



Standard Practice for Radiologic Examination of Flat Panel Composites and Sandwich Core Materials Used in Aerospace Applications¹

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1. Scope

1.1 This practice is intended to be used as a supplement to Practices [E 1742](#), [E 1255](#), and [E 2033](#).

1.2 This practice describes procedures for radiologic examination of flat panel composites and sandwich core materials made entirely or in part from fiber-reinforced polymer matrix composites. Radiologic examination is: *a*) radiographic (RT) with film, *b*) Computed Radiography (CR) with Imaging Plate, *c*) Digital Radiology (DR) with Digital Detector Array's (DDA), and *d*) Radioscopic (RTR) Real Time Radiology 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 radiological 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.

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

- [C 274](#) Terminology of Structural Sandwich Constructions
- [D 1434](#) Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheet
- [D 3878](#) Terminology for Composite Materials
- [E 94](#) Guide for Radiographic Examination
- [E 543](#) Specification for Agencies Performing Nondestructive Testing
- [E 747](#) Practice for Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology
- [E 1000](#) Guide for Radioscopy
- [E 1025](#) Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology
- [E 1165](#) Test Method for Measurement of Focal Spots of Industrial X-Ray Tubes by Pinhole Imaging
- [E 1255](#) Practice for Radioscopy
- [E 1309](#) Guide for Identification of Fiber-Reinforced Polymer-Matrix Composite Materials in Databases
- [E 1316](#) Terminology for Nondestructive Examinations
- [E 1471](#) Guide for Identification of Fibers, Fillers, and Core Materials in Computerized Material Property Databases
- [E 1742](#) Practice for Radiographic Examination
- [E 1815](#) Test Method for Classification of Film Systems for Industrial Radiography
- [E 1817](#) Practice for Controlling Quality of Radiological Examination by Using Representative Quality Indicators (RQIs)
- [E 2007](#) Guide for Computed Radiography
- [E 2033](#) Practice for Computed Radiology (Photostimulable

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.

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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.

Luminescence Method)

E 2446 Practice for Classification of Computed Radiology Systems

E 2597 Practice for Manufacturing Characterization of Digital Detector Arrays

2.2 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 2.4 Aerospace Industries Association Document:⁵

NAS 410 Certification & Qualification of Nondestructive Test Personnel

2.5 ASNT Documents:⁶

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

SNT-TC-1A Personnel Qualification and Certification

3. Terminology

3.1 *Definitions*—Terminology in accordance with Terminologies **C 274**, **D 3878**, and **E 1316** 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 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.

3.2.2 *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. See also *sandwich core construction* in Terminology **C 274**.

3.2.3 *digital detector array (DDA), n*—an electronic device that converts ionizing or penetrating radiation into a discrete array of analog signals which are subsequently digitized and transferred to a computer for display as a digital image corresponding to the radiologic energy pattern imparted upon the input region of the device. The conversion of the ionizing

or penetrating radiation into an electronic signal may transpire by first converting the ionizing or penetrating radiation into visible light through the use of a scintillating material. These devices can range in speed from many minutes per image to many images per second, up to and in excess of real-time radioscopy rates.

3.2.4 *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 radiological examination is required. This, in addition to design personnel, may include personnel from engineering, material and process engineering, nondestructive testing (usually the certified Radiographic Level 3), or quality groups, as appropriate.

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 **E 543**.

4.2 RT shall be conducted in accordance with Practice **E 1742**, Guide **E 94**, and the additional requirements of this practice.

4.3 DR and RTR shall be conducted in accordance with Practice **E 1255**, Guide **E 1000**, and the additional requirements of this practice.

4.4 CR shall be conducted in accordance with Practice **E 2033**, Guide **E 2007**, and the additional requirements of this practice.

4.5 *Image Quality Indicators (IQI)*

4.5.1 IQI's shall be used with the following stipulations: Dimensions shall be in accordance with **E 1025** for hole type IQI's, and **E 747** for wire type IQI's, and shall be fabricated from materials radiologically similar to the material being examined. Calculations and experiments to ensure absorption similarities shall be available for audit purposes. Reference Practice **E 1742** for information regarding absorption similarities requirements.

4.6 *Representative Quality Indicators (RQI)*

4.6.1 RQI's may be used in lieu of IQI's when approved by the CEO and/or the certified Level 3 radiographer. RQI's shall be used in accordance with Practice **E 1817**.

5. Significance and Use

5.1 Radiologic examination may be used during product and process design optimization, on line process control, after manufacture inspection, and in service inspection. In addition to verifying structural placement, radiologic examination can be used in the case of honeycomb core materials to detect node bonds, core-to-core splices, and core-to-structure splices. Radiologic examination is especially well suited for detecting sub-surface flaws. The general types of defects detected by radiologic examination include blown core, core corrosion, damaged filaments, density variation, entrapped fluid, fiber debonding, fiber misalignment, foreign material, fractures, inclusions, microcracks, node bond failure, porosity/voids, and thickness variation.

5.2 Factors that influence image formation and X-ray attenuation in radiologic examination, and which are relevant to interpreting the images for the conditions of interest, should be

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

included in the examination request. Examples are, 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, specimen geometry relative to the beam (flat panels and sandwich core materials).

6. Qualification

6.1 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.

6.2 Qualification of Nondestructive Testing (NDT) Agencies—When specified in the contractual agreement, non-destructive testing agencies shall be qualified and evaluated as described in Practice **E 543**.

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 radiological 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 Standard.

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. For evaluation of a proper focal spot size, refer to Guide **E 1000**, subsection 11.3 and Fig. 19.

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 certified 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.

(3) Wash and Stop Bath Tanks—The wash tank and stop bath tanks shall be cleaned whenever the fixer or developer tanks are cleaned.

7.1.4 Digital Detector Array, or CR, or Both—The DDA, or CR, or both, must have an appropriate signal to noise ratio, contrast sensitivity, spatial resolution capability, image lag for DDA (or burn in)/effective erasure capability for CR, and dynamic range to show the required radiological quality level as agreed upon between user and the CEO. Practices **E 2446** and **E 2597** may be consulted for aid in determining relevant variables and values to consider.

7.1.4.1 Users shall comply with the manufacturers' recommendations of temperatures for both operation and shipping, and tolerances in the temperature thereof.

TABLE 1 Image Unsharpness (U_i) (Maximum)

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

7.1.5 Upon installation of the DDA, or CR, or both, an initial series of user tests to baseline attributes such as (but not limited to) signal to noise ratio, contrast sensitivity, spatial resolution, image lag (for DDA)/adequate erasure for CR, bad pixels (for DDA), etc., shall be as agreed upon between user and the CEO. Practices E 2446 and E 2597 may be consulted for aid in determining relevant tests to measure these attributes.

7.1.5.1 The DDA, or CR, or both, should be calibrated using the manufacturers' recommendation both for frequency of calibration and the method used.

NOTE 1—The calibration process is done to remove spatial inhomogeneities of the images, and interpolation of bad pixels in a DDA.

7.1.6 *Software*—The DDA, or CR, or both, cannot be operated without computing hardware and software for image acquisition and image display. The software should be capable to acquire the images frame by frame from a DDA and do an image calibration to correct the inhomogeneities of the DDA and to substitute bad DDA pixels. The software shall be capable to scale images in size (zoom) and gray levels by converting images for optimal monitor display.

7.1.7 *Film, or Imaging Plate Cassettes, or Both*—In addition to the requirements in Practice E 1742, exposure cassettes used for film and computed radiography imaging plates with energies below 40 kV shall not interfere with the clarity of the radiological image.

7.2 Materials:

7.2.1 *Film*—Only film systems meeting the Class I (or better) requirements of Test Method E 1815 shall be used. Class II films may be used in multi-load applications to image varying thickness ranges when approved by the CEO, or the certified Level 3 Radiographer, or both.

8. Procedure

8.1 *Special Handling Requirements*—Identify special handling requirements from purchase orders, engineering drawings, work orders, work instructions, or other authorizing documents that may be applicable. Special handling requirements shall be noted on the Radiographic Technique, or Scan Plan, or both.

8.2 *Written Procedure (Radiologic Technique, or Scan Plan, or Both)*—A radiologic technique and/or scan plan shall be established and documented for each part radiographed. The technique/scan plan shall be established with the acceptance criteria for defect type and size in mind, and shall be capable of consistently producing the requirements for the required radiological quality level and when applicable, radiographic film density and contrast. When digitizing techniques are used the acceptable pixel value range shall be agreed upon by the CEO and/or the Radiographic Level 3. Detailed information required to be documented on the technique is referenced in Practice E 1742, Section 6, and Practice E 1255, subsections 5.2, A1.7, and A2.4, as applicable.

8.3 *IQI Selection*—As stated in Section 4, either hole type or wire type IQI's may be used provided they are fabricated from radiologically similar material as described in Practice E 1742.

8.4 *Non Requirement of IQI's*—IQI's are not required when:

8.4.1 Examining assemblies for debris,

8.4.2 Conducting radiology for defect removal provided final examination of the area includes an IQI,

8.4.3 Examining to show material details or contrast between two or more dissimilar materials, for example, such as examining honeycomb structures to determine location, presence, or absence of inserts or core splices,

8.4.4 Non-use of IQI for other reasons not listed here requires approval by the CEO, or the certified Level 3 Radiographer, or both.

8.5 *Source to Detector Distance*—The minimum allowable source-to-detector distance shall be calculated by the following equation using the appropriate image unsharpness (U_i) value shown in Table 1.

$$SDD = (FT/U_i) + T \quad (1)$$

where:

SDD = source-to-detector distance,

U_i = image unsharpness,

F = size of radiation source, using the manufacture's nominal size or the effective focal spot size in accordance with Test Method E 1165, and

T = distance from the source side of the object to the detector (regardless of whether or not the object is in contact with the detector).

8.6 *Radioscopy*—When RTR is used, a permanent record shall be produced in the form of electronic images. RTR systems that do not provide permanent records may only be used when approved by the CEO, or the Radiographic Level 3, or both.

8.7 *Image Interpretation*—All images, whether film or electronic shall be qualified by the certified interpreter. Verification of film density or pixel value, contrast, radiologic quality level/correct IQI, image identification, complete coverage, etc. is required for image qualification prior to evaluation of hardware to accept/reject criteria.

9. Safety and Hazards

9.1 The safety procedures for the handling and use of ionizing radiation sources must be followed. Mandatory rules and regulations are published by governmental licensing agencies. Careful radiation surveys should be made in accordance with regulations and codes and should be conducted in the examination area as well as in adjacent areas under all possible operating conditions.

9.2 Issues associated with personnel protection against X-rays and gamma rays are not covered by this document. For information on personnel protection, refer to documents issued by the National Committee on Radiation Protection and Measurement, Federal Register, U.S. Energy Research and Development Administration, and to state and local regulations, if such exist. For specific radiation safety information, refer to 10 CFR 20, 21 CFR 1020.40, and 29 CFR 1910.1096 or state regulations for agreement states.

9.3 Radiologic examination procedures shall be conducted under protective conditions so that personnel will not receive radiation dose levels exceeding that permitted by company, city, state, or national regulations. The recommendations of the National Committee on Radiation Protection (NCRP) should be a guide to radiation safety. NCRP 49, NCRP 144, and

NCRP 116 may be used as guides to insure the radiographic or radioscopy procedures are performed so that personnel shall not receive a radiation dose exceeding the maximum permitted by city, state, or national codes.

9.4 Radiologic systems wherein the radiation source and detection system are manipulated instead of, or in addition to, the test article necessitate the use of more stringent shielding requirements.

9.5 *Electrical Safety*—The radiographer or radioscopist must comply with safe electrical practices when working with X-ray equipment. Modern X-ray equipment uses high voltage circuits. Permanently installed X-ray facilities are designed so that personnel will encounter few electrical hazards; however, use of portable X-ray equipment requires that added precaution be taken such as insuring that units are grounded appropriately, power cables are free from wear, and condensers are discharged prior to checking of circuits.

10. Report

10.1 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 **E 1309**. 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 **E 1471** should be consulted.

10.2 To insure test validity, including reproducibility and repeatability, essential information about test method, specimen preparation, specimen geometry, specimen conditioning, test equipment, test environment, loading (if applicable), raw and normalized data, and statistical analysis (if applicable) shall be recorded as described in Guide **D 1434**.

10.3 The inspection report shall reference the acceptance criteria, provide traceability to the specific part or the lot of parts examined, the disposition of the part (accept or reject), the reason for rejection of any items, and shall include the name and/or signature of the radiographic interpreter(s), or their acceptance stamp as applicable.

11. Keywords

11.1 aerospace composites, Computed Radiology (CR); digital detector array (DDA); digital radiology (DR); fiber-reinforced polymer matrix composites; flat panels; high modulus fibers; high performance composites; honeycomb core; laminates; nondestructive evaluation (NDE); nondestructive inspection (NDI); nondestructive testing (NDT); polymeric matrix composites (PMC); radiography (RT); radioscopy (RTR); sandwich core materials; sandwich constructions; structural sandwich constructions

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