U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Repairs and Alterations to Composite and Bonded Aircraft Structure

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Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance concerning an acceptable means, but not the only means, of demonstrating compliance with the requirements of Title 14 of the Code of Federal Regulations (14 CFR) parts 21, 23, 25, 26, 27, 29, 31, 33, 35, 43, 91, 121, 125, (U.S.-registered airplanes), 135, 137, and 145 regarding procedures and facilities for repairs and alterations of structure consisting of adhesively bonded (including metal bond) and fiber-reinforced materials (e.g., carbon, aramid, and glass-reinforced polymeric materials mentioned in the current edition of AC 20-107, Composite Aircraft Structure). The information in this AC is applicable to repairs and alterations of bonded and composite structure, whether it is a damaged part that can be removed from the airplane for repairs, or repairs and alterations on the aircraft itself. Examples include repair patches, on-wing bonded repairs, and fabrication and bonding of replacement parts. The Federal Aviation Administration (FAA) will consider any other method of compliance that the applicant elects to present. This AC uses mandatory terms such as “must” only in the sense of ensuring the applicability of these particular methods of compliance when using the acceptable means of compliance (AMC) described herein. This AC does not change regulatory requirements and does not authorize changes in, or deviations from, regulatory requirements.

2. DEFINITIONS.

a. Batch. In general, a quantity of material formed during the same process or in one continuous process and having identical characteristics throughout, using a discrete quantity of material with commonality of raw materials and process history.

b. B-Stage. An intermediate stage in the reaction of certain thermosetting resins, in which the material (plastic and fusible) softens when heated, but may not entirely dissolve or fuse. This stage helps facilitate handling and processing. The resin in an uncured, pre-impregnated (prepreg) material is usually in this stage.

c. Composite. A combination of two or more materials (reinforcing elements, fillers, and composite matrix binder), differing in form or composition on a macro-scale. The constituents retain their identities—that is, they do not dissolve or otherwise merge completely into one another, although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another.

d. Debulk. Compacting of an uncured laminate under vacuum and/or moderate heat and pressure (i.e., noncuring conditions) to remove air, to ensure seating on the tool, and to prevent wrinkles.

e. Design Approval Holder (DAH). A person who has been issued a type design approval by the FAA and who controls the design and quality of the product or part. Approval may take the form of a type certificate (TC), Supplemental Type Certificate (STC), Parts Manufacturer Approval (PMA), or Technical Standard Order Authorization (TSOA).

f. Maintenance Organization (MO). Persons performing a repair or alteration under parts 121 and 135, or repair stations certificated under part 145. As used in this AC, this term includes Maintenance Repair Organizations (MRO), certificated repair stations (CRS), and operators' maintenance facilities.

g. Out Life. The cumulative length of time a material may be out of freezer storage, prior to curing, and still maintain the required processability characteristics and mechanical properties. Also known as a limit on the amount of accumulated out time before further action needs to be taken to ensure the raw material is still usable (also known as work life).

h. Out Time. The cumulative length of time a material spends out of freezer storage.

i. PAH-Approved Supplier. A supplier that has been approved for direct shipment under a Production Approval Holder's (PAH) Production Certificate (PC) or foreign equivalent, also known as an approved vendor. The PAH maintains a list of approved suppliers, which may be called the Approved Supplier List (ASL) or the Approved Vendor List (AVL). The PAH is responsible for ongoing oversight of its approved suppliers in support of its PC.

j. Production Approval Holder (PAH). A person who has been issued a production approval by the FAA, and who controls the manufacturing and quality of the product or part. Approval may take the form of a PC, PMA, or TSOA.

k. Qualified Material. A raw material that has been qualified in accordance with the requirements of a particular material specification. In general, each specification has an associated Qualified Products List (QPL) that identifies the raw materials that have been qualified to that specification. Qualification of a material to a particular specification does not necessarily mean it is approved for use, unless that specification is called out on a drawing or other document.

l. Shelf Life. The length of time a raw material may be in storage under specific conditions and still meet the requirements of the applicable material specification, also known as storage life.

m. Shipment. An order of raw material received by a purchaser. A shipment of prepreg may include rolls of raw material from more than one batch and more than one lot. A shipment of resins or adhesives may include resins or adhesives from one or more batches and more than one lot.

3. RELATED READING MATERIAL (current editions).

a. FAA ACs:

- AC 00-56, Voluntary Industry Distributor Accreditation Program.
- AC 20-107, Composite Aircraft Structure.
- AC 21-26, Quality System for the Manufacture of Composite Structures.
- AC 21-47, Submittal of Data to an ACO, a DER or an ODA for a Major Repair or a Major Alteration.
- AC 23-20, Acceptance Guidance on Material Procurement and Process Specifications for Polymer Matrix Composite Systems.
- AC 43.13-1, Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair.
- AC 43.13-2, Acceptable Methods, Techniques, and Practices – Aircraft Alterations.
- AC 43-210, Standardized Procedures for Requesting Field Approval of Data, Major Alterations, and Repairs.
- AC 65-31, Training, Qualification, and Certification of Nondestructive Inspection (NDI) Personnel.
- AC 65-33, Development of Training/Qualification Programs for Composite Maintenance Technicians.
- AC 120-77, Maintenance and Alteration Data.

b. Society of Automotive Engineers (SAE) Documents.

(1) Procedures:

- SAE ARP4916, Masking and Cleaning of Epoxy and Polyester Matrix Thermosetting Composite Materials.
- SAE ARP4977, Drying of Thermosetting Composite Materials.
- SAE ARP4991, Core Restoration of Thermosetting Composite Components.
- SAE ARP5089, Composite Repair NDT/NDI Handbook.
- SAE ARP5143, Vacuum Bagging of Thermosetting Composite Repairs.
- SAE ARP5144, Heat Application for Thermosetting Resin Curing.
- SAE ARP5256, Mixing Resins, Adhesives and Potting Compounds.
- SAE ARP5319, Impregnation of Dry Fabric and Ply Lay-Up.
- SAE AIR5431, Repair Tooling.

(2) Training:

- SAE AIR4938, Composite and Bonded Structure Technician/Specialist: Training Document.
- SAE AIR5278, Composite and Bonded Structure Engineers: Training Document.
- SAE AIR5279, Composite and Bonded Structure Inspector: Training Document.
- SAE AIR5719, Teaching Points for an Awareness Class on “Critical Issues in Composite Maintenance and Repair.”

(3) Nondestructive Inspection (NDI) Standards:

- SAE ARP5605, Solid Composite Laminate NDI Reference Standards.
- SAE ARP5606, Composite Honeycomb NDI Reference Standards.

(4) Other. SAE AIR5416, Maintenance Life Cycle Cost Model.

c. FAA Policy Statements:

- PS-ACE100-2001-006, Static Strength Substantiation of Composite Aircraft Structure, dated 12/21/2001.
- PS-ACE100-2002-006, Material Qualification and Equivalency for Polymer Matrix Composite Material Systems, dated 9/15/2003.
- PS-ACE100-2004-10030, Substantiation of Secondary Composite Structure, dated 4/19/2005.

d. Other Documents:

- Composite Materials Handbook, CMH-17.
- ASTM D3878, Standard Terminology for Composite Materials.
- SAE AIR4844, Composites and Metal Bonding Glossary.

4. BACKGROUND. This AC provides information on repairs and alterations to composite materials and bonded aircraft structure and on facilities, equipment, and inspection processes that a Maintenance Organization (MO) with the appropriate ratings must have to perform repairs and alterations on such structure. These guidelines supplement the procedures in Design Approval Holders' (DAH) Structural Repair Manuals (SRM). In addition, the MO must perform all major repairs and alterations using data approved by the FAA Administrator. The word "composites," as used in this AC, does not imply a relationship with a certificated repair station (CRS) Airframe Class 1 or Class 2 composite construction rating. Also, operations under parts 91, 121, 125, 129 (U.S.-registered airplanes), 135, and 137, and repair stations certificated under part 145, must comply with part 43, § 43.13.

5. ENGINEERING DATA AND PROCEDURES.

a. Source of Data.

(1) The MO must accomplish repairs/alterations to composite and bonded aircraft structure in accordance with parts 43; 121, § 121.379; 129, §§ 129.14 and 129.207; 135, § 135.437; and 145. It is incumbent upon the MO to work closely with the DAH of the particular product and the FAA, when necessary, to determine what specific data may be necessary to support the repair/alteration. The DAH's maintenance manual and SRM contain much of the information needed for maintenance, repairs, and alterations.

(2) Data for major repairs and alterations must be approved by the FAA (or its designee). FAA approval is also required for major changes to technical data that was previously FAA approved. Minor repairs and alterations, and minor changes to previously approved data, do not require FAA approval. Certain documents associated with the instructions for continued airworthiness (ICA), such as the Aircraft Maintenance Manual (AMM), are acceptable to the Administrator. However, the Airworthiness Limitations section of the ICA is FAA approved. For part 25 airplanes, the SRM and Service Bulletins (SB) are typically approved by the FAA. Where this AC mentions "approved or acceptable data," refer to AC 120-77 for guidance on which term applies.

(3) The MO must use data approved by the FAA when performing major repairs or alterations. In the event that the DAH's repair/alteration data are deficient with regard to specific information, techniques, or repair/alteration methods, or if the damage being repaired/altered exceeds that covered by the DAH's repair/alteration data, the MO must obtain FAA-approved data for the major repair/alteration. A simple concurrence by the DAH does not constitute FAA approval. In addition, FAA approval of data is limited to the repair/alteration specified in that data. While an MO can use previously approved data to develop data, the FAA must approve data for a major repair/alteration. Refer to ACs 21-47, 43-210, and 120-77 for additional information.

b. Data Requirements and Compliance. Each MO must have and maintain data required to define the materials, configuration, and accomplishment procedures for the repairs or alterations it performs. Data must include the drawings and specifications that define the repair or alteration, including required dimensions, materials, and processes necessary to achieve structural strength and other design properties (e.g., transmissivity, lightning strike protection, and flammability). The data must be approved by or acceptable to the FAA, as appropriate (refer to AC 120-77). MOs must perform and document the inspections and tests required to determine compliance with applicable airworthiness requirements and the approved repair or alteration data.

c. Data for Repairs or Alterations Not in Compliance with the DAH's Manuals. For repairs or alterations other than those defined in the DAH manuals (e.g., AMM or SRM), the following data containing the information indicated must be available and used by the MOs when purchasing and receiving materials, fabricating repairs or alterations, and installing the repairs or alterations. Proprietary information for the substantiation might not be in the MO's possession, but retained by the DAH.

(1) Drawings. Engineering drawings must define the following:

(a) Materials. A part whose failure could adversely affect safety must be fabricated from (and repaired or altered by) materials that meet approved specifications that ensure that they have the strength and other properties assumed in the design data. Other materials used in the process of repair or alteration (e.g., vacuum bag and breather cloth) may be called out by material manufacturer's designation;

(b) A method and/or illustration of the number of plies and proper stacking orientation/sequence (for composites);

(c) Fabrication and processing procedures (may be called out by fabrication and in-production process specification);

(d) Shape;

(e) Dimensions and tolerances;

(f) Location and attachment to existing structure; and

(g) Protective coating and sealant.

(2) Substantiation Documentation. FAA-approved or accepted data, as required, (e.g. engineering reports, analyses, and other data) must show that the repaired or altered structure complies with applicable type certification and airworthiness regulations. Repairs/alterations to fatigue critical baseline structure (FCBS) and fatigue critical alteration structure (FCAS) must also be evaluated for part 26 requirements when applicable. The DAH may retain proprietary information and provide the MO with an approval statement (e.g. FAA Form 8110-3, Statement of Compliance with Airworthiness Standards, and FAA Form 8100-9, Statement of Compliance with Airworthiness Standards).

(3) Material Specifications. When material specifications are called out in the repair/alteration drawings or other documents, the materials used must meet the qualification requirements in the material specification. AC 23-20 provides guidance on specifications for polymer matrix composites. Material specifications (for adhesives, resins, prepreg tape and fabric, core materials, metals, etc.) must define the required material and must include the following sections and data:

(a) Material Classifications. Identifies the material specified and acceptable types, classes, grades, and styles of that material.

(b) Material Properties. Specifies the required physical, processability, chemical, and mechanical (e.g., laminate, sandwich, and bond strength) properties for a material that meets the specification.

(c) Material Qualification. Specifies tests and procedures to qualify a material to the specification.

(d) Supplier Quality Control (QC). Specifies supplier QC tests and procedures, and specifies compliance certifications and data that the supplier must provide with each material batch.

(e) Purchaser QC. Specifies purchaser acceptance test and procedures required for each batch per shipment received.

(f) Material Test Methods. Specifies the types of tests, types of specimens, and test procedures for testing the materials for physical, processability, chemical, and mechanical properties.

(g) Packaging and Marking Requirements. Specifies requirements for suppliers to follow when packaging and shipping an order of material to a purchaser.

(h) Storage Conditions. Specifies environmental conditions and time scale for storage.

(i) Recertification Procedures. Specifies the requirements for retest prior to use of over-aged material (e.g., material whose out life or shelf life has been exceeded).

(j) QPL. Specifies a list of supplier products that are currently qualified to the requirements of the specification. Qualified materials must be listed on an approved QPL and purchased from qualified suppliers. Materials used must be in accordance with the material specification and its QPL, unless the substitution is in accordance with procedures approved by or acceptable to the Administrator as appropriate for the MO.

(4) Fabrication and Process Specifications. Fabrication and process specifications must:

(a) Define fabrication and process procedures requirements.

(b) List each major step in the fabrication process and process procedure, including in-process tests and inspections. Steps may include a specific repair/alteration sequence (e.g., for repair/alteration on a vertical surface), and specific material mixing requirements.

(c) Specify appropriate process verification. If witness test coupons are required, specify type and number of coupons, test method, and acceptable property limits.

(d) Define requirements for facility, environmental conditions, equipment, and storage.

(e) Specify cure cycle requirements.

(f) Specify qualifications required for the personnel who will carry out the requirements of the specification. This may include qualification in material control, material handling, and processing techniques such as mixing, layup, etc. (see paragraph 11).

(5) NDI Procedures. NDI procedures must:

(a) Identify method (ultrasonics, x-ray, thermography, etc.);

(b) Define NDI methods and outline test procedures;

(c) Specify equipment and calibration procedures;

(d) Include accept/reject NDI criteria; and

(e) Specify the qualifications for the personnel who will carry out the requirements of the specification (see paragraph 11).

(6) Defect Accept/Reject Criteria. The MO must establish accept/reject criteria for cured or bonded structure corresponding to defects considered in the design data. The DAH's SRM or applicable fabrication specification identifies these criteria. Inspection procedures and equipment used to detect flaws must be consistent with the DAH's standards or other FAA-approved or accepted data (refer to AC 120-77).

6. RAW MATERIAL INSPECTION PROCEDURES.

a. General. The processability and resulting strength-related properties of composite materials used in structural repair/alteration depend upon the composition of the materials from which they are manufactured. In general, a prepreg consists of surface-treated glass, aramid, or carbon fibers impregnated with a reactive and chemically complex resin. Thermosetting resins (e.g., epoxies) are often "staged" or partially reacted during the prepregging process and may undergo compositional changes during transport, handling, and storage.

(1) Changes in resin composition or improper storage and handling may cause problems in processing. It may have adverse effects on the performance and long-term properties of many composite repairs/alterations. This also applies to adhesive systems used in structural bonding (e.g., film adhesives and primers).

(2) The capability of a repair or alteration to satisfactorily maintain its structural integrity for the remaining life of the part or aircraft is dependent, in part, on the MO's knowledge of the physical, processability, chemical, and mechanical properties of the incoming raw materials used (e.g., prepreg materials and adhesives). The physical, processability, chemical, and mechanical test results are, therefore, vital to the continued airworthiness of the structure.

b. Material Acceptance.

(1) General. The MO must have a material receiving plan that addresses incoming material control and conditions to ensure the incoming material is stored properly prior to material acceptance, and a plan addressing the issues in subparagraph 6a(2) that ensures conformity of purchased material to appropriate material specifications. The MO is responsible for ensuring that the materials are protected from contamination, temperature deviations, and problems caused by storage and handling after the original manufacturing process after receipt of the material (see paragraph 7 for material handling and storage procedures).

(2) Material without Reference to Specification. Non-structural materials that have no impact on the strength of the repair/alteration may be used without a controlling material specification. These materials are typically consumable items such as bagging film, breather cloth, etc. Materials called out in the SRM, maintenance manuals, or other repair/alteration documents without reference to a material specification and without requirements for storage, handling, and processing must be controlled as indicated in the material manufacturer's recommendations covering designation, storage, and handling requirements.

(3) Supplier QC Testing. The material supplier is responsible for supplier QC testing (also known as batch acceptance testing) on each batch of material, as defined in the applicable material specification (see subparagraph 5c(3)). Copies of the original material manufacturer and supplier laboratory test reports showing actual test results, if applicable, must accompany each batch of material received for purchaser review and approval.

(4) Purchaser QC Testing and Receiving Inspection. The MO is responsible to ensure purchaser QC testing and receiving inspection are accomplished on each batch of material received, as defined in the applicable material specification (see subparagraph 5c(3)). As part of its incoming material acceptance plan, the MO may choose to perform the purchaser QC testing itself, to have the testing performed at an independent laboratory, or to rely on the purchaser QC testing accomplished by a material vendor or distributor. Once the MO establishes confidence in the quality of materials received from a particular source, it may reduce the level of testing, in accordance with a QC plan approved by the FAA Administrator.

(5) Purchasing Material from a PAH-Approved Supplier. The SRM, material specifications, or related documents may include a list of PAH-approved suppliers/vendors for the materials used in the repairs/alterations, and may state that materials purchased from these PAH-approved suppliers qualifies for an exception to the requirements for purchaser testing in the applicable material specification.

(a) In this case, the MO may waive the purchaser control testing required by the material specification for material purchased from a PAH-approved supplier.

(b) The PAH assumes responsibility for the exception to the specification requirements, and performs quality audits to assure that the supplier manufactures and controls the material in accordance with accepted industry standards and the applicable specification requirements.

(6) Purchasing Material from a Distributor. If the PAH or foreign equivalent identifies the distributor as a PAH-approved supplier, then the MO may rely upon the systems in place to address material handling and storage issues. If the distributor is not identified as a PAH-approved supplier, then the MO must provide oversight. Refer to AC 00-56 for acceptable procedures for such oversight. Distributors must provide the purchaser a copy of the supplier's initial paperwork for traceability. Since distributors typically buy large quantities of material and subdivide it, an MO should consider the following issues:

(a) Possible contamination by water condensation or chemicals, such as mold release compounds and oils (see paragraph 7 for material handling and storage procedures).

(b) Additional out time accumulated during cutting.

(c) Procedures for protecting the raw material during shipment and after cutting. In some cases, the material specifications and SRMs do not envision the use of distributors, so the MO must address what is required through other means.

(d) Recording of storage time and environmental exposure (i.e., temperature and humidity). The MO must have a system that ensures that knowledge of storage and shipment times and environmental exposures are known, and in compliance with the requirements, through whatever path is taken from the material manufacturer until the material is in environmentally controlled storage at the MO. Temperature recorders used from the material supplier to the distributor will usually have expired by the time the raw material is shipped to the MO. This means that the distributor must supply temperature recorders in the shipment from the distributor to the MO.

(7) Types of Tests. The following discussions identify QC tests of physical, processability, chemical, and mechanical properties that an MO will ensure are performed, as specified in the material QC sections of the applicable FAA-approved material specifications.

(a) Physical Tests. Physical tests typically include resin content and fiber area weight, volatile content, tack, flow, and gel time.

(b) Processability Tests. Laminate processability tests may include laminate ply thickness measurements, resin content, void content, and density tests conducted on laminates fabricated from at least one roll per batch of prepreg material.

(c) Chemical Characterization Tests. High performance liquid chromatography (HPLC) and Infrared Spectroscopy (IR) are two chemical characterization tests that provide the capability for rapid screening and QC fingerprinting of the resin's constituents. They are applicable both to prepregs and adhesive resins. HPLC and IR are fundamentally different test methods. They provide direct, but different, information about a resin's composition. The supplier conducts HPLC and IR tests to ensure that the resin type, purity, concentration, and the distribution of resin components are consistent from batch to batch and per the material specification. In the case of prepreg, the supplier conducts these tests on resin samples extracted from a number of rolls in each batch of prepreg material. B-staging alters the chemical composition of the resin, increasing the variety of chemical components. The resin may chemically advance as a function of time in the prepreg.

(d) Mechanical Tests. Mechanical testing should be relevant to the intended use of the material. The use of standard test methods is recommended. For adhesive bonding, appropriate tests include lap shear, wedge, climbing drum, T-peel, and fracture toughness (G_{Ic}) tests. For laminates, the mechanical property tests normally include longitudinal tension (room temperature, ambient), compression (room temperature and elevated temperature, both ambient), short beam shear (room temperature, ambient), and double cantilever beam (DCB) (room temperature, ambient). The room temperature ambient tensile modulus of elasticity and ultimate tensile strain are obtained from the stress-strain curve of the longitudinal tension test. For sandwich structures, the mechanical property tests normally include at least flatwise tensile and 4-point bending tests.

7. MATERIAL HANDLING AND STORAGE PROCEDURES.

a. General. Improper refrigerated storage and handling of materials, such as prepreg tape, core, core splice, fabric, adhesives, potting compounds, and resins can adversely affect the structural integrity of the finished part. Therefore, an MO's accepted system for bonding of aircraft structure and for composite material repair and alteration must include specified procedures for storage and handling of raw materials. The MO's accepted procedures must require materials to be stored and handled in ways that ensure they will be acceptable for use and will provide expected finished properties when processed. When stored at specified temperatures, material specifications normally specify material shelf life. The MO must carefully follow instructions regarding handling and storage.

b. Shelf Life and Temperature Considerations. The MO must handle and store polymer matrix prepreg tape and fabric, adhesives, potting compounds, and resins in accordance with the requirements of the appropriate FAA-approved material specification to ensure retention of material properties. Thermoset matrix composites and structural adhesives are typically stored in sealed containers or bags at 0 °F (-18 °C) to retard the "aging," or partial curing, of the polymer and to extend the shelf life. The sealed containers or bags prevent moisture condensation on the cold material and moisture absorption. When the MO removes the material from the freezer for processing, it thaws within the sealed container or bag until the condensation on the exterior has dissipated. Thin rolls of prepreg and adhesives do not need as long a thaw period. The MO must document the allowed accumulated period of time and track the actual accumulated time the material is outside the freezer. The MO's FAA-accepted system must include recordkeeping procedures for shelf life and out time.

c. Storage and Handling. Polymer matrix prepreg materials and film adhesives normally have a backing sheet that improves their handling characteristics and protects the raw material from handling-related damage. Non-woven unidirectional tapes, for example, can otherwise easily split between fibers.

(1) Material must be supported by the ends of the support tube, or in its original shipping container, to prevent flat spots on the material. Stacking of rolls on top of one another is not allowed.

(2) Clean hands are mandatory when working with these raw materials. Appropriate gloves are required when handling adhesives, prepregs, and surfaces prepared for bonding or layup, as called out in the process specification. Gloves prevent contamination of the bonding surface or prepreg and protect the personnel, since many people are sensitive to adhesives and resins.

(3) The MO personnel can damage many of today's composite material fibers if they bend or fold them with small radii. For this reason, handling procedures should prohibit sharp bending, creasing, gouging, or other actions that could break or damage fibers. Properly trained personnel must handle these materials.

(4) The MO's procedures for storage and handling of these raw materials must include the following:

(a) Using frost-free cold storage equipment. A freezer that opens from the top is recommended. An MO may use walk-in freezers for large volume storage.

(b) Using a temperature gauge or thermometer. The temperature gauge or thermometer should be calibrated as per manufacturing specifications.

(c) Identification of which raw materials (e.g., prepreg tapes and fabrics, film adhesives, and paste adhesives) an MO must store in a freezer.

(d) Placing a tag or record on each roll or container showing the batch number, lot number, roll number, shelf life ending date, and the total, allowable, and accumulated out life. The tag or record must include a place to record accumulative out life.

(e) Specifying the highest allowable freezer storage temperature.

(f) Regularly monitoring freezer storage temperature.

(g) Requiring that the MO stores raw materials in moisture-tight bags or containers in the freezer to prevent moisture absorption. If an MO returns kitted parts to the freezer for storage, the MO should also place them in moisture-tight bags that are sealed to prevent moisture and dust contamination and labeled with the information in subparagraph 7c(3)(d), to maintain traceability.

(h) Specifying that the MO must allow the raw material to thaw within the container or bag until the condensation on the exterior of the container has dissipated. This is to prevent atmospheric moisture from condensing on the material.

(i) Requiring the MO to place remaining raw material on the roll back in its moisture-tight container or bag and placed back in the freezer after recording the out time on the attached record.

(j) Requiring the use of appropriate clothing and gloves for handling adhesives, pre-impregnated composite materials, and prepared bond surfaces (e.g., protective glasses and breathing mask). Carbon/graphite materials are considered hazardous materials and require special handling. The MO must follow regulations and consult the local authorities on the proper procedures for waste disposal.

(k) Requiring the MO to retain the batch number, lot number, roll number, shelf life, and out time records for a specified time (recommended period is a minimum of 2 years from the time an MO depletes or disposes of the material).

(l) Describing how the MO should position/orient the roll material in the freezer to prevent fiber breakage or resin migration, as required in the applicable material specification.

(m) Requiring that the MO scrap or recertify materials that have exceeded their shelf life or out time limit in accordance with the applicable material specification or other FAA-approved procedures.

d. Support of Material. Material must be supported by the ends of the support tube, or in its original shipping container to prevent flat spots on the material. Stacking of rolls on top of one another is not allowed.

8. HANGARS, FACILITIES, AND EQUIPMENT. Repairs/alterations performed on the aircraft in a hangar must have substantiating data that shows it meets the requirements appropriate for a given structure. This would need to be demonstrated for the repair/alteration design and processes to be applied with the structure attached to the aircraft. The facilities and equipment used for repair or alteration of composite or metal-bonded structure must be capable of meeting the repair/alteration process requirements established by the DAH or other FAA-approved/acceptable repair/alteration processes. The MO must maintain and calibrate its equipment in accordance with its applicable procedures acceptable to the Administrator. This section gives examples of facilities and equipment used in repair or alteration of composite or adhesively bonded aircraft structure, and guidelines for controlling part quality.

a. Autoclave. An autoclave capable of providing positive pressures and temperatures consistent with the repair/alteration process. The autoclave should have integral vacuum and thermocouple capability for each part.

b. Oven. An air-circulating oven capable of providing the required cure or drying temperature and equipped with vacuum capability when required.

c. Other Methods. Other methods used for temperature and pressure control include vacuum bagging, thermal blanket, mechanical pressure, heat lamp, and heat gun.

d. Layup and Clean Rooms. Unless otherwise validated for the material system in use, an MO must environmentally and operationally control layup and clean rooms in the following areas:

(1) Temperature and humidity in accordance with the repair/alteration process acceptable to the Administrator.

(2) Air filtration and pressurization capable of providing slight positive over-pressure.

(3) Room designed to minimize dirt traps (e.g., recessed lights, sealed floors, no ledges, etc.) with a routine cleaning schedule established.

(4) Contamination restrictions in cutting, layup, and bonding areas must prohibit the use of uncontrolled sprays, exposure to dust, handling contamination, fumes, oily vapors, and the presence of other particulate or chemical matter that may adversely affect the repair or alteration process (e.g., release agents or material containing uncured silicone must not be permitted). Also, an MO must prohibit eating and smoking in these areas and ensure that other work by technicians does not introduce contaminants into the repair/alteration.

(5) Clean and filtered compressed air when used in the clean room.

e. Freezers. Freezers must be capable of storing adhesives, prepregs, etc., in accordance with the applicable material specification.

f. Cleaning. The MO must provide equipment to accomplish the various cleaning processes (e.g., alkaline or acid etching bath, abrasive blasters, etc.).

g. Spray Room. For adhesively bonded metallic structures, a dedicated spray capability should be available for bonding primer application. Spraying the primer produces greater uniformity and consistency than other methods of application.

h. Core Cutting and Core Foam Cutting Tools. Capability should be available to cut, rout, and profile the honeycomb in either the compressed or expanded form. The MO should keep hand routing to a minimum.

i. Part Drying Capability. For bonded repairs/alterations where the MO reuses some composite parts, a moisture dry-out capability should be available to adequately dry the entire part before layup and bonding of the repair/alteration. The dry-out capability should provide uniform heat and a flow of dry air or gas. One method is a large oven with integral vacuum capability and dry air input into the vacuum bag of the part.

j. Laboratory Test Facilities. Laboratory test facilities must be available if required to perform routine testing of etch solutions, finished laminates for resin content, chemical composition of materials, etc. In addition, laboratory equipment and facilities for mechanical testing of specimens, such as the tests listed in subparagraph 6b(7)(d), must also be available if required.

k. NDI. X-ray, ultrasonic, or other types of nondestructive test equipment must be available for inspection of parts as required in the repair/alteration documentation.

l. Repair Staging Area. A dedicated area for staging of kitted detail parts prior to bond helps to reduce contamination of detail parts.

m. Cutting Tools. Tooling materials and configurations depend on the materials being machined. Diamond or carbide saws and router bits are suitable for cutting and trimming of carbon composites. Hole-drilling operations in carbon composites should also use carbide drills and countersinks, or other means recommended by the DAH. It is important to have backside support when drilling to prevent damage. Generally composite machining requires a vacuum system incorporated in the cutting head.

n. Layup Tooling. Composite materials are laid up on a tool or in a mold, and generally cured under vacuum, with temperature controlled by an autoclave, oven, or by other means such as a heat blanket. Tooling may assist in obtaining the proper part geometry and layup orientation. In the case of a repair/alteration, it may not be necessary to use separate tooling.

(1) Initial Qualification.

(a) The tooling used in the repair/alteration or fabrication of the part should undergo an approval procedure that demonstrates its capability to consistently produce parts of proper fit, form, and function. This procedure should:

1. Include a thermal profile of the tool to assess the temperature distribution during cure and to select thermocouple locations.

2. Encompass the use of the tooling, raw material, expendable items (e.g., release films and bagging materials), layup and bagging techniques, and cure cycle used in fabrication.

3. Include inspection of the cured part to ensure conformance to design requirements prior to release of the tooling for repair/alteration operations.

(b) Any significant change in the tooling, materials, and processing methods after initial approval requires reapproval.

(2) Requalification. The tooling must be requalified periodically by inspection of a cured part produced with the tool for proper fit, form, and function to ensure continued conformance to established requirements.

(3) Routine Checks. Before each use, an MO must visually check the tool for damage such as scratches, distortion, etc.

9. FABRICATION AND PROCESSES PROCEDURES. The MO must use detailed processing specifications and procedures for repair or alteration of composite or adhesive-bonded structure. The specifications and procedures must be consistent with FAA-approved/accepted maintenance instructions and with available facilities and equipment. If not already incorporated in the applicable SRM, the specifications and procedures developed must incorporate and address the following points.

a. Damage Assessment and Teardown. If the MO needs to accomplish localized repair/alteration on a damaged area, it must fully and clearly define the extent of the damage. Since teardown generates dust and dirt, the MO should accomplish teardown in a separate area, segregated from the fabrication area. The FAA recommends that the MO accomplish additional NDI after teardown to identify any additional damage that may have occurred or become apparent as a result of the teardown. Due to the tendency of composites to rebound and mask any impact damage, the MO should supplement a visual inspection or coin tap test for determination of the extent of any composite damage with additional NDI techniques (e.g., ultrasonic or other approved NDI methods). This is especially true for those instances when the sandwich face sheets are thicker than 3 to 4 plies or for any solid laminate construction; the SRM should provide guidance. For information on in-hangar repairs/alterations, see paragraph 8.

b. Fabrication and Processing of Repair and Alteration Parts. The MO must fabricate detailed parts using materials approved by the DAH or qualified to the applicable FAA-approved/accepted specifications. The configuration of the details must be traceable to the applicable drawings, tooling, repair/alteration configurations identified in the SRMs, or other FAA-approved drawings and/or documents. Key steps in repair/alteration part fabrication and processing are:

(1) Prefit. The MO should prefit detail parts of adhesively bonded and composite material structure using tooling intended for repair, alteration, or manufacture. Detail parts must be controlled from the point of bonding prefit until they become an integral part of the assembly.

(2) Preparation of Metallic Details. Proper cleaning and surface preparation are critical to achieving a good bond. Care must be taken to prevent contamination of the bondline.

(a) Cleaning and Drying. For metal details, the cleaning processes should remove oxides and contaminants (e.g., oils, waxes, greases, cutting oils) from the part surface. The MO generally uses emulsifiers and solvents for contaminant removal and as a preliminary cleaning process. For subsequent cleaning operations to remove oxides and light surface scratches, the MO generally uses acid and alkaline etching processes. The MO may also use abrasive cleaning methods for removal of corrosion and paint. The MO must be careful when removing excess cleaning fluids before further processing. The MO must sufficiently dry the surface in accordance with the FAA-approved repair/alteration process. Phosphoric etch is typically used for metal bonds.

(b) Surface Preparation. After successful prefit of the bonded metallic structure, the MO must prepare the detail parts and the bond surface using the procedure recommended by the DAH or an alternate procedure approved by/acceptable to the FAA. The MO must control and maintain surface preparation solutions at the proper concentration in accordance with FAA-approved procedures. After addition of makeup material or complete change of solution, the MO must retest the cleaning solutions and find the solutions acceptable before production use.

(c) Adhesive Primer Application. After surface preparation, the MO must spray-prime detail metallic parts without delay, using the procedure recommended by the DAH or an alternate procedure approved by or acceptable to the FAA. The MO must exercise special care to avoid physical contact or contamination of the prepared surface prior to and after priming. Any compressed air used must be filtered and free of contaminants.

(3) Preparation of Cured Composites and Nonmetallic Honeycomb Details. Proper surface preparation and drying are critical to achieving a good bond.

(a) Paint Removal. The MO must remove paint from all surfaces for bonding since it prevents good adhesion. Mechanical abrasion or hand sanding is acceptable for local paint removal on composites. If power sanding, the MO must take particular care not to damage the laminate. Before use, the MO must carefully evaluate and approve alternative methods, such as chemical stripping or blast removal processes. These processes may cause damage to the laminate. Inspect sanded area to ensure plies have not been compromised during the abrasion/sanding process.

NOTE: Sanding composite fiber may pose a health risk. Wear protective clothing during this operation.

(b) Cleaning. For composites, the MO must clean the surfaces with compatible chemicals approved by the SRM, material specification, or other FAA-approved or accepted data, in order to remove contaminants and avoid damage to the composite resin system. Care must be taken to remove excess cleaning fluids before further processing.

(c) Drying. The structure must be completely dried in accordance with the FAA-approved/accepted repair/alteration process. Drying the damaged composite for a period of time (below the temperature of boiling water) suppresses the tendency for delaminations and face sheet separation in the repair/alteration cycle. The length of time for drying is dependent upon the number of plies and the exposure to moisture the part has experienced.

NOTE: The FAA has found that moisture absorbed in composite and honeycomb materials has a significant effect on the performance of repairs/alterations and the manner in which the MO should complete them. Moisture in composites can frequently cause delaminations away from the repair/alteration location during the repair/alteration cure cycle, and in

honeycomb structure it can result in blown face sheets (face sheets separated from the core).

(4) Composite Ply Cutting. The MO must cut composite plies to orientation and stacking sequence as required. If returning the cut plies to the freezer before use, the MO should kit and collate them as to stacking sequence and ply orientation and stored in a protective bag. If templates are developed for ply cutting, they should be identified as to ply orientation and sequence. Plies should not be cut directly on the tool, in order to avoid damage to the tool surface. If returning cut plies to the freezer, store plies flat or rolled around a supporting tube. No folding or creasing of the plies is allowed.

(5) Layup. In laying up composites, the MO must take special care to ensure proper ply orientation (and that repair/alteration plies are within Original Equipment Manufacturer (OEM) SRM alignment tolerance). The exact method of layup is dependent on part, tooling, resin/adhesive flow, surface prep, etc. It must be consistent with the DAH's process specification or other FAA-approved/accepted specifications.

(a) The MO should accomplish layup in accordance with environmental conditions required by the process specification. The MO should be careful to accomplish the layup or bonding within the remaining allowable out time and/or work life of the material. The MO's procedure should specify a maximum time for accomplishment.

(b) Adhesives or primed faying surfaces to be bonded should not be handled with bare hands, nor should the MO allow any contamination to result from contact with supporting fixtures or mechanical handling equipment. Appropriate gloves should be worn by all persons handling cleaned parts, cleaned and primed parts, or adhesive films.

(6) Bagging. Bagging must be sufficient to remove all trapped air and produce the desired resin/adhesive flow. If necessary, the MO must incorporate an intermediate debulk cycle. The MO should use only non-contaminating films, tapes, etc. for flow control purposes. When using vacuum-bagging techniques, the MO must vacuum check the vacuum-bagged repair/alteration for leaks to ensure air does not contaminate the repair/alteration during the cure cycle. A vacuum bag reduces the pressure to about 0.5 atmospheres (atm) to apply pressure to consolidate the composite. It will contain some air. The MO must ensure the bagging process includes the correct bleeder cloth and pressure plates.

(7) Curing. The MO must accomplish curing by controlling the appropriate parameters such as vacuum, pressure, temperature, viscosity, etc., with respect to time in accordance with the approved process specification or other FAA-approved procedures to establish the correct state of cure. The MO must pay attention to both the lowest temperature thermocouple and the maximum temperature rise to avoid undercure and overheating, respectively. The MO must use a sufficient number of thermocouples in contact with the part to monitor the temperature of the curing material. It should give particular attention to bondlines and heatsinks.

(8) QC. The MO must establish and implement a plan that critical process parameters (such as temperature and humidity) shall be verified. Test coupons may be necessary to verify the repair/alteration process.

(9) Inspection. The fabrication specification must specify methods of NDI for each part and specify accept/reject criteria. The types of NDI specified must be consistent with the types of flaws expected and the type of construction. The MO may leak-check small honeycomb parts for porous bondlines or edges and improperly sealed fasteners by submersion. When an entire part or a large area of a part is subject to an elevated temperature cure cycle to cure a repair/alteration to an area of the part, the MO should nondestructively inspect the entire area of the heated part after curing. This is necessary because moisture absorbed in laminate or core areas of the part that the MO isn't repairing/altering can damage the part during the elevated temperature curing cycle of the repair/alteration.

(10) Documentation. A detailed shop record must accompany every part from prefit or assembly of details through final acceptance. The record must address each critical step required during the fabrication process and must include in-process QC checks that the MO must complete before moving to the next process step. The FAA recommends that the shop record identify the part number, process and material specification numbers, adhesive/prepreg roll number, ply number and orientation, cure parameters, date, and the results of specimen testing.

c. Process Changes. The MO must review and requalify procedures, if necessary, whenever there are any significant changes to items such as type or source of material, cure cycle, equipment controls or tool design. Process capability must be demonstrated by inspection and testing as necessary to determine conformity to repair/alteration data requirements. Any changes to FAA-approved procedures, processes, or data will require approval by the FAA.

10. NDI PROCEDURES.

a. NDI Techniques. The MO may use several NDI techniques to detect discrepancies in aircraft composite structures and components; however, the most commonly used techniques are visual, audio sonic (tap testing), radiography, ultrasonic, shearography, mechanical impedance testing, and infrared thermography.

(1) Visual. Visual inspection is the most widely used NDI method. Discrepancies that the MO can usually observe include: discoloration (due to overheating), foreign matter, crazing, cracks, scratches, blisters, dents, orange peeling, pitting, air bubbles, porosity, resin-rich and resin-poor areas, and surface wrinkles. Reflected light is used for observing surface irregularities and other defects. Transmitted light helps to reveal discrepancies within the specimen in cases where both surfaces are accessible and the material is translucent.

(2) Audio Sonic. Sonic testing makes use of frequencies in the audible range from about 10 hertz (Hz) to 20 Hz. The "tap test" is a common technique/procedure used for detecting voids or delaminations in thin face sheet honeycomb construction. When tapping any area, the MO may use a small tap hammer, coin, or other suitable object. When using this technique, a clear, sharp ringing sound is indicative of a well-bonded solid structure, while a dull sound or thud indicates a void or delamination. Automated sonic devices that produce a consistent tapping rate and force are available and can be used for this test. The tap test may not be reliable for composite layups over three plies or thicker metal skins without a calibration standard.

(3) Radiography. The MO may occasionally use radiography in composite fabrication and repairs/alterations. In addition, the MO may also use radiography to inspect for the presence of foreign material, adhesive voids, location of internal parts, honeycomb core defects, mislocated or misdrilled holes, poor fit-up, thick bonds, fiber discontinuities, poor tape layup, or lack of adhesive fillets, and for water ingress in honeycomb panels. In the case of carbon/epoxy, glass/epoxy, and aramid (Kevlar)/epoxy, the resolution differences are low and defect detection becomes difficult due to the low contrast in the film. An MO usually performs radiography through the thickness of the product for detection of anomalies.

(4) Ultrasonic. In this technique, the MO uses the attenuation of sound wave energy for flaw detection. Two methods of ultrasonic techniques are available: through-transmission and pulse-echo. Three methods of recording and display generally used are A-scan, B-scan, and C-scan. An A-scan is an amplitude versus time display for a specific point on the part inspected. It generally lends itself to the contact pulse-echo methods. A B-scan displays a long, cross-sectional view of the part under test and shows discovered discrepancies. A C-scan displays a plan view of the signal amplitude across the part. C-scans provide detailed images and location of defect and are capable of detecting defects in the magnitude of 0.01 square inch. That said, the practical limits are typically on the order of 0.5 x 0.5 inch defect detectability. C-scans are used to satisfy the inspection records requirements. A-scans and B-scans are used for real-time defect detection.

(a) Generally, the MO can use ultrasonic techniques to detect porosity, laminar inclusions, delaminations, and fastener hole flaws.

(b) A disadvantage of the ultrasonic method is the inability to distinguish between voids and small delaminations since the attenuation characteristics of the two flaws are identical. An advantage to ultrasound is the ability to detect the depth of the defect and not just the profile of the defect.

(c) Another disadvantage is the requirement for representative calibration standards.

(5) Acoustical Impedance. These are methods by which the MO measures structural response to strain excitation to detect delaminated areas or disbonds. The sensitivity of this method decreases with increasing structural flexibility or discrepancy depth.

(6) Infrared Thermography. This technique produces an image of invisible (to our eyes) infrared light emitted by the object due to its thermal condition. The MO may use thermography to detect corrosion, subsurface damages, and degradation of skins, structural members, and joints. A disadvantage of the infrared method is that it is harder to detect temperature differences on the outside surface during windy weather. It is generally used for inspections performed in a hangar or other maintenance facility because they benefit from reduced air movement.

(7) Shearography. This technique is a non-contact, full-field inspection method that uses coherent laser light and interferometry. The instrumentation captures an image of the structure in the unloaded state and compares it with images of the deformed shape as a small load is applied.

The MO uses this technique to detect damage or defects such as disbonds or delaminations, which will locally affect the deformed shape of the structure.

b. Controlling NDI Techniques. Certain controls are necessary for NDI techniques to be effective, repeatable, and reliable. An approved NDI specification and procedure must include:

(1) Periodic qualification of personnel conducting the inspection technique.

(2) Establishment of realistic acceptance standards consistent with FAA-approved repair/alteration requirements for use by in-process and final inspection personnel.

(3) Calibration of equipment used in the inspection technique, including any QC standards with known defects that may be used. The calibration system should provide for periodic requalification of any such equipment at specific time intervals.

(4) An internal audit program for validating the effectiveness of the NDI program.

11. PERSONNEL QUALIFICATION.

a. MO. Personnel who are performing repairs or alterations to composite or metal-bonded structures must be fully qualified in the preparation and handling of the materials used and in the procedures for layup and curing of a composite or metal-bonded structure, as appropriate. Personnel must be qualified under a program that assures that the MO's performance is in accordance with established, acceptable performance standards for repair/alteration practices and product quality. The program must include provisions for revalidating MO qualifications on a predetermined basis. The MO is responsible to determine the abilities of its employees performing maintenance functions based on training, knowledge, or practical tests.

b. NDI Personnel. NDI personnel should be qualified in accordance with a recognized industry or government standard. The MO should develop and maintain a list of qualified NDI inspectors, indicating each person's qualifications and level of proficiency and their requalification date. Refer to AC 65-31 for additional information.

12. INSPECTION RECORDS PROCEDURES. The MO must maintain inspection records for a repaired, altered, and/or fabricated composite and metal-bonded structure that demonstrate compliance with the following:

a. Part Identification. The inspection record must identify the part name, part number, and the FAA-approved or accepted data with which the part complies after repair or alteration.

b. Material Traceability. The inspection record must identify the structural raw materials (e.g., adhesives, prepregs, resins) by material specification, manufacturer, and batch/lot number that MO personnel used in fabrication.

c. Conformance to Fabrication Requirements. The inspection record must identify and show compliance with the fabrication process specifications, destructive and nondestructive inspection specifications, and other specifications defining product acceptance/rejection standards that MO personnel have used for fabrication and QC acceptance purposes. It must also show evidence of QC acceptance of the structural raw materials (e.g., adhesives, prepregs, resins) used in fabrication. If MO personnel use salvaged parts in the fabrication process, the inspection record must also identify the specifications and/or procedures used in their repair/alteration. Each completed operation necessary to repair, alter, or fabricate the complete part must show evidence of acceptance by authorized and qualified personnel.

d. Product Conformity and Airworthiness. The appropriate MO personnel and authorized inspectors must annotate the inspection record as evidence of compliance with FAA-approved repair or alteration procedures. The MO must complete maintenance record entries (approval for return to service) in accordance with part 43.

e. Record Retention. Inspection records are to be retained for the length of time required by parts 121, 125, 129, 135, 137, and 145, as appropriate.

/s/ 

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