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# Standard Guide for Nondestructive Examination of Polymer Matrix Composites Used in Aerospace Applications<sup>1</sup>

This standard is issued under the fixed designation E2533; 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 ( $\epsilon$ ) 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 guide provides information to help engineers select appropriate nondestructive testing (NDT) methods to characterize aerospace polymer matrix composites (PMCs). This guide does not intend to describe every inspection technology. Rather, emphasis is placed on established NDT methods that have been developed into consensus standards and that are currently used by industry. Specific practices and test methods are not described in detail, but are referenced. The referenced NDT practices and test methods have demonstrated utility in quality assurance of PMCs during process design and optimization, process control, after manufacture inspection, in-service inspection, and health monitoring.

1.2 This guide does not specify accept-reject criteria and is not intended to be used as a means for approving composite materials or components for service.

1.3 This guide covers the following established NDT methods as applied to PMCs: Acoustic Emission (AE, Section 7); Computed Tomography (CT, Section 8); Leak Testing (LT, Section 9); Radiographic Testing, Computed Radiography, Digital Radiography, and Radioscopy (RT, CR, DR, RTR, Section 10); Shearography (Section 11); Strain Measurement (Contact Methods, Section 12); Thermography (Section 13); Ultrasonic Testing (UT, Section 14); and Visual Testing (VT, Section 15).

1.4 The value of this guide consists of the narrative descriptions of general procedures and significance and use sections for established NDT practices and test methods as applied to PMCs. Additional information is provided about the use of currently active standard documents (an emphasis is placed on applicable standard guides, practices, and test methods of ASTM Committee E07 on Nondestructive Testing), geometry and size considerations, safety and hazards considerations, and information about physical reference standards.

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.10 on Specialized NDT Methods.

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1.5 To ensure proper use of the referenced standard documents, there are recognized NDT specialists that are certified in accordance with industry and company NDT specifications. It is recommended that a NDT specialist be a part of any composite component design, quality assurance, in-service maintenance, or damage examination.

1.6 This guide summarizes the application of NDT procedures to fiber- and fabric-reinforced polymeric matrix composites. The composites of interest are primarily, but not exclusively, limited to those containing high modulus (greater than 20 GPa ( $3 \times 10^6$  psi)) fibers. Furthermore, an emphasis is placed on composites with continuous (versus discontinuous) fiber reinforcement.

1.7 This guide is applicable to PMCs containing, but not limited to, bismaleimide, epoxy, phenolic, poly(amide imide), polybenzimidazole, polyester (thermosetting and thermoplastic), poly(ether ether ketone), poly(ether imide), polyimide (thermosetting and thermoplastic), poly(phenylene sulfide), or polysulfone matrices; and alumina, aramid, boron, carbon, glass, quartz, or silicon carbide fibers.

NOTE 1—Per the discretion of the cognizant engineering organization, composite materials not developed and qualified in accordance with the guidelines in CMH-17, Volumes 1 and 3 should have an approved material usage agreement.

1.8 The composite materials considered herein include uniaxial laminae, cross-ply laminates, angle-ply laminates, and sandwich constructions. The composite components made therefrom include filament-wound pressure vessels, flight control surfaces, and various structural composites.

1.9 For current and potential NDT procedures for finding indications of discontinuities in the composite overwrap and thin-walled metallic liners in filament-wound pressure vessels, also known as composite overwrapped pressure vessels (COPVs), refer to Guides E2981 and E2982, respectively.

1.10 For a summary of the application of destructive ASTM standard practices and test methods (and other supporting standards) to continuous-fiber reinforced PMCs, refer to Guide D4762.

1.11 *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.

1.12 *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.*

1.13 *This international standard was developed in accordance with internationally recognized principles on standardization 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:<sup>2</sup>

**D3878** Terminology for Composite Materials

**D4762** Guide for Testing Polymer Matrix Composite Materials

**E94/E94M** Guide for Radiographic Examination Using Industrial Radiographic Film

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

**E214** Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves (Withdrawn 2007)<sup>3</sup>

**E251** Test Methods for Performance Characteristics of Metallic Bonded Resistance Strain Gages

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

**E427** Practice for Testing for Leaks Using the Halogen Leak Detector Alkali-Ion Diode (Withdrawn 2013)<sup>3</sup>

**E432** Guide for Selection of a Leak Testing Method

**E493/E493M** Practice for Leaks Using the Mass Spectrometer Leak Detector in the Inside-Out Testing Mode

**E498/E498M** Practice for Leaks Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Tracer Probe Mode

**E499/E499M** Practice for Leaks Using the Mass Spectrometer Leak Detector in the Detector Probe Mode

**E515** Practice for Leaks Using Bubble Emission Techniques

**E543** Specification for Agencies Performing Nondestructive Testing

**E569/E569M** Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation

**E650/E650M** Guide for Mounting Piezoelectric Acoustic Emission Sensors

**E664/E664M** Practice for the Measurement of the Apparent Attenuation of Longitudinal Ultrasonic Waves by Immersion Method

**E747** Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology

**E750** Practice for Characterizing Acoustic Emission Instrumentation

**E976** Guide for Determining the Reproducibility of Acoustic Emission Sensor Response

**E1000** Guide for Radioscopy

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

**E1002** Practice for Leaks Using Ultrasonics

**E1003** Practice for Hydrostatic Leak Testing

**E1025** Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiography

**E1065/E1065M** Practice for Evaluating Characteristics of Ultrasonic Search Units

**E1066/E1066M** Practice for Ammonia Colorimetric Leak Testing

**E1067/E1067M** Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels

**E1118/E1118M** Practice for Acoustic Emission Examination of Reinforced Thermosetting Resin Pipe (RTRP)

**E1211/E1211M** Practice for Leak Detection and Location Using Surface-Mounted Acoustic Emission Sensors

**E1213** Practice for Minimum Resolvable Temperature Difference for Thermal Imaging Systems

**E1237** Guide for Installing Bonded Resistance Strain Gages

**E1255** Practice for Radioscopy

**E1311** Practice for Minimum Detectable Temperature Difference for Thermal Imaging Systems

**E1316** Terminology for Nondestructive Examinations

**E1324** Guide for Measuring Some Electronic Characteristics of Ultrasonic Testing Instruments

**E1411** Practice for Qualification of Radioscopic Systems

**E1419/E1419M** Practice for Examination of Seamless, Gas-Filled, Pressure Vessels Using Acoustic Emission

**E1441** Guide for Computed Tomography (CT)

**E1543** Practice for Noise Equivalent Temperature Difference of Thermal Imaging Systems

**E1570** Practice for Fan Beam Computed Tomographic (CT) Examination

**E1603/E1603M** Practice for Leakage Measurement Using the Mass Spectrometer Leak Detector or Residual Gas Analyzer in the Hood Mode

**E1647** Practice for Determining Contrast Sensitivity in Radiology

**E1672** Guide for Computed Tomography (CT) System Selection

**E1695** Test Method for Measurement of Computed Tomography (CT) System Performance

**E1742/E1742M** Practice for Radiographic Examination

**E1815** Test Method for Classification of Film Systems for Industrial Radiography

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

- E1817** Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
- E1862** Practice for Measuring and Compensating for Reflected Temperature Using Infrared Imaging Radiometers
- E1897** Practice for Measuring and Compensating for Transmittance of an Attenuating Medium Using Infrared Imaging Radiometers
- E1901** Guide for Detection and Evaluation of Discontinuities by Contact Pulse-Echo Straight-Beam Ultrasonic Methods
- E1932** Guide for Acoustic Emission Examination of Small Parts
- E1933** Practice for Measuring and Compensating for Emissivity Using Infrared Imaging Radiometers
- E1934** Guide for Examining Electrical and Mechanical Equipment with Infrared Thermography
- E1935** Test Method for Calibrating and Measuring CT Density
- E2002** Practice for Determining Total Image Unsharpness and Basic Spatial Resolution in Radiography and Radioscopy
- E2007** Guide for Computed Radiography
- E2024/E2024M** Practice for Atmospheric Leaks Using a Thermal Conductivity Leak Detector
- E2033** Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)
- E2076/E2076M** Practice for Examination of Fiberglass Reinforced Plastic Fan Blades Using Acoustic Emission
- E2104** Practice for Radiographic Examination of Advanced Aero and Turbine Materials and Components
- E2191/E2191M** Practice for Examination of Gas-Filled Filament-Wound Composite Pressure Vessels Using Acoustic Emission
- E2208** Guide for Evaluating Non-Contacting Optical Strain Measurement Systems
- E2445/E2445M** Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
- E2446** Practice for Manufacturing Characterization of Computed Radiography Systems
- E2580** Practice for Ultrasonic Testing of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications
- E2581** Practice for Shearography of Polymer Matrix Composites and Sandwich Core Materials in Aerospace Applications
- E2582** Practice for Infrared Flash Thermography of Composite Panels and Repair Patches Used in Aerospace Applications
- E2597/E2597M** Practice for Manufacturing Characterization of Digital Detector Arrays
- E2661/E2661M** Practice for Acoustic Emission Examination of Plate-like and Flat Panel Composite Structures Used in Aerospace Applications
- E2662** Practice for Radiographic Examination of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications
- E2736** Guide for Digital Detector Array Radiography
- E2737** Practice for Digital Detector Array Performance Evaluation and Long-Term Stability
- E2981** Guide for Nondestructive Examination of Composite Overwraps in Filament Wound Pressure Vessels Used in Aerospace Applications
- E2982** Guide for Nondestructive Testing of Thin-Walled Metallic Liners in Filament-Wound Pressure Vessels Used in Aerospace Applications
- F1364** Practice for Use of a Calibration Device to Demonstrate the Inspection Capability of an Interferometric Laser Imaging Nondestructive Tire Inspection System
- 2.2 *ASNT Standards and Documents:*<sup>4</sup>
- 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
- Leak Testing, Volume 1**, Nondestructive Testing Handbook Nondestructive Testing Handbook, Visual and Optical Testing, Vol. 8
- 2.3 *ASTM Adjuncts:*
- Curing Press Straining Block (13 Drawings)<sup>5</sup>
- 2.4 *ISO Standard:*<sup>6</sup>
- ISO 9712** Non-destructive Testing—Qualification and Certification of NDT Personnel
- 2.5 *AIA Standard:*<sup>7</sup>
- NAS 410** Certification & Qualification of Nondestructive Test Personnel
- 2.6 *MIL Documents:*<sup>8</sup>
- CMH-17** Composite Materials Handbook, Volume 1. Polymer Matrix Composites, Guidelines For Characterization Of Structural Materials (formerly MIL-HDBK-17)
- CMH-17** Composite Materials Handbook, Volume 3. Polymer Matrix Composites, Materials Usage, Design, and Analysis (formerly MIL-HDBK-17)
- MIL-HDBK-6870** Inspection Program Requirements, Non-destructive for Aircraft and Missile Materials and Parts
- MIL-HDBK-732A** Nondestructive Testing Methods of Composite Materials—Acoustic Emission
- MIL-HDBK-728 /5A** Radiologic Testing
- MIL-HDBK-733** Nondestructive Testing Methods of Composite Materials—Radiography
- MIL-HDBK-731** Nondestructive Testing Methods of Composite Materials—Thermography
- MIL-HDBK-787** Nondestructive Testing Methods of Composite Materials—Ultrasonics
- MIL-L-25567D** Leak Detection Compound, Oxygen Systems

<sup>4</sup> Available from American Society for Nondestructive Testing, P. O. Box 28518, 1711 Arlington Lane, Columbus, OH 43228-0518.

<sup>5</sup> Available from ASTM International Headquarters. Order Adjunct No. ADJf1364.

<sup>6</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

<sup>7</sup> Available from Aerospace Industries Association (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209, <http://www.aia-aerospace.org>.

<sup>8</sup> Available for Standardization Documents Order Desk, Bldg 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.