AEROSPACE RECOMMENDED PRACTICE

ARP1611™ REV. A

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Superseding ARP1611

Quality Inspection Procedure, Composites
Tracer Fluoroscopy and Radiography

RATIONALE

ARP1611A has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE:

1.1 Purpose:

This document describes an inspection procedure for detecting, by use of a radiographic opaque tracer and fluoroscopy or radiography methods, flaws which have been produced as the result of cutting, machining, or drilling operations in composite or laminate structures.

1.2 Application:

These instructions are applicable to composite materials, such as carbon/epoxy, fiberglass/epoxy, boron/epoxy, and other fibrous reinforcements and resin systems, such as organic fiber reinforcement and polyimide, polyester, and thermoplastic resins.

1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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https://www.sae.org/standards/content/ARP1611A/

2.1 SAE Publication:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2825 Material Safety Data Sheets

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-410 Nondestructive Testing Personnel Qualifications and Certification Reviewer
MIL-STD-453 Inspection, Radiographic

3. INSPECTION PROCEDURE:

3.1 Description:

The radiographic opaque (radiopaque) tracer material is applied to the area to be inspected and allowed to penetrate the flaws open to the surface. The tracer penetrates the flawed area by capillary action and thereby allows the flaw to be detected and sized by fluoroscopy or radiographic procedures. The diiodobutane (DIB) tracer liquid leaves no trace of its presence 48 h after penetration into a flaw (see 5.3 and 5.4).

3.2 Types of Flaws:

There are five primary types of flaws generated by cutting, machining, or drilling of composite materials. These flaws, depending on their size and on the design requirements for the part, may necessitate repair of the composite structure or cause the structure to be rejected.

3.2.1 Delamination: A separation between laminate plies as a result of internal or external stresses. Delaminations may occur on either the tool entrance or exit side of the composite or may be within the composite.

3.2.2 Breakout: A splintering effect, usually on the exit side of a drilled hole or a cut piece. A breakout may be one or more plies thick.

3.2.3 Microcracks: Intralaminar resin cracks, usually running parallel to the cutting or ply direction. These cracks can range from 0.001 to 0.400 in (0.02 to 10.16 mm) in length and are sometimes difficult to detect visually. Occasionally these cracks may run perpendicular to the ply direction during certain machining operations, such as routing. In some resins this may appear as random matrix cracking not caused by machining.

3.2.3.1 (R) Matrix Cracking: Localized cracking confined to the pockets of resin within a composite material. The cracks may cross to adjacent laminate layers but remain confined to resin pockets and do not propagate through fibers. Matrix cracking within the interior of a part would not normally be detected by this method.

3.2.4 Fiber/Resin Pullout: Very small pieces of resin or composite fibers pulled away from the matrix.

3.2.5 Shredding: Tearing of one or more composite plies as a result of forces pulling materials away from the composite. This problem is most prevalent in organic fiber composites and occurs predominately in the top or bottom plies.

4. IMPLEMENTATION OF THE NONDESTRUCTIVE EVALUATION METHOD:

4.1 Work Area Requirements: Work areas wherein tracer fluoroscopy is to be performed should conform to the premises, equipment, and safety requirements of MIL-STD-453.

4.2 Personnel Requirements:

4.2.1 (R) Personnel performing tracer fluoroscopy should be certified for radiographic inspection in accordance with applicable specifications, such as MIL-STD-410, and internal company standards and regulations.

4.2.2 (R) Personnel should be instructed in the care, use, and handling of tracer material, and should be thoroughly familiar with the safety recommendations of the material suppliers, including material safety data sheets (MSDS) conforming to AMS 2825, or equivalent, for materials being used.

4.3 Equipment Requirements:

4.3.1 Radiation Source: A portable X-ray tube with a beryllium window is recommended. A focal spot size in the "micro-focus" range is also recommended. In general, radiographic inspection of composite materials is best accomplished utilizing relatively low kV and high mA. Ranges of 10 to 110 kV and 5 to 40 mA are recommended and should be continuously variable.

4.3.2 Fluoroscopy Screens: The screens should be sensitive to the low-energy X-rays required for composite inspection (see 5.2).

4.3.3 Television Camera: The TV camera should be a light, portable unit with very high gain of about 5000 Angstroms wavelength light and with a remote controlled focusing system.

4.3.4 Video Scanning Display: The display should be capable of resolution of at least 600 lines per inch (23 lines per mm) and have a 14-in (356-mm) or larger diagonal screen measurement, with an external synchronization for use with edge enhancement.

4.3.5 Video Tape System: A video tape system, capable of operating off a video display, and recording the requirements per 4.3.4 is recommended if a permanent record is required of flaws detected.

4.3.6 Miscellaneous Equipment: An aspirator, rubber gloves, cotton swabs, lead identification tape, wiping cloths, and X-radiation counter are also required.

4.4 Material Requirements:

4.4.1 Tracer Material: Tracer material recommended is tetramethylene diiodide (1,4 diiodobutane, or DIB) as follows (see 5.3):

a. Chemical Formula: $I(CH_2)_4I$
b. Specific Gravity: 2.33 ± 0.01 at 23 °C/4 °C
c. Boiling Point: 147 to 152 °F (64 to 67 °C)

4.4.1.1 (R) Alternate Tracer Material: A less toxic tracer material of zinc iodide in alcohol is available. This tracer will leave a residue of zinc iodide within the detected flaws (see 5.4). The solution may be prepared as follows:

a. By Volume: 49% Zinc iodide (see 5.4)
49% Alcohol (Reagent grade)
2% Immunol 438 (wetting agent)

4.4.1.2 New and/or additional tracer materials may be considered for use provided they exhibit similar radiographic density characteristics based upon experimentation.

4.4.2 Composite Test Samples: Test samples (standards) should be prepared from the same composite material and of the same thickness as the parts, or a series of thicknesses to encompass the part thickness, to be inspected. Samples should be sufficiently large to be prepared by drilling, cutting, or other fabrication processes that will be used on the parts. Flaws, such as delaminations or cracks, should be placed into the composite test samples so they emanate from the hole or cut composite edge. The size of the test sample flaws should be such that they can be detected by the tracer fluoroscopy or radiography system with a degree of confidence required by the design considerations (see 5.5).

4.5 Testing Procedure:

4.5.1 Tracer Material Application:

4.5.1.1 Tracer solution should be applied with a cotton swab or similar applicator and should adequately wet the composite edge, hole, or other area to be inspected with sufficient liquid to penetrate flaws. In the case of zinc iodide tracer, the solution may be applied with an eye dropper, disposable pipette, or syringe.

4.5.1.2 (R) When applying DIB tracer material, as with any toxic material, personnel should wear rubber gloves, aspirator, protective clothing, and eye protection and work in a well-ventilated area, especially if considerable tracer material is used.

4.5.1.3 Excess tracer material, which runs down the side of the composite part from the edge or hole, should be wiped dry immediately so as not to cause false positive indications. Use an industrial wipe or similar absorbing material.

4.5.1.4 Tracer material should be effective within 2 min and will retain most of its absorption characteristics up to 6 h after application. No evidence of the DIB tracer material should be present after approximately 24 h and all DIB tracer material should evaporate within 48 h.

4.5.1.5 Dispose of wipes, used to absorb excess tracer material, in accordance with the tracer manufacturer's instruction.

4.5.2 Area Marking: Each hole or edge to be inspected should be marked and identified with lead tape or other effective radiographic marking procedure to maintain adequate traceability to the part and material, when such traceability is required.

4.5.3 Fluoroscopic Inspection:

4.5.3.1 Arrange the work piece, X-ray generation source, fluoroscopic screen (or X-ray film), TV camera, and video output display as shown in Figure 1, or in a logical arrangement for maximum convenience and good visibility of the parts being inspected.

4.5.3.2 If fluoroscopy or radiography is being undertaken in an exposed area, shielding of the X-ray source and subsequent radiation scatter monitoring must be accomplished. Subsequent radiation leakage checks should be made with appropriate survey meter.

4.5.3.3 (R) Calibrate the system by applying tracer material onto the test sample as specified in 4.5.1 and establish the correct voltage of the system to observe adequately the flaw in the standard. Note the voltage and distance settings for the test sample. The calibration sample should be of a thickness equivalent to the part and contain flaws of the minimum rejectable size and orientation.

4.5.3.4 Set the image enhancement controls to give the best contrast and edge enhancement of the flawed area. Note the settings and remove the test sample.

4.5.3.5 Place the composite structure to be inspected into the fixture when an automated system is being used, or place the structure into the fluoroscopy or radiography unit for manual inspection. Check the settings developed on the standard and proceed to inspect the composite, noting the indication of flaws from the video scanning display or film (see 5.5).

4.5.3.6 Record the video scanning display (monitor) data onto video tape when permanent record of the flaws found by fluoroscopy is required.

4.5.3.7 Recheck the calibration of the system with the appropriate standard after each production run.