU, they are unsuitable for conventional ultrasonic flaw detection because the objective of AU is not the detection and imaging of individual micro- or macro-flaws.

5.2 The AU results may be affected adversely by the following factors: (*1*) couplant (squirter or water jet) variations and bubbles, (*2*) vessel surface texture and roughness, (*3*) improper selection of probe characteristics (center frequency and bandwidth), (*4*) probe misalignment, (*5*) probe resonances and insufficient damping, and (*6*) inadequate instrument (pulser-receiver) bandwidth.

5.3 Misinterpretations of AU results can occur if there are intermittent disbonds or gaps in the composite shell or at the interface between the composite and inner shell. Using conventional flaw detection methods, care should be taken to ensure that major delaminations, disbonds, or gaps are not present. Extensive gaps or disbonds will produce the same effect as low attenuation within the composite shell by causing more energy to be reflected or channeled to the receiving probe.

6. Basis of Application

6.1 *Personnel Qualification*

6.1.1 If specified in the contractual agreement, personnel performing examinations to this standard shall be qualified in

[6] Vary, A., "Material Property Characterization," *Nondestructive Testing Handbook—Ultrasonic Testing*, Vol 7, A. S. Birks, R. E. Green, Jr., and P. McIntire, eds., American Society for Nondestructive Testing, Columbus, OH, 1991, Section 12, pp. 383–431.

[7] Sundaresan, M. J., Henneke, E. G., and Brosey, W. D., "Acousto-Ultrasonic Investigation of Filament-Wound Spherical Pressure Vessels," *Materials Evaluation*, Vol 49, No. 5, 1991, pp. 601–6012.

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