U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

Subject: REPAIR STATIONS FOR COMPOSITE AND BONDED AIRCRAFT STRUCTURE	**Date:**	**11/15/96**	**AC No:**	**145-6**
	Initiated by:	**AFS-350**	**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, 43, 121, 125, 127, 135, and 145 regarding procedures and facilities for repairs and alterations of structure consisting of metal-bonded and fiber-reinforced materials (e.g., carbon, boron, aramid, and glass-reinforced polymeric materials mentioned in AC 20-107, Composite Aircraft Structures). Consideration will be given to any other method of compliance the applicant elects to present to the Federal Aviation Administration (FAA). Mandatory terms used in this AC, such as "must," are used only in the sense of ensuring the applicability of these particular methods of compliance when the acceptable means of compliance described herein is used. This AC does not change regulatory requirements and does not authorize changes in, or deviations from, regulatory requirements.

2. DEFINITIONS. As used in this AC, the following definitions apply:

a. 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.

b. Batch. In general, a quantity of material formed during the same process or in one continuous process and having identical characteristics throughout. Also referred to as a lot. A discrete quantity of material with a total commonality of raw materials and process history.

c. Lot. A specific amount of material produced at one time using the same process and the same conditions of manufacture, and offered for sale as a unit quantity.

d. Shipment. An order of material received by a purchaser. A shipment of pre-impregnated (prepreg) material may include rolls of 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.

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

f. Original Equipment Manufacturer (OEM). A manufacturer that is the holder of an FAA-approved Type Certificate (TC), Production Certificate (PC), Approved Production Inspection System (APIS), Production Manufacturing Approval (PMA), Technical Standards Order Approval (TSOA), or Delegated Option Authorization (DOA) who controls the design and quality of the product/part thereof.

NOTE: A supplier to a manufacturer is not an OEM.

3. RELATED READING MATERIAL. Current editions of the AC's, listed below, may be obtained free of charge from the following address: U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

a. AC 20-107, Composite Aircraft Structures.

b. AC 21-26, Quality Control for the Manufacture of Composite Structures.

c. AC 145-3, Guide for Developing and Evaluating Repair Station Inspections Procedures Manuals.

4. BACKGROUND. Part 145, subpart B and C, provide for limited ratings for specialized services for domestic and foreign repair stations, respectively. The certificated repair station operations specifications should contain or reference the material and process specifications used in performing repair work on composite material structures, components, and adhesive-bonded components listed under that specialized service. All major repairs and alterations must be performed using data, including material and process specifications, approved by the Administrator. This AC is intended to provide information on the repair and fabrication of composite materials and adhesive-bonded components, and on the inspection systems, equipment, and facilities that a certificated repair station with the appropriate ratings should have to perform repairs or alterations on such materials and components. These guidelines are intended to supplement the procedures in Original Equipment Manufacturers (OEM) structural repair manuals. Also, it should be understood that the word "composites" as used in this AC does not imply a relationship with a certificated repair station Airframe Class 1 or Class 2 composite construction rating. The rating used in this context refers to older aircraft that were manufactured using wood, fabrics, and metal or any combination of these. It should also be understood that all air carriers operating under parts 121, 125, 127, and 135, and all repair stations certificated under part 145, must comply with 14 CFR part 43, § 43.13 (a) and (b). In addition, for the purposes of this AC the term Maintenance Organization (MO) will be substituted for persons performing maintenance under parts 121, 125, 127, 135, and 145.

5. ENGINEERING DATA AND PROCEDURES.

a. Source of Data.

(1) Maintenance organizations must accomplish bonding of aircraft structure and composite material repairs/alterations in accordance with parts 43, 145, and 14 CFR parts 121, 127, and 135, §§ 121.379, 127.140, and 135.437. It is incumbent upon the repair facility to work closely with the manufacturer of the particular product and the FAA, when necessary, to determine what specific data may be necessary to support the repair. Much of the information needed for maintenance, repairs, and alterations is contained in the manufacturer's maintenance manual or structural repair manual (SRM).

(2) The maintenance organization must use data approved by the FAA Administrator (approved data) when performing a major repair or alteration. In the event that the manufacturer's repair specifications are deficient with regard to specific information, technique, or repair method, or if the damage being repaired exceeds that covered by the manufacturer's repair specifications, the maintenance organization must obtain FAA-approved data prior to accomplishing the repair. The maintenance organization can request the TC or supplemental type certificate (STC) holder to develop repair data and to obtain FAA approval, or the maintenance organization can develop the data and submit it to the FAA for approval. Other sources of FAA-approved data include an FAA Aircraft Certification Office (ACO), an appropriately rated FAA Designated Engineering Representative (DER), a maintenance organization having SFAR 36 authorization to approve repair data, a holder of a Delegation Option Authorization (DOA), and an FAA-approved Designated Alteration Station (DAS). Maintenance organizations are cautioned that simple OEM concurrence for a major repair does not constitute FAA approval unless specifically stated and documented (e.g., FAA, DOA, or DER signature). In addition, utilization of various FAA-approved data and documents do not constitute approved data for other than the repair specified in the data. Therefore, the maintenance organization is at risk in making a judgmental evaluation to use various FAA-approved data that are not specifically approved for the particular repair.

b. Data Requirements and Compliance. Each maintenance organization must have and maintain the approved or acceptable data necessary to formulate and support the repairs or alterations it makes. Data should include the drawings and specifications necessary to define the repair or alteration including dimensions, materials, and processes necessary to define the structural strength. In addition, maintenance organizations should perform and document the inspections and tests necessary to determine compliance with the applicable airworthiness requirements and the approved repair or alteration data.

c. Data Types. For repairs or alterations that are not covered by the manufacturer's manuals, the following design data containing the information indicated should be available and utilized by the maintenance organizations when purchasing and receiving materials, fabricating repairs or alterations, and installing the repairs or alterations.

(1) **Drawings**. Engineering drawings should at least describe the following:

(a) Materials (called out by material specification).

(b) Attachment to existing structure.

(c) Fabrication and processing procedures (called out by fabrication and process specification).

(d) Number of plies and stacking orientation/sequence.

(e) Shape.

(f) Dimensions and tolerances.

(g) Protective coating and sealant.

(2) **Reports.** Engineering reports, analyses, and checklists should show that the repaired structure would continue to comply with applicable type certification regulations.

(3) **Material Specifications.** Materials used for repair or alteration must meet the qualification requirements established by the OEM's approved type design or the maintenance organization's FAA-approved data. Material specifications (adhesives, resins, prepreg tape and broadgoods, core materials, etc.) should completely describe the material required and should normally 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 material's physical, processability, chemical, and mechanical (laminate, sandwich, and bond strength tests, etc.) properties for a material that meets the specification.

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

(d) **Supplier Quality Control.** Specifies supplier quality control tests and procedures, and specifies compliance certifications and data required with each material batch.

(e) **Purchaser Quality Control.** Specifies purchaser acceptance tests and procedures required for each batch per shipment received.

(f) **Material Test Methods.** Specifies the types of tests, types of test specimens, and test procedures for testing the material's physical, processability, mechanical, and chemical 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-time or shelf life has been exceeded).

(j) **Qualified Products List Section.** Specifies a list of supplier products that are currently qualified to the requirements of the specification. Qualified materials must be listed on an approved Qualified Products/Parts List (QPL) and purchased from qualified suppliers. Substitutions to the QPL should be made in accordance with procedures approved by the Administrator for the maintenance organization.

(4) **Fabrication and Process Specifications.** Fabrication and process specifications should:

(a) Completely describe fabrication and process procedures requirements.

(b) List each major step in a fabrication and process procedure, including in-process tests and inspections.

(c) Include accept/reject Nondestructive Inspection (NDI) test standards.

(d) Specify appropriate type and number of witness test coupons to verify processing parameters.

(e) Give limits for adhesive bond, laminate, and sandwich panel strength properties.

(f) Identify facility, equipment, and storage requirements.

(g) Specify material cure cycle requirements.

(5) **NDI Specifications.** NDI specifications should:

(a) Identify method type.

(b) Completely describe NDI methods and procedures.

(c) Specify equipment and calibration frequency.

(d) Outline test procedures.

(6) Defect Acceptance/Rejection Criteria. Standards for accept/reject criteria for cured or bonded structure should be established from the design data. Usually these are identified in the OEM's structural repair manual or applicable fabrication specifications. Inspection procedures and equipment used to detect flaws should be consistent with these standards or other FAA-approved data.

6. RAW MATERIAL INSPECTION PROCEDURES.

a. General. The processability and resulting strength-related properties of composite materials used in structural repair depend upon the composition of the fiber/resin prepreg materials from which they are manufactured. In general, prepregs consist of surface-treated glass, aramid, or carbon fibers impregnated with a reactive and chemically complex thermoset resin formulation or an amorphous or semicrystalline thermoplastic resin. Thermosetting resins are often "staged" or partially reacted during the prepreging process and may undergo compositional changes during transport, handling, and storage. Inadvertent or minor changes in resin composition may cause problems in processing and may have adverse effects on the performance and long-term properties of many composite repairs. This also applies to adhesive systems used in structural bonded repairs (e.g., film adhesives, primers). The capability of a repair to satisfactorily maintain its structural integrity for the remaining life of the part or aircraft is dependent, in part, on the maintenance organization's knowledge of the physical, chemical, mechanical, and processability properties of the incoming materials (e.g., prepreg materials, adhesives, etc.) used in that repair. The physical, chemical, mechanical, and processability test results are; therefore, vital to the continued airworthiness of the repaired structure.

b. Material Acceptance.

(1) General. The maintenance organization should have an incoming material acceptance plan (see paragraph 7 for material handling and storage procedures) addressing the issues in paragraph 6a, above, that ensures conformity of purchased material (i.e., prepreg material, film and paste structural adhesives, and wet lay-up resins, etc.) to OEM or other FAA-approved material specifications. Copies of the original material manufacturer and supplier laboratory test reports showing actual test results, if applicable, should accompany each batch of material received for review and approval. When material is purchased from an approved supplier in accordance with the OEM or other FAA-approved material specification, such test reports are usually adequate documentation of the material condition and conformity to the material specification. When material is purchased from a non-approved source, verification testing should be performed. Specific material called out in the SRM or maintenance manuals without material specifications should be controlled as indicated in the material manufacturer's recommendations covering the material designation, storage, and handling requirements.

(2) Verification Testing. Unless the maintenance organization can provide evidence that the approved material from a given source is of an acceptable and consistent quality, verification testing should be performed by the maintenance organization or by an independent laboratory, which has been approved for such testing by the maintenance organization as part of its incoming material acceptance plan. The type and frequency of the testing should be consistent with the material specification (reference paragraph 5c(3)). Once confidence in the quality of materials received from a particular source has been established, the maintenance organization may reduce the level of verification testing.

c. Supplier Quality Control Tests. The following discussions identify quality control tests of physical, chemical, mechanical, and processability properties typically performed by the supplier. In most cases the required tests were performed as specified in material quality control sections of OEM or other FAA-approved material specifications.

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

(2) 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 quality control fingerprinting of the resin's constituents. They are fundamentally different from one another and provide direct, but different, information about a resin's composition. HPLC and IR tests are conducted by the supplier to ensure that the resin type, purity, and concentration, and the distribution of resin components are consistent from batch to batch and per the material specification. These tests are conducted on resin samples extracted from a number of rolls in each batch of prepreg material, because B-staging alters the chemical composition of the resin increasing the variety of chemical components and because the resin may chemically advance as a function of time in the prepreg.

(3) Mechanical Tests. For laminates, the mechanical property tests normally performed by the supplier for each batch of prepreg material are longitudinal tension (room temperature, dry) and compression (room temperature and elevated temperature, both dry). The room temperature dry tensile modulus of elasticity and ultimate tensile strain are obtained from the load-deflection curve of the longitudinal tension test. Mechanical testing relevant to the use of the material should be chosen (e.g., lap shear, climbing drum, and T-peel are most appropriate for adhesive bonding).

(4) 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.

7. MATERIAL HANDLING AND STORAGE PROCEDURES.

a. General. Improper storage and handling of repair materials such as prepreg tape and broadgoods, adhesives, potting compounds, and resins can adversely affect material properties. This makes it important that a maintenance organization's approved system for bonding of aircraft structure and for composite materials repair includes specified procedures for storage and handling of raw materials used for repairs. A maintenance organization's approved procedures should require repair materials to be stored and handled in ways that assure they will be acceptable for use and will provide expected finished properties when processed. Material specifications normally specify shelf life when the material is stored at the specified temperatures. Instructions regarding handling and storage should be carefully followed.

b. Shelf Life and Temperature Considerations. Polymer matrix prepreg tape and broadgoods, adhesives, potting compounds, and resins should be handled and stored in accordance with approved specifications to ensure retention of material properties. Thermoset matrix composites and structural adhesives in current use should be stored in sealed containers or bags in accordance with the requirements specified in the appropriate material or process specification, often near 0°F (-18°C). This retards the "aging," or partial curing, of the polymer and extends the shelf life. The sealed containers or bags prevent moisture condensation on the cold material and moisture absorption. When the material is removed from the freezer for processing, it is allowed to thaw within the sealed container or bag until the condensation on the exterior has dissipated. Thin rolls of prepreg and adhesives do not need a long thaw period. The period of time the material is outside the freezer should be documented in an "out time" ledger. In order to keep track of "shelf life" and "out-time," a maintenance organization's approved system should include record keeping procedures for these items.

c. Storage and Handling Recommendations. Polymer matrix prepreg materials and film adhesives normally have a backing sheet that improves their handling characteristics and protects the material from handling-related damage. Non-woven unidirectional tapes, for example, can otherwise easily split between fibers. Clean, white, lint-free cotton gloves are recommended when handling adhesives and surfaces prepared for bonding to prevent skin oils from being transferred to the material. Clean hands are mandatory when working with these materials. Many of today's composite material fibers can be damaged if they are bent or folded with small radii. For this reason handling procedures should prohibit sharp bending, creasing, gouging, or other actions that could break or damage fibers. These materials should be handled by properly trained personnel. It is recommended that a maintenance organization's procedures for storage and handling of these materials include the following:

(1) Frost-free cold storage equipment that opens from the top is recommended. Walk-in freezers can be used for large volume storage.

(2) Determining which raw materials (e.g., prepreg tapes and broadgoods, film adhesives, paste adhesives, etc.) must be stored in a freezer.

(3) Placing a tag or record on each roll or container showing the batch number, roll number, shelf life ending date, and the total allowable out of freezer time (out-time). The tag or record should include a place to record cumulative out time.

(4) Specifying the highest allowable freezer storage temperature.

(5) Regularly monitoring freezer storage temperature.

(6) Requiring that materials be stored in moisture-tight bags or containers in the freezer to prevent moisture absorption. If kitted parts are returned to the freezer for storage they should also be placed in moisture-tight bags labeled to maintain traceability.

(7) Specifying that the material should be allowed to thaw within the container or bag until the condensation on the exterior of the container has dissipated. This is to prevent atmospheric moisture condensation on the material.

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

(9) Requiring the use of appropriate clothing and gloves for handling adhesives, prepregs, and prepared bond surfaces.

(10) Requiring that batch number, lot number, roll number, shelf life, and out-time records be retained for a specified time (suggest a minimum of 2 years from the time material is depleted or disposed).

(11) Describing how the roll material is to be located/oriented in the freezer to prevent fiber breakage or resin migration.

(12) Requiring that materials that have exceeded their shelf life or out-time limit be scrapped or recertified in accordance with the material specification or other FAA-approved procedures.

8. FACILITIES AND EQUIPMENT. The facilities and equipment used for repair or alteration of composite structure must be capable of meeting the repair process requirements established by the OEM or other FAA-approved repair process. The following guidelines are offered as examples of facilities and equipment used to control part quality when accomplishing repair or alteration of composite or adhesively bonded metallic structure of aircraft:

a. Autoclave. An autoclave capable of providing positive pressures and temperatures consistent with the repair 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. Temperature and Pressure Controller. A method of temperature and pressure control (e.g., vacuum bag, thermal blanket, heat lamp, mechanical pressure, etc.).

d. Lay-up and Clean Rooms. Unless otherwise validated for the material system in use, lay-up and clean rooms should be environmentally and operationally controlled in the following areas:

(1) Temperature and humidity in accordance with the OEM or other FAA-approved repair process.

(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, lay-up, and bonding areas should 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 process (e.g., release agents or material containing uncured silicone should not be permitted). Also, eating and smoking should be prohibited in these areas.

e. Freezers. Freezers capable of storing adhesives, prepregs, etc., at manufacturer's recommended conditions should be used.

f. Cleaning. Equipment must be provided to accomplish the various cleaning processes.

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. Honeycomb Core Cutters. Capability should be available to cut, rout, and profile the honeycomb in either the compressed or expanded form. Hand routing should be kept to a minimum.

i. Part Drying Capability. For composite material repairs where some composite parts are re-used, a moisture dry-out capability should be available to adequately dry the entire part before lay-up and bonding of the repair. 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 should 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 tension, compression, lap shear, climbing drum peel, short beam shear, T-peel, and wedge should also be available if required.

k. NDI. X-ray, ultrasonic, or other types of acoustic test equipment should be available for inspection of parts. The use of tanks for submersion leak testing of parts has been shown to be a good way to verify proper adhesive/resin flow and sealing of honeycomb sandwich parts.

l. Kit Storage Area. A dedicated area for storage of kitted detail parts prior to bond helps to reduce contamination of detail parts.

m. Cutting Tools. Diamond or carbide saws and router bits are suitable for cutting and trimming of composites. Carbide drills and countersinks for hole drilling operations in composites, or other means recommended by the OEM, should also be used.

9. TOOLING.

a. Initial Qualification. The tooling used in the repair 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 include inspection of the cured part to ensure conformance to design requirements prior to release of the tooling for repair operations. The procedure may encompass the use of the tooling (e.g., molds, dies), raw material, expendable items (e.g., release films, bagging materials), lay-up and bagging techniques, and cure cycle used in fabrication. Any significant changes in the tooling, materials, and processing methods after initial approval would require reapproval.

b. Requalification. The tooling should 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.

10. FABRICATION AND PROCESSES PROCEDURES. A maintenance organization should use detailed processing specifications and procedures for repair or alteration of composite or adhesive-bonded structure. The specifications and procedures should be consistent with FAA-approved maintenance instructions and with available repair facilities and equipment. The specifications and procedures developed should incorporate and address the following points, if they are not already incorporated in the Structural Repair Manual.

a. Damage Assessment and Teardown. If localized repair of a damaged area needs to be accomplished, the extent of the damage should be fully and clearly defined. Due to the tendency of composites to rebound and mask any impact damage, and the strong likelihood of non-visible microcracking, a visual inspection or coin tap test for determination of the extent of any composite damage should be supplemented with additional NDI techniques (i.e., ultrasonic or other approved NDI methods). Because of the dust and dirt generated, teardown should be accomplished in a separate area segregated from the fabrication area. It is recommended that additional NDI be accomplished after teardown to identify any additional damage that may have occurred, or become apparent, as a result of the teardown. Absorbed moisture in composite and honeycomb materials has been found to have a significant effect on the performance of repairs and the manner in which the repairs should be made.

Moisture in composites can frequently cause delaminations away from the repair location during the repair cure cycle, and in honeycomb structure it can result in blown skins (face skin separated from the core). To suppress this tendency for blown skins in sandwich structure, drying of the damaged moisture-contaminated part is recommended. To suppress the tendency for interlaminar delaminations and face sheet separation in the repair cycle, the damaged composite should be dried for a period of time (below the temperature of boiling water). The length of time for drying is dependent upon the number of plies and the exposure to moisture the part has experienced. Paint should be removed from all surfaces to be bonded since it prevents good adhesion. Mechanical abrasion or hand sanding is acceptable for local paint removal on composites. Particular care should be taken not to damage the laminate if power sanding is used. Alternative methods, like chemical stripping or blast removal processes, should be carefully evaluated and approved before use. These processes may cause damage to the laminate.

b. Fabrication and Processing of Repair Parts. Detail parts should be fabricated using OEM-approved materials or using materials qualified to the applicable FAA-approved specifications. The configuration of the details should be traceable to the applicable drawings, tooling, repair configurations identified in the Structural Repair Manuals, or other FAA-approved drawings and/or tooling. Key steps in repair part fabrication and processing are:

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

(2) Cleaning and Drying. For metal details, the cleaning processes should remove contaminants (e.g., oils, waxes, greases, cutting oils) and oxides from the part surface. Emulsifiers and solvents are generally used for contaminant removal and as a preliminary cleaning process. For subsequent cleaning operations to remove oxides and light surface scratches, acid and alkaline etching processes are generally used. For composites, the surfaces should be cleaned with compatible chemicals in order to remove contaminants and avoid damage to the composite resin system. Abrasive cleaning methods may also be used for metal and composite parts for removal of corrosion and paint. Care must be taken to remove excess cleaning fluids before further processing. The structure should be sufficiently dried in accordance with the FAA-approved repair process.

(3) Metallic Surface Preparation. After successful prefit of the bonded metallic structure, the detail parts and the bond surface should be prepared using the OEM-recommended procedure or alternate procedure approved by the FAA. Surface preparation solutions should be controlled and maintained at the proper concentration in accordance with FAA-approved procedures. After addition of make-up material or complete change of solution, cleaning solutions should be retested and found acceptable before production use.

(4) Adhesive Primer Application. After surface preparation, detail metallic parts and the bond surface should be expeditiously spray-primed consistent with the approved OEM or other FAA-approved procedures. Special care should be exercised to avoid physical contact or contamination of the prepared surface prior to and after priming. Any compressed air used should be filtered and free of contaminates.

(5) Composite Ply Cutting. Composite plies are cut to orientation and stacking sequence, as required by the approved repair data. If cut plies are to be returned to the freezer before use, they should be kitted and collated 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.

(6) Lay-up and Bagging. The exact method of lay-up is dependent on part, tooling, resin/adhesive flow, surface prep, etc., and should be consistent with the OEM's process specification, or other FAA-approved specifications. Lay-up should be accomplished in accordance with environmental conditions approved by the OEM. Care should be taken to accomplish the repair within the remaining allowable out-time and/or pot life of the material. The maintenance organization's procedure should specify a maximum time for accomplishment. Adhesives or primed faying surfaces to be bonded should not be handled with bare hands, nor should any contamination be allowed to result from contact with supporting fixtures or mechanical handling equipment. Clean, white, lint-free gloves should be worn by all persons handling cleaned parts, cleaned and primed parts, or adhesive films. In laying up composites, special care should be taken to ensure proper ply orientation and stacking sequence. Bagging should be sufficient to remove all trapped air and produce the desired resin/adhesive flow. If necessary an intermediate debulk cycle should be incorporated. Only non-contaminating films, tapes, etc., should be used for flow control purposes. When vacuum bagging techniques are used the vacuum bagged repair should be vacuum checked for leaks to insure air does not contaminate the repair during the cure cycle. A sufficient number of thermocouples in contact with the part should be used to monitor the temperature of the curing material and particular attention should be given to bondlines and heatsinks.

(7) Curing. Curing should be accomplished by controlling the appropriate parameters such as vacuum, pressure, temperature, viscosity, etc., with respect to time in accordance with OEM or other FAA-approved procedures to establish the correct state of cure. Attention should be paid both to the lowest temperature thermocouple and the maximum temperature rise to avoid undercure and overheating respectively.

(8) Quality Control. The maintenance organization should establish and implement a plan that verifies that the parameters affecting material integrity and process capability are operating under controlled conditions. For metal bonded structure, test specimen coupons may be necessary to verify the repair process.

(9) NDI. The fabrication specification should specify methods of NDI for each part and specify accept/reject criteria. The types of NDI specified should be consistent with the types of flaws expected and the type of construction. It is recommended that small honeycomb parts be leak-checked, by submersion, for porous bond lines or edges and improperly sealed fasteners. When an entire part, or a large area of a part, is subjected to an elevated temperature cure cycle to cure a repair to an area of the part, the entire area of the part that was heated should be non-destructively inspected after repair curing. This is necessary because moisture absorbed in laminate or core areas of the part not being repaired can damage the part during the elevated temperature curing cycle of the repair.

(10) Documentation. A detailed shop record should accompany every part from prefit or assembly of details through final acceptance. The record should address each critical step required during the fabrication process and should include in-process quality control checks to be completed before moving to the next process step. It is recommended that the shop record identify the part number, process and material specification numbers, adhesive/prepreg roll number, cure parameters, date, and the results of specimen testing.

c. Process Change. Procedures should be reviewed and requalified if necessary, whenever any significant changes are made to items such as type or source of material, cure cycle, equipment controls, or autoclave loading patterns and tool design. Process capability should be demonstrated by inspection and testing as necessary to determine conformity to repair data requirements. Any changes to FAA-approved procedures, processes, or data will require approval by the FAA.

11. NONDESTRUCTIVE INSPECTION (NDI) PROCEDURES.

a. NDI Techniques. Several NDI techniques may be used to detect discrepancies in composite structures; however, the most commonly used techniques are visual, audio sonic (coin tapping), radiography, ultrasonic, and mechanical impedance testing.

(1) Visual. Visual inspection is the most widely used NDI method. Discrepancies that can usually be observed 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 (assuming both surfaces are accessible and the material is translucent) helps to reveal discrepancies within the specimen.

(2) Audio Sonic. Sonic testing makes use of frequencies in the audible range from about 10 Hz. to 20 Hz. "Coin tapping" is a common technique used for detecting voids or delaminations. When tapping any area, a coin or other suitable object may be used. When this technique is used, 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.

(3) Radiography. Radiography is generally used in composite fabrication for the detection of bondline defects. In addition, radiography may also be used 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 lay-up, 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. Radiography is usually performed through the thickness of the product for detection of anomalies.

(4) **Ultrasonic.** In this technique, the attenuation of sound wave energy is used 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. B-scan displays a long cross-sectional view of the part under test and show discovered discrepancies. C-scan displays the effect in a plan view usually on a paper that is rolled across the printer bar. C-scans provide no defect depth or orientation information; however, they are capable of detecting defects in the magnitude of 0.01 square inch. Ultrasonic techniques can generally be used to detect porosity, laminar inclusions, delaminations, and fastener hole flaws. 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. Another disadvantage is the requirement for representative calibration standards.

(5) **Mechanical Impedance.** These are methods in which structural response to strain excitation is measured to detect delaminated areas or disbonds. The sensitivity of this method decreases with increasing structural flexibility or discrepancy depth.

b. Controlling NDI Techniques. In order for NDI techniques to be effective, repeatable, and reliable, certain controls are necessary. An approved NDI specification and procedure should include:

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

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

(3) Calibration of equipment used in the inspection technique, including any quality control 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.

12. PERSONNEL QUALIFICATION AND TRAINING.

a. Maintenance Organization. Repair personnel should be fully qualified in the preparation and handling of repair materials and in the repair of bonded honeycomb sandwich and composite laminate construction. Personnel should be qualified under a program which assures the maintenance organization's performance is in accordance with established acceptable performance standards for repair practices and product quality. The program should include provisions for revalidating maintenance organization qualifications on a predetermined basis.

b. NDI Personnel. NDI personnel should be qualified in accordance with a recognized industry or government standard. A list of qualified NDI inspectors should be developed and maintained indicating each person's qualifications and level of proficiency, and their requalification date.

13. INSPECTION RECORDS PROCEDURES. The repair facility should have inspection records for repaired and/or fabricated composite items, which demonstrate compliance with the following:

a. Part Identification. The inspection record should identify the part name, part number, and the approved repair data with which the part complies after repair.

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

c. Conformance to Fabrication Requirements. The inspection record should identify and show compliance with the fabrication process specifications, destructive and NDI specifications, and other specifications defining product acceptance/rejection standards that have been used for fabrication and quality control acceptance purposes. It should also show evidence of quality control acceptance of the structural raw materials (e.g., adhesives, prepregs, resins) used in fabrication. If salvaged parts are used in the fabrication process, the repair specifications and/or procedures should also be identified on the inspection record. Each completed operation necessary to repair or fabricate the complete part should show evidence of acceptance by authorized and qualified personnel.

d. Product Conformity and Airworthiness. The inspection record should be annotated by the appropriate maintenance organizations and authorized inspectors as evidence of compliance with approved repair procedures. Maintenance record entries (approval for return to service) should be made in accordance with part 43.

e. Record Retention. Inspection records are to be retained for the length of time required by parts 121, 125, 127, 135, and 145, as appropriate.

William J. White
Deputy Director, Flight Standards Service

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591