Designation: E2662 – 15

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

This standard is issued under the fixed designation E2662; 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 is intended to be used as a supplement to Practices E1742, E1255, E2033, and E2698.

1.2 This practice describes procedures for radiographic examination of flat panel composites and sandwich core materials made entirely or in part from fiber-reinforced polymer matrix composites. Radiographic examination is: *a*) Film Radiography (RT), *b*) Computed Radiography (CR) with Imaging Plate, *c*) Digital Radiography (DR) with Digital Detector Array's (DDA), and *d*) Radioscopic (RTR) Real Time Radiography with a detection system such as an Image Intensifier. The composite materials under consideration typically contain continuous high modulus fibers (> 20 GPa), such as those listed in 1.4.

1.3 This practice describes established radiographic examination methods that are currently used by industry that have demonstrated utility in quality assurance of flat panel composites and sandwich core materials during product process design and optimization, process control, after manufacture inspection, in service examination, and health monitoring. Additional guidance can be found in E2533, Guide for Nondestructive Testing of Polymer Matrix Composites Used in Aerospace.

1.4 This practice has utility for examination of flat panel composites and sandwich constructions 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. Typical as-fabricated geometries include uniaxial, cross ply and angle ply laminates; as well as honeycomb core sandwich constructions.

1.5 This practice does not specify accept-reject criteria and is not intended to be used as a means for approving flat panel composites or sandwich core materials for service.

1.6 To ensure proper use of the referenced standards, there are recognized nondestructive testing (NDT) specialists that are certified according to 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.

1.7 *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
D1434 Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting
D3878 Terminology for Composite Materials
E94 Guide for Radiographic Examination
E543 Specification for Agencies Performing Nondestructive Testing
E747 Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
E1000 Guide for Radioscopy
E1025 Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
E1165 Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
E1255 Practice for Radioscopy
E1309 Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases

[1] This practice is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.01 on Radiology (X and Gamma) Method.

Current edition approved June 1, 2015. Published July 2015. Originally approved in 2009. Last previous edition approved as E2662–15. DOI: 10.1520/E2662-15.

[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.

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

E1316 Terminology for Nondestructive Examinations
E1471 Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases
E1742 Practice for Radiographic Examination
E1815 Test Method for Classification of Film Systems for Industrial Radiography
E1817 Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
E2007 Guide for Computed Radiography
E2033 Practice for Computed Radiology (Photostimulable Luminescence Method)
E2445 Practice for Performance Evaluation and Long-Term Stability of Computed Radiography Systems
E2446 Practice for Classification of Computed Radiology Systems
E2533 Guide for Nondestructive Testing of Polymer Matrix Composites Used in Aerospace Applications
E2597 Practice for Manufacturing Characterization of Digital Detector Arrays
E2698 Practice for Radiological Examination Using Digital Detector Arrays
E2736 Guide for Digital Detector Array Radiology
E2737 Practice for Digital Detector Array Performance Evaluation and Long-Term Stability

2.2 *National Council on Radiation Protection and Measurement (NCRP) Documents:*[3]

NCRP 49 Structural Shielding Design and Evaluation for Medical Use of X-Rays and Gamma Rays of Energies up to 10 MeV
NCRP 116 Limitation of Exposure to Ionizing Radiation
NCRP 144 Radiation Protection for Particle Accelerator Facilities

2.3 *Federal Standards:*[4]

10 CFR 20 Standards for Protection Against Radiation
21 CFR 1020.40 Safety Requirements of Cabinet X-ray Systems
29 CFR 1910.1096 Ionizing Radiation (X-rays, RF, etc.)

2.4 *Aerospace Industries Association Document:*[5]

NAS 410 Certification and Qualification of Nondestructive Test Personnel

2.5 *Department of Defense (DoD) Documents:*[4]

MIL-I-24768/10 Insulation, Plastics, Laminated, Thermosetting, Paper-Base, Phenolic-Resin (PBE)
MIL-I-24768/11 Insulation, Plastics, Laminated, Thermosetting, Paper-Base, Phenolic-Resin (PBG)

2.6 *ISO Documents:*[6]

ISO 19232-1 Non-destructive Testing—Image Quality of Radiographs—Part 1: Determination of the Image Quality Value using Wire-type Image Quality Indicators

2.7 *EN Documents:*[7]

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

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *CEO—Cognizant Engineering Organization, n*—the company, government agency, or other authority responsible for the design, or end use, of the device(s) for which radiographical examination is required. This, in addition to design personnel, may include personnel from engineering, material and process engineering, nondestructive testing (usually the cognizant Radiographic Level 3), or quality groups, as appropriate.

3.2.2 *flat panel composite, n*—any fiber reinforced composite lay-up consisting laminae (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.

3.2.3 *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. See also *sandwich core construction* in Terminology C274.

4. Summary of Practice

4.1 *Agency Evaluation*—When specified in the contractual agreement, NDT agencies shall be evaluated and qualified in accordance with Practice E543.

4.2 RT shall be conducted in accordance with Practice E1742, Guide E94, and the additional requirements of this practice.

4.3 RTR shall be conducted in accordance with Practice E1255, Guide E1000, and the additional requirements of this practice.

4.4 CR shall be conducted in accordance with Practice E2033, Guide E2007, and the additional requirements of this practice.

4.5 DR shall be conducted in accordance with Practice E2698, Guide E2736, and the additional requirements of this practice.

5. Significance and Use

5.1 Radiographic examination may be used during product and process design optimization, on line process control, after manufacture inspection, and in service inspection. In addition

[3] Available from NCRP Publications, 7010 Woodmont Ave., Suite 1016, Bethesda, MD 20814.

[4] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

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

[6] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[7] Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, http://www.cen.eu.

to verifying structural placement, radiographic examination can be used in the case of honeycomb core materials to detect node bonds, core-to-core splices, and core-to-structure splices. Radiographic examination is especially well suited for detecting sub-surface flaws. The general types of defects detected by radiographic examination include blown core, core corrosion, damaged filaments, density variation, entrapped fluid, fiber debonding, fiber misalignment, foreign material, fractures, inclusions, micro-cracks, node bond failure, porosity/voids, and thickness variation.

5.2 Factors that influence image formation and X-ray attenuation in radiographic examination, and which are relevant to interpreting the images for the conditions of interest, should be included in the examination request. Examples include, but not limited to, the following: laminate (matrix and fiber) material, lay-up geometry, fiber volume fraction (flat panels); facing material, core material, facing stack sequence, core geometry (cell size); core density, facing void content, adhesive void content, and facing volume percent reinforcement (sandwich core materials); overall thickness, specimen alignment, and specimen geometry relative to the beam (flat panels and sandwich core materials).

5.3 Information regarding discontinuities that are detectable using radiographic examination methods can be found in Guide E2533.

6. Qualification

6.1 *Personnel Qualification*—Personnel performing examinations to this practice shall be qualified in accordance with NAS410 or EN 4179 and certified by the employer. Other equivalent qualification documents may be used when specified on the contract or purchase order. The applicable revision shall be the latest unless otherwise specified in the contractual agreement between parties.

6.2 *Qualification of Nondestructive Testing (NDT) Agencies*—When specified in the contractual agreement, nondestructive testing agencies shall be qualified and evaluated as described in Practice E543.

6.2.1 *Safety*—The NDT facility shall present no hazards to the safety of personnel and property. NCRP 144 and NCRP 116 may be used as guides to ensure that radiographic procedures are performed so that personnel shall not receive a radiation dose exceeding the maximum safe limits as permitted by city, state, or national codes.

7. Equipment and Materials

7.1 *Equipment:*

7.1.1 *X-Radiation Sources*—Selection of suitable X-ray machines will depend upon variables regarding the specimen being examined and the size and type of defects being sought. The suitability of an X-ray machine shall be demonstrated by attainment of the required radiographic quality level, radiographic contrast, and compliance with all other requirements stipulated in this practice.

7.1.1.1 Geometric magnification may be used with the following caveats and considerations:

(a) The higher the magnification factor used, the smaller the area of inspection becomes within the part that is normal to the radiation beam. This makes detection of certain discontinuities, such as cracks that occupy a significant portion of the part thickness more challenging to detect.

(b) System spatial resolution increases with magnification, which can increase overall system sharpness. However, the maximum magnification allowed shall be based on the unsharpness requirements of Table 1.

(c) Contrast to Noise increases with greater object-to-detector distance because less scatter radiation reaches the detector.

7.1.1.2 When using magnification, the focal spot size should be small enough to avoid unsharpness due to the size of the focal spot in accordance with section 8.5 herein.

7.1.2 *Gamma Radiation Sources*—Gamma radiation sources are generally not suitable for the high contrast, high sensitivity requirements needed to meet the requirements of this practice. The use of gamma ray sources will only be allowed when approved by the CEO, or the cognizant Level 3 Radiographer, or both. The suitability of a specific gamma ray source shall be demonstrated by attainment of the required radiographic quality level, radiographic contrast, and compliance with all other requirements stipulated in this practice.

7.1.3 *Film Processing Equipment*—The following are the descriptions of automatic processors and manual processing in regards to film processing equipment.

7.1.3.1 *Automatic Film Processors*—Automatic film processors shall conform to the film manufacturer's requirements (that is, time, temperature, and replenishment rates) for film processing, and be maintained in accordance with the manufacturer's recommendations in such a manner as to consistently produce blemish-free and archival quality radiographs. Automatic processor replenisher tanks, including auto mixers shall be set up and maintained in accordance with the film manufacturer's recommendations, that is, floating lid in developer tank, filters on replenishment lines, or cleaned periodically.

7.1.3.2 *Manual Film Processing*—Manual processing tanks and film dryers shall conform to the film manufacturer's requirements (that is, stainless steel or other non-reactive material, proper covers) and shall be large enough to consistently produce blemish-free and archival quality radiographs. Manual tanks shall be cleaned and supplied with fresh chemistry using the following guidelines:

(1) Developer Tank—Drain and clean it when replenisher has been added to an amount equal to five times the volume of the tank. The amount of replenisher added shall be recorded for reference.

(2) Fixer Tank—Drain and clean it when the clearing time is twice as long as it was when fresh (fresh fixer will usually clear a film in approximately 60 seconds). The initial clearing time shall be recorded for reference.

TABLE 1 Image Unsharpness (U_i) (Maximum)

Material Thickness (t), in. (mm)		U_i, in. (mm)
t ≤ 0.5	(t ≤ 12.7)	0.008 (0.203)
0.5 < t ≤ 1.0	(12.7< t ≤ 25.4)	0.010 (0.254)
1.0 < t ≤ 2.0	(25.4< t ≤ 50.8)	0.020 (0.508)
2.0 < t ≤ 4.0	(50.8< t ≤ 101.6)	0.030 (0.762)
4.0 < t	(101.6 < t)	0.040 (1.016)