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Low Observable Aircraft Structural Maintenance Journeyman

Volume 3. Composites and Low Observable Material/Coatings

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Author: MSgt Charles Anderson
359th Training Squadron, Detachment 1
Low Observable Aircraft Structural Maintenance (AETC)
359TRS/Det 1/TDE
230 Chevalier Field Ave.
Naval Air Station Pensacola, FL, 32508
DSN: 459–7477
E-mail address: charles.anderson.14@us.af.mil

Instructional Systems Specialist: Todd Knowles
DSN: 596–1189

Editor: Carrie Rodgers

Air Force Career Development Academy (AFCDA)
Air University (AETC)
Maxwell AFB, Gunter Annex, Alabama 36114–3107

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THIS 5-LEVEL career development course (CDC) Z2A755, *Low Observable Aircraft Structural Maintenance Journeyman*, is designed to prepare you for the responsibilities and duties of a journeyman in the low observable aircraft structural maintenance (LOASM) career field. It is also a prerequisite for the awarding of your 5-skill level. A journeyman must be able to perform repairs using basic hand tools, specialized equipment, and an in-depth knowledge of low observable (LO) principles. This final volume has four units and is layed out as follows.

Unit 1 covers composite material, identification, and repair methods. We will discuss identification and characteristics of composite materials. We will also discuss the various methods for working with the different types of composite materials.

Unit 2 covers LO history and fundamentals and how they are incorporated into the aircraft structure. In this unit, we will cover the basics behind radar and radar cross section. Additionally, we learn about aircraft signature sources and techniques for reducing radar cross section. Lastly, we talk about LO inspection techniques.

Unit 3 provides you with a look at LO material and repair layout. We go in-depth on LO material and its different uses on the aircraft. We also discuss how and why the different types of material are placed on the aircraft.

Unit 4 explores information on LO coating repair and application. We discuss the different procedures for removal, to include finding defects, removing coatings, and racetracking. Next, we discuss how to reapply the material. This includes preparing the surface, using primers, paints, and fillers, and the curing process. Lastly, we cover how to verify the process when your work is complete.

A glossary is included for your use.

Code numbers on figures are for preparing agency identification only.

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This volume is valued at 12 hours and 4 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

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Unit 1. Composites

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AS A LOW OBSERVABLE aircraft structural maintenance (LOASM) journeyman, you'll have many opportunities to repair composite components. Information is given in this unit to provide you a more comprehensive knowledge and understanding of these complex materials, including their identification, characteristics, and the materials used in their repair. Typical repair and maintenance techniques as applied to composite components and parts are explained to provide you with a greater understanding. The information given will greatly help you acquire the necessary skills to effectively work with these advanced materials.

1–1. Identification and Characteristics of Composite Material

Today's aircraft are extremely sophisticated machines that are constructed using some of the world's most advanced materials. It is your job to maintain these aircraft in a fully mission capable status, and therefore, you must be able to repair them as necessary. To repair them, you first need to know what you are dealing with. This section will provide you with the basic identification and characteristic information you will need to be successful.

401. Composite material identification and characteristics

A composite material is made of a fibrous material embedded in a resin matrix, generally laminated in a cross ply method where fibers are oriented in alternating directions to give the material strength and stiffness. Fibrous materials are not new as wood is the most common fibrous structural material known to man.

To produce the required strength characteristics, composites rely on a combination of matrix type, fiber type, ply orientation, and processing method. All fibrous materials are characterized as having strength parallel to the fiber direction and a lack of strength perpendicular to the fiber direction. Plywood was the first practical laminated composite material, formed by laying plies in two directions. Fiberglass brought improved structural strength to this class of materials, and the much stiffer fibers of boron and graphite have given composite materials structural properties superior in several ways to the metal alloys they have replaced.

Fiber types

Let's begin our discussion looking at some of the more common fibrous materials you will use. Several different types of fibers are used for composites. After the individual fibers are made, they are bundled together into groups; these groups are called strands for fiberglass products and tows for graphite. Larger fiber groups consisting of multiple strands or tows are called yarns when twisted or rovings when not twisted. Strands, tows, yarns, and/or rovings are combined in different ways to make different types of fabric. The fabric may be coated or left unfinished. The finish affects bond strength and durability, depending upon the resin type to be used (e.g., epoxy, polyester, phenolic).

Aramid

Kevlar is DuPont's trademark name for aramid fibers. This type of fiber is produced from two liquid chemicals using a complex process resulting in spun filaments. Aramid is an organic fiber that is 43 percent lighter than and twice as strong in tension as glass. One of the outstanding properties of aramid fibers is that they have very good energy absorption characteristics; therefore, aramid is often used for ballistic protection and body armor. Aramid fibers are generally weak in compression and are often hybridized with other fibers when used in areas that dictate moderate compression behavior. In addition, they are difficult to cut due to fuzzing. Bundles of aramid fibers are not sized by the number of fibers but by the weight. The weight term (denier) is defined as the weight in grams of 9000 meters of filament. Aramid fibers are available in a variety of woven fabric forms that will be discussed later.

Manufacturing

Aramid materials are manufactured in unidirectional tape and woven goods. These fibers are resistant to most chemicals and are flame retardant. At 800 degrees Fahrenheit (°F), these fibers will carbonize but not ignite. Their excellent dielectrical properties make them well suited for radomes and insulators.

The manufacturing and repair procedures for aramid materials are similar to those employed for fiberglass. They differ only in their toughness to cut and machine. For instance, fiberglass is easily sanded, whereas aramid materials are considerably more difficult and will literally fuzz up.

Inherent problems

There are two problems inherent to parts manufactured from aramid materials—ultraviolet (UV) penetration and moisture ingestion.

- Aramid materials must be protected from direct sunlight. Failure to do so can result in 50 percent or more reduction to the materials' tensile strength. Aramid is naturally yellow in color and turns a darker color of gold when exposed to UV radiation.
- These materials also absorb moisture from the air. This moisture can considerably weaken the ability of the matrix to do its job. Moisture absorption cannot be completely stopped but must be minimized. This can be done by sealing unused aramid materials in plastic bags that have a drying agent and painting parts made from this material.

Boron

One of the stiffest and strongest reinforcing fibers is boron and is made by vapor depositing boron onto a tungsten wire. Boron's high tensile and compressive strength plus its lack of galvanic corrosion potential makes the fiber very popular for repairs to cracked metallic structures. Boron is so stiff that it cannot be woven into fabric or formed into a tight radius without snapping. Boron is only available as pre-preg, nonwoven tape.

Fiberglass

Fiberglass is made from glass marbles melted and pulled through tiny holes into fibers. Glass is an inorganic material that will not burn and will not support combustion. These fibers are normally clear but appear white, and any color may be added during manufacture. Glass fibers are very flexible and may be woven, draped, or formed to almost any contour. Glass fibers have a high tensile strength and because they are moisture resistant, do not shrink, stretch, rot, or decay. Fiberglass resists most acids, alkalis, oils, solvents, sea water, and corrosive atmospheres. Fiberglass structures include fiberglass laminates and fiberglass honeycomb sandwich structures.

Laminated fiberglass

Laminated fiberglass construction consists of two or more layers of fiberglass cloth saturated with a catalyzed resin and bonded together under heat and pressure. The lower illustration in figure 1–1 shows this type of construction. Fiberglass laminates, sometimes called solid wall–type or solid laminate construction, are widely used in fabricating aircraft antenna housings for communication, navigation, and radar equipment.

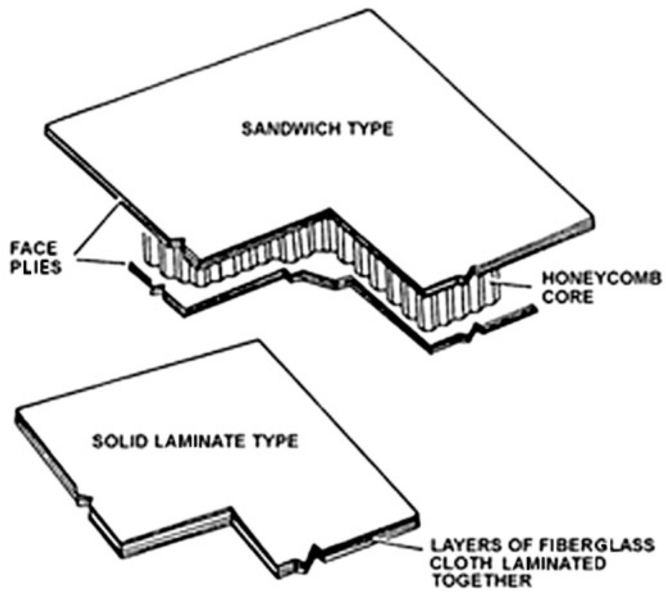


Figure 1–1. Types of fiberglass structures.

The properties of fiberglass laminates are affected by conditions of exposure (temperature, moisture, and weather), thickness of laminates, and variables of fabrication. In many applications, laminates are exposed to moisture through high humidity or free water. The amount of moisture absorbed is generally quite small, but under long exposure, the strength of the fiberglass laminates decrease. The amount of decrease depends on the type of finish applied to the structure, exposure site, type of resin, and reinforcing agent used. Laminates made with polyester, epoxy, phenolic, and silicon resins have withstood up to three years of weathering without severe reduction in strength. To reduce erosion of the resin, keep the exposed face of laminates painted. Moisture in laminates reduces electrical properties. The strength of glass fiber base laminates at elevated temperatures is dependent on the laminating resin. The polyester resins conforming to military specification vary in heat resistance. Most of the resins produce laminates that retain most of their strength at temperatures from around 76°F to as high as 200°F. A few of them retain much of their room temperature strength at even 300°F. Epoxy resins also vary in heat resistance. Heat-resistant resins are being designed for high-temperature use.

Fiberglass honeycomb sandwich

Fiberglass radomes and parts consist of a honeycomb core to which face plies of laminated fiberglass cloth are bonded. The top portion of figure 1–1 shows this type of fiberglass assembly. This type of structure has proven very satisfactory because of its excellent nonconductive qualities, strength, and resistance to weather erosion. The core is used to separate the outer facings and give the assembly a high degree of stiffness. The core keeps the facings elastically stable when highly stressed. This construction makes strong, rigid parts with a minimum amount of weight.

Graphite

Graphite materials are characterized by their high to ultra-high stiffness, high tensile strength, and low density. Tensile strengths of graphite materials range up to 300,000 pounds per square inch (psi). The most desirable property of graphite for high-performance structures is the high stiffness-to-weight ratio. In terms of weight, graphite materials are lighter than aluminum and even fiberglass.

Graphite can be used for parts that have sharp corners. This quality of formability permits graphite materials to be formed into various shaped substructural members. Graphite fibers are made by subjecting strands of synthetic materials to intense heat and pressure, and then the filament (consisting of 3,000–16,000 individual fibers) is placed into unidirectional tapes or woven into fabrics. These materials can be manufactured in a dry condition or in the B-stage resin condition. When uncured, it has the flexibility and handling characteristics similar to fiberglass cloth. The same basic types of weave patterns used for fiberglass are also used for graphite-woven materials. The purpose of the different weave patterns is to accommodate the shape and strength requirements of the composite part. The type of weave pattern being used can be determined by closely examining the part. Graphite fibers are always dark gray or black in color.

CAUTION: Graphite fibers have a high potential for causing galvanic corrosion when used with metallic fasteners and structures.

Fabric forms

Composite materials come in both woven and unidirectional forms. The information provided below will help you identify the different fabric forms that you may come across.

Woven fabrics

A woven fabric is a material constructed by interlacing yarns, fibers, or filaments to form a fabric with specific structural and workability characteristics. For applications where more than one fiber orientation is required, a fabric combining 0° and 90° fiber orientations is often used during part manufacture.

Woven fabrics are produced by the interlacing of warp (0°) fibers and weft (90°) fibers in a regular pattern or weave style. To explain the warp and weft, if you look at a roll of fabric, some of the fibers run in the direction of the roll (0°) and are continuous for the entire length of the roll. These are the *warp* fibers. The short fibers, which run crosswise (90°) to the roll direction, are called the *weft* fibers.

The fabric's integrity is maintained by the mechanical interlocking of these fibers. Drape, or the ability of a fabric to conform to a complex surface, surface smoothness, and stability of a fabric are controlled primarily by the weave style. There are many different weave styles and the following table describes a few of the more common types:

Type of weave	Description
Plain	In a plain weave (fig. 1–2), each warp fiber passes alternately under and over each weft fiber. The fabric is symmetrical with good stability and reasonable porosity.
Twill	The twill weave (fig. 1–3) has one or more warp fibers alternately weave over and under two or more weft fibers in a regular, repeated manner. This produces the visual effect of a straight or broken diagonal rib in the fabric.

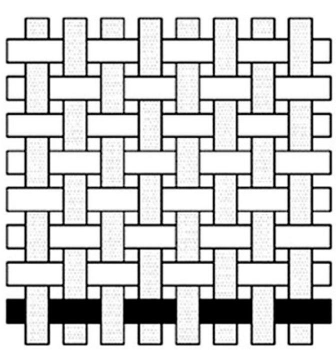


Figure 1–2. Plain weave.

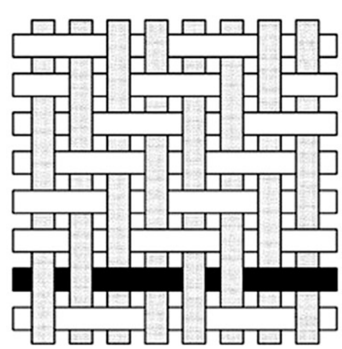


Figure 1–3. Twill weave (2×2).

Type of weave	Description
Satin	Satin weaves are twill weaves modified to produce fewer intersections of warp and weft. The harness number used in the designation (typically 4, 5 or 8) is the total number of fibers crossed and passed under before the fiber repeats the pattern. The asymmetry causes one face of the fabric to have fiber running predominantly in the warp direction, while the other face has fibers running predominantly in the weft direction.
Basket	Basket weave is the same as plain weave except that two or more warp fibers alternately interlace with two or more weft fibers. An arrangement of two warps crossing two wefts is designated as a 2×2 basket; however, the arrangement of fiber need not be symmetrical. Therefore, it is possible to have 8×2, 5×4, and so forth.

Unidirectional fabrics

A unidirectional (UD) fabric is one in which the majority of fibers run in one direction only. A small amount of fiber or other material may run in other directions to hold the primary fibers in position. These other fibers may also offer some structural properties. UDs usually have their primary fibers along the roll in the 0° direction (a warp UD) but can also have them at 90° to the roll length (a weft UD). True UD fabrics offer the ability to place strength in the component exactly where it is required and in the optimum quantity desired. UD fibers are straight and uncrimped, resulting in the highest possible structural properties in fabric composite construction. UD fabrics can only be improved on mechanically, by pre-preg UD tape in which fibers are held in place exclusively by resin.

In UD fabric construction, there are various methods of maintaining the primary fibers in position in a UD fabric; these include weaving, stitching, and bonding. As with other fabrics, the surface quality of a UD fabric is determined by the following two main factors:

- The combination of fiber bundle size.
- Thread count of the primary fiber as well as the amount and type of the secondary fiber.

The drape, surface smoothness, and stability of a fabric are controlled primarily by the construction style, while the areal weight, porosity, and (to a lesser degree) wet-out are determined by the number of fibers per centimeter.

Core materials

Core materials are used in conjunction with metal or composite skins to create sandwich panels. In these constructions, the high stiffness skins carry tensile and compressive loads while the low-density core separates the skins and carries shear loads. Thanks in part to their core materials, sandwich panels offer the highest strength-to-weight and rigidity-to-weight ratios available. Core materials are typically thick, compared to the skins, and come in a variety of materials and geometries. Honeycomb core is the most common core material used for aircraft parts.

Honeycomb core (fig. 1–4) is commonly produced from aluminum, Nomex paper, plastic, and composite materials and is available with several types of cell geometry. Some of the more common types of honeycomb core are hexagonal, over-expanded, and flexible.

Hexagonal

Hexagonal honeycomb core is the most common geometry available, made by strip gluing sheets of material together into a block of the desired sheet thickness. The block is then mechanically expanded into a sheet of honeycomb. An alternate method is the corrugation process, which does not require expansion, and is often used to produce higher density hexagonal honeycombs.

Over-expanded

Over-expanded honeycomb core is extended in the W direction to create rectangular, rather than hexagonal, cells. This cell shape facilitates forming to contours in the L direction.

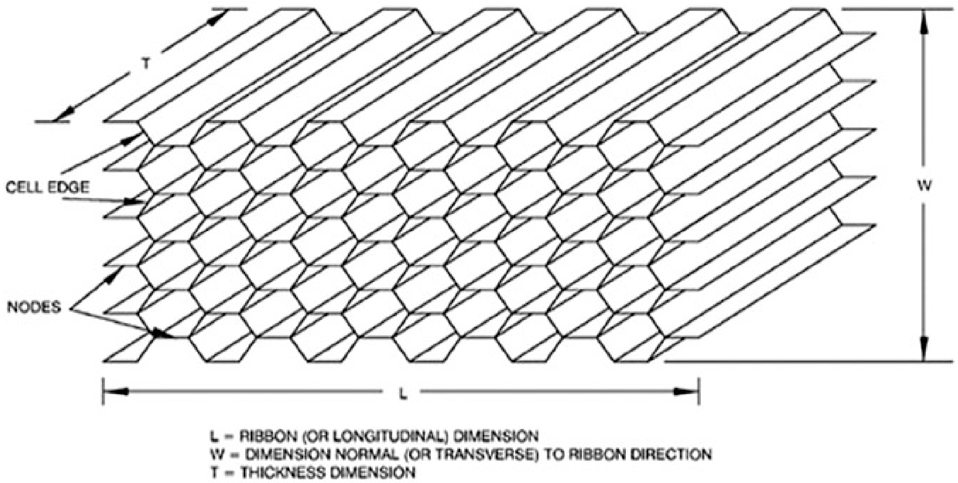


Figure 1–4. Honeycomb core.

Flexible

Flexible core cell configuration results in excellent formability in compound curvatures with reduced anti-clastic curvature and cell wall buckling. When formed into tight radii, this type of core provides higher shear strengths than comparable hexagonal cores of equivalent density.

402. Composite repair materials

The materials used to repair composite structures are, themselves, unique in many ways. Take a close look at the “what’s and whys” associated with the materials used to repair composite structures.

Although the filaments are the primary load-carrying elements of composite structures, and the source of exceptional stiffness, the structures are not complete without a liquid matrix.

A matrix is essentially a uniform resin material in which layered fibers of a high-strength material are imbedded to create a composite structure. These high-strength materials can be fiberglass, graphite, or aramid.

The matrix (or resin) has these essential functions:

- Stabilizes the slender filaments against compression instability.
- Carries transverse and laminar loads in the individual layers.
- Provides the body to the composite in its cured state.
- Prevents the filaments from drooping.
- Protects the filaments from abrasion and erosion.

A matrix is considered to be in one of the three stages described in the following table:

Stage	Condition (Form)
A	Liquid or paste.
B	Pre-preg into a high-strength composite material.
C	Cured.

Laminating resins and paste adhesives

Laminating resins and paste adhesives are viscous materials that undergo a chemical reaction, referred to as curing, to generate a rigid structure. Laminating resins are used to bond fibers together, while paste adhesives are used to bond structures together. Once cured, they are considered permanently formed; however, they can deform if overheated.

Laminating resins and paste adhesives are typically two-part systems. Both parts are in a viscous state and are supplied in separate containers. The two parts are mixed in a precise ratio prior to use. There are several types of thermosetting resins that are generally used with composites. Epoxy and bismaleimide (BMI) are the most commonly used resin systems in the Air Force.

Film adhesives

Film adhesives consist of a thin film of resin, usually epoxy or phenolic. While they do not contain fibers, they may have a woven or nonwoven carrier material embedded in them to prevent tearing during handling and to aid in bond line thickness control. Adhesive films have a separator film or backing paper which is applied to keep the material from sticking to itself.

Film adhesives are tacky at room temperature and above (provided the shelf life is good) and are available with One Side Tacky or Both Sides Tacky. These adhesives require a high-temperature cure cycle, often 250°F or higher. They are available in different sizes, usually measured by the thickness or by areal weight in pounds per square foot.

Film adhesives are used to bond patches to the part either by co-curing or by bonding pre-cured patches. They can be used to bond either composite or metal patches. Adhesive films are not used as laminating resins because they do not wet-out the fabric; however, research is underway to develop film adhesives for laminating.

Foam adhesives

Foaming adhesives (core splice adhesives) consist of a thin, unsupported epoxy film containing a blowing agent. During the rise to cure temperature, an inert gas is liberated causing an expansion or foaming action in the film. As a general rule, the expansion must be performed under positive pressure to prevent over-expansion and reduced strength; however, there are some exceptions in which the foam can be expanded under reduced vacuum levels.

Following expansion, the adhesive is cured into a strong, highly structured foam. It is most often used as a lightweight splice material for splicing honeycomb core repair sections. Like film adhesives, foaming adhesives have the disadvantage of requiring a high-temperature cure cycle and must be shipped and stored at or below 0°F.

Pre-preg fabrics and tapes

A pre-preg material consists of a fabric form which has a resin added to it and is partially cured to the B stage. Pre-pregs are ready-to-use in sheet, roll, tape, or mat form. The tape form is usually UD. Pre-pregs can be distinguished from dry fabrics by separator film or backing paper which is usually applied to keep it from sticking to itself, tackiness at room temperatures and above (provided the shelf life is good), and the tendency of the individual strands to stick together as if they have been starched. Pre-preg is pliable and drapable until cured at an elevated temperature.

Pre-preg offers several advantages over wet layup. These advantages often lead to a stronger repair and consist of exact resin mix ratio, exact resin-to-fiber content ratio, and ease of handling/cutting the material. The main disadvantage to pre-preg materials is their refrigerated/frozen storage requirement and short shelf life.

Pre-preg fabrics and tapes come in many different types to include graphite/epoxy and aramid/epoxy. Graphite/epoxy pre-preg patches are normally circular or oval. The number of plies required is determined by the size and location of the damaged area. Aramid/epoxy pre-preg is yellow. It consists of aramid woven cloth impregnated with epoxy resin in the B-stage condition that requires hot bonding to fully cure.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Composite material identification and characteristics

1. What do composites rely on to produce the required strength characteristics?

2. What happens to fiberglass and graphite after the individual fibers are made?

3. What effect does the finish of a composite fabric have?

4. Why is aramid often used for ballistic protection and body armor?

5. What properties make boron very popular for making repairs to metallic structures?

6. What color are fiberglass fibers normally?

7. What is laminated fiberglass construction?

8. What is the core used for in a fiberglass honeycomb sandwich component?

9. How are graphite materials characterized?

10. What is the most desirable property of graphite for high-performance structures?

11. What is a woven fabric?

12. How are woven fabrics produced?

13. What is a UD fabric?

14. What do true UD fabrics offer?

15. What is the most common geometry available for honeycomb core?

402. Composite repair materials

1. What is a matrix?

2. List five functions of the matrix in composite construction?

3. What are laminating resins and paste adhesives?

4. What is the purpose of a woven or nonwoven carrier material embedded in a film adhesive?

5. What temperature do film adhesives require to cure?

6. How are foam adhesives most often used?

7. List the four forms in which pre-preg materials are ready-to-use.

8. List three advantages of pre-preg materials over wet layup.

1–2. Working with Composite Materials

Now that you have a better understanding of what composite materials are, it is time to look at how to handle them. In this section, you will learn some of the preliminary steps you must take to ensure a sound repair. Some of the topics we will cover include storage and handling, applying vacuum pressure, moisture removal, ply orientation, and damage removal. We will also cover how to machine composite materials.

403. Bonded repair preparation

The key to a successful composite repair is good preparation. It is vitally important for you to start with good materials; store these materials properly, keep the repair surfaces and materials clean and dry, and cure the materials correctly. Failure to store the materials properly or keep the repair surfaces and materials clean and dry and/or cure them properly will result in repairs that are cosmetic only. These cosmetic repairs will not be able to carry the intended structural loads and will fail.

Storage and handling

Care must be taken to ensure materials are maintained at temperatures in accordance with (IAW) manufacturer's specifications during transit and local storage. Repair materials must also remain free of contaminants (e.g., dust, moisture, oil) during handling. Various contaminants may degrade the bonding properties of the repair. For example, protective hand creams must not come in contact with the adhesives or bonding surfaces.

Many materials associated with composite repairs require freezer storage. To ensure quality materials are being incorporated into a repair, a comprehensive material shipping, receiving, storage, and tracking program shall be implemented and followed. Different materials have different storage and handling requirements, and you should always refer to the applicable technical orders (TO) and manufacturer's instructions. Let's look at some basic storage-and-handling requirements for a few of the more common materials you will be exposed to.

Pre-preg fabrics

Pre-preg materials will generally require freezer storage. Nonfrost-free cold-storage equipment is *mandatory*. This equipment should have sufficient capacity to meet local needs for a period of 6–12 months. Freezer storage temperature must be held at 0ºF or lower.

Storage life and maximum time out of the freezer, prior to use, are specified by material manufacturers and should be closely followed. You should store pre-preg materials in sealed, moisture-proof bags IAW with the applicable technical data.

The time that material can be at room temperature and still usable, known as the "out-time," can range from minutes to 30 days or longer. A record of out-time shall be maintained for all pre-preg materials. This record will be used to establish the useful life of the material and to determine when retesting is required.

If the out-time has been exceeded, the material must be scrapped or tested and revalidated to specification before use. The shelf life of material can be improved by cutting large batches of the material into smaller sections (*kitting*) the first time it is thawed.

When kitting, lay the material flat or wrap it around a tube, which is at least three inches in diameter and two inches longer than the material; do not fold the material as this will distort it. All refrigerated and frozen item packages/containers must be sealed before storing and warmed to room temperature before opening; failure to warm to room temperature will result in moisture absorption, which will degrade the resin.

Backing or separator film must not be removed from the repair material until it is ready for use. If pre-preg materials were received without dry ice in the shipping container, determine how much time it was out of the freezer, then add that time to the out-time log.

Wear clean, impermeable (latex, nitrile, etc.) gloves when handling pre-pregs. If powdered gloves are all that are available, ensure exterior of gloves are cleaned before handling repair materials and hands are thoroughly washed immediately after removal of gloves to prevent contaminating the area and materials. Always make material preparation in a controlled environment to minimize exposure to uncontrolled conditions. When materials must be used in an uncontrolled environment, take the material to the repair site in sealed plastic bags in the most practical processed state (e.g., core plugs precut, patches and adhesive pre-stacked, etc.), and then quickly place the materials in place, apply the vacuum bag, and begin the cure. If airborne contaminants are present or the environment is uncontrolled, the repair surface will require a thorough solvent cleaning immediately before material application.

Adhesive materials, including pre-preg, that are to be scrapped should be cured before disposal. The cured material can usually be disposed of as a nonhazardous material with other composite waste; check with your local bioenvironmental engineering flight for disposition.

Laminating resins

Laminating resins and paste adhesives must be stored in clean containers and IAW manufacturer's instructions. The containers must be kept closed to prevent moisture absorption, which will degrade the resin properties. Many of the two-part systems can be stored under normal ambient temperature conditions. Shelf-life limitations imposed by the manufacturer must be observed.

Before opening refrigerated materials, the containers must be allowed to warm up, typically a few hours or until moisture is no longer condensing on the package. Wear latex or nitrile gloves when handling resins and adhesives; if powdered gloves are all that are available, ensure exterior of gloves are cleaned before handling repair materials and hands are thoroughly washed immediately after removal of gloves to prevent contaminating the area and materials. When handling these materials, low-lint garments should be worn to prevent contamination of the repair area and materials.

Preparing a liquid matrix

Two-part repair materials must be prepared properly before they can be used in a repair. Wet layup resins and adhesives often come in two parts: Part A contains the base resin, and Part B contains the curing agent. To determine how much Part A and Part B are needed, the overall amount of repair material must first be determined. Once the amount repair material is known, it is possible to calculate how much resin is needed. Each part is then weighed out in separate containers before thoroughly mixing.

Proper mixing is paramount in producing a full-strength repair. Two things you must be concerned with are catalyst and air. Adding too *much* catalyst to your matrix produces what is known as a "hot" mixture as it literally gets hot when mixed. More importantly, the hot matrix cures too quickly and becomes brittle, reducing the strength of the matrixes by as much as 65 percent. Adding too *little* curing agent to base resin could result in low mechanical properties as well as slow down the curing cycle when curing at room temperature. Avoid using too much or too little catalyst by following the manufacturer's mixing instructions exactly.

Mixing air into the matrix is another concern. When mixing, be sure to fold or blend the mixture into itself slowly. Never whip or mix the matrix components mechanically as this introduces air into your compound and increases porosity. Porosity can be described as the amount of pores, or air bubbles, in a substance; increased porosity greatly reduces the matrix strength at the repair bond line. Bonding is also degraded when solvents are used to thin adhesives; as a result, solvents shall not be used to aid in mixing adhesives.

Measuring scales

When you are required to mix sealants, adhesives, resins, promoters, catalysts, and many other substances, the correct mixture is achieved by weight. Precise ratios are required so the components being mixed can properly cure. Improper ratios (i.e., too much base component) can cause the curing process to slow considerably or prevent total cure; too much accelerator can cause your component to become “hot,” cure too quickly, or become brittle.

Digital scale

The primary way you will be measuring your repair materials is with the use of an electronic top-loading scale with a minimum 500 grams (g) capacity and 0.01 g resolution. You *must zero* the scale before use. An adequate number of scales should be available for peak usage needs.

Triple-beam scale

The triple-beam balance scale is used to obtain precise weight measurements, which are measured in grams. Triple-beam scales are used to measure the weight of both solids and liquids. When liquid is weighed, be sure to place it in a mixing cup; in addition, after you zero the scale, weigh the cup so you can deduct its weight from the total weight.

Whenever you use a triple-beam scale, always ensure it is on a flat, level surface. Just like the digital scale, you *must zero* the scale before use. Do this by moving all three poise assemblies to the far left position and adjusting the knurled balance spindle assembly knob on the left end of the beam. The beam pointer should now be at zero.

Programming a hot bonder

Hot bonders are programmable heat and vacuum-control units, which provide power to heat blankets automatically to an operator-specified cure cycle. The hot bonder monitors bond line temperatures through thermocouples (TC) placed on or near the repair area and varies power to the heat blanket according to cure requirements. This assures acceptable cure temperatures. Hot bonders often have a vacuum pump included. The electrical draw of a hot bonder is approximately 30 amps, and a suitable power source (110 volts) must be available. If they are to be used on-aircraft, you must use some form of explosion-proofing of the hot-bonder system. Fuel vapors, which seep into the hot-bonder case, may present an explosion hazard.

There are many different brands of hot bonders in the field; be sure to read and understand the operating procedures of the hot-bonding system you are using. For the purpose of this lesson, we are going to cover just one specific type of bonder: the Wichitech HB–2 hot bonder.

Wichitech HB–2 hot bonder

This hot-bonding system is a portable, self-contained system designed to monitor and control cure temperatures and monitor vacuum pressures. The HB–2 hot bonder is a dual-zone unit with a power-in receptacle, a built-in vacuum pump, a keypad, two printers, two power-out receptacles for heat blankets, and two banks of eight TC receptacles per zone.

The HB–2 hot-bonder program is menu driven, and you use the keypad on the unit to program it. A paper printout of the program is produced upon program start. A revised program printout is produced upon modification of the program during the cure process. Programs may be stored in the memory (library) of the controller and can be recalled by the operator for quick and easy programming.

The hot-bonder program controls the conditions of time and temperature in steps. Electric heating blankets are used to provide the heat required for proper curing of the repair. TCs are used to monitor the temperature of the cure area. The built-in vacuum pump may be used or an outside source (air-driven vacuum generator or shop vacuum) can be routed through the unit to provide monitoring of the recommended 22 mercury (Hg) needed for the composite repair.

The hot bonder also has a built-in monitoring alarm system. If there is a change from the selected program, the alarm system will activate. An audible alarm will sound, an alarm message will be printed, and an alarm message will appear on the control display. If a problem occurs during the curing process, the control display will change from the real-time cure process display screen (CURE SCREEN) to the alarm screen (ALARM SCREEN), which will display a code.

To acknowledge the alarm, the operator must press the “E” key. This will silence the alarm and change the ALARM SCREEN back to the CURE SCREEN. If power is lost at any time, the hot bonder has a power-loss feature that retains the cure program, and the cure will resume (up to a two-minute time frame) when power is restored.

Upon completion of the cure, a three second alarm will sound, a “CURE COMPLETE” message will be displayed, and the completion time and date will be printed on the printout tape (if used).

Programming a HB–2 hot bonder

The HB–2 system has four modes of operation that we will discuss. These include the test thermocouple (TEST TC) mode, the assign thermocouple (ASSIGN TC) mode, program cure (PROGRAM CURE) mode, and START CURE mode (fig. 1–5).

Figure 1–5. Hot bonder.

The system is menu driven and user programmable. The user can only select the range of values that appear on the MENU screen. After each value is selected, the MENU screen will automatically move to the next required entry. This process will continue until all required entries are made. After the program has been identified, the MENU screen will advance to the START CURE screen, which will carry out the program to perform the bonding process. The following paragraphs describe each of the four modes.

Zone selection

The zone select switch allows the operator to select either ZONE 1 or ZONE 2 for the TCs. Only the selected zone will respond to the keypad.

TEST TC mode

Thermocouples are hooked up to a hot bonder to monitor temperatures for various processes, including cure cycles, moisture removal, and monitoring freezer temperatures for storing adhesive materials. Good TCs are the key to getting accurate temperature readings when working with composites. You must test your TCs prior to using them. Failure to do so could result in severe damage to the structure. The TEST TC mode allows the user to test each selected TC to ensure proper operation. On occasion, you will be required to repair the TCs. When required to repair the end where the wires connect, it is preferred to weld the end (fig 1–6). A twisted TC does not form as reliable of a junction as a welded TC; what's more, its reliability decreases with repeated use. When a TC-wire welder is available, weld the ends of the twisted wires together IAW the equipment manufacturer's instructions.

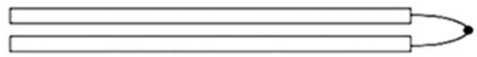


Figure 1–6. Thermocouple (TC) wire end.

ASSIGN TC mode

The ASSIGN TC mode allows the user to select between one to eight active TCs to tell the hot bonder how many TCs are attached. Then the user will select between one to four TCs to be control TCs. These are the TCs that drive the hot bonder, telling it how much power to apply to the heat blanket. If only one TC is assigned, it becomes the control TC to drive the hot bonder. However, a minimum of two TCs should be used. Failure to use two or more TCs could result in injury to user and/or physical damage to equipment and/or materials. Always use the maximum number of TCs required; this will ensure that the hot bonder works at maximum efficiency.

PROGRAM CURE mode

The PROGRAM CURE mode allows the user to install the program for the cure that is needed. To gain access to the program mode, select "3" on the keypad from the main menu window. The programming sequence consists of the steps presented in the following table.

NOTE: After making the entry, the "E" key must be pressed to enter the change into the program. The "M" key is used to return to the menu without changing the program.

Step	Name	Description
1	Number of soaks	The number of soaks requires a keypad entry of 1–6. The number selected will be the number of soak levels. As an example, if "2" is selected, the program will have two levels of soak. This means the heater blankets will be heated to a user-determined temperature during a specified period of time. When the temperature has been obtained, the heat will remain the same for a period of time (soak). After the soak time has elapsed, the heat for the blanket may be increased or decreased, depending on the program, until the next level of soak is reached.
2	Ramp rate	The ramp rate requires a keypad entry of 1°–15°F per minute. As an example, let's say that 5°F is selected; the program will now increase the temperature by 5°F every minute until the soak temperature is reached.
3	Soak temperature	The soak temperature requires a keypad entry of 70°–500°F. This entry determines the temperature the heating blanket will maintain while in the soak stage of the curing process.
4	Soak time	The soak time requires a keypad entry of 1–999 minutes. This entry will determine the length of time the heating blanket will remain at the soak temperature.
5	Cooling rate	The cooling rate requires a keypad entry of 1°–15°F per minute. This entry will program the cool-down rate of the repair. This is a passive function and is dependent upon ambient temperature.
6	Final temperature	The final temperature requires a keypad entry of 70°–150°F. This entry determines the temperature at which the program will terminate.

Step	Name	Description
7	High/low limit	The high/low limit requires a keypad entry of 10°–60°F. The temperature selected is the temperature in degrees above or below the “programmed temperature” value that will cause an alarm to sound. The high/low limit allows the operator to monitor areas that may be above/below the required temperatures for a satisfactory cure. The temperature selected will be the same for both the high and low limits. As an example, let’s say 10°F is entered; the swell temperature is set at 170°F and the TC senses the temperature has reached 181°F or higher, and then an alarm indication will be seen on the MENU window. If the TC senses the temperature has fallen to 159°F or less, then just as before, an alarm indication will be seen on the MENU window. The audible alarm also sounds in both cases.
8	Vacuum alarm levels	The vacuum alarm level requires a keypad entry of 0–27 inches of mercury (inHg). This is the minimum vacuum requirement for the repair. If the vacuum level falls below selected parameters, an audible alarm will sound and an alarm code will be printed on the tape.
9	Print interval	The print interval requires a keypad entry of 1–15 minutes or 0. If a printout tape of the cure process is not wanted, enter “0” on the keypad. If a printout tape of the cure process is wanted, enter the number of minutes between 1 and 15; that will determine how often the system should print. If the print interval is selected, the cycle, stage elapsed time, control temperature, and vacuum will be printed at the selected interval. Additionally, the printout will show the initial program, any program changes, and any alarms that are experienced during the cycle.

START CURE mode

The START CURE mode starts the program; to gain access to the START CURE mode, select “4” on the keypad from the main MENU window. Using the keypad, enter the operator identification and job identification. After entering the job identification, the program will start. While the cure mode is in operation, the computer is constantly monitoring the program to ensure it is operating in the selected parameters.

Alarms

If a deviation is detected, an audible alarm will sound and an ALARM screen will replace the MENU screen. Additionally, if the print function was selected, the alarm code will be printed on the tape. The user must acknowledge the alarm by pressing “E” on the keypad. After “E” is pressed, the MENU screen will change to the START CURE mode screen, and the audible alarm will stop. By pressing the “E” key, the user has not corrected the problem, only acknowledged that a problem exists. Until the problem is corrected, an alarm letter located between HEAT 1 and VAC on the MENU window will blink. When the problem is corrected, the alarm letter will cancel. Although alarms are in use, the cure should never be left unattended to ensure quick response to alarms.

Cure completion

Upon completion of the cure, a three-second alarm will sound, a “CURE COMPLETE” message will be displayed, and the completion time and date will be entered on the print out tape (if used).

Heat blankets

Heat blankets are controlled by hot bonders to perform elevated temperature cures with or without vacuum bags. The two commonly used types of blankets are fiberglass and silicone (fig. 1–7). The temperature range of the heat blankets vary on the type used but can reach temperatures up to 600°F. These blankets may require periodic nondestructive inspection (NDI) to insure none of the internal

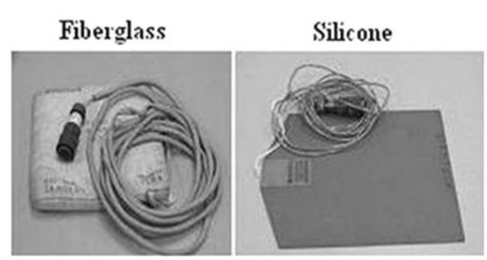


Figure 1–7. Fiberglass and silicone heat blankets.

filaments are damaged or broken, which could cause a malfunction or fire.

Applying vacuum pressure

Vacuum bags serve a two-fold purpose. First, they assist in the removal of entrapped air from wet layups and pre-preg materials. Removing air reduces porosity, which makes the laminate stronger. Second, they give the ability to apply uniform pressure to composite repairs. The pressure is created because the atmospheric pressure outside the bag is greater than the pressure inside the bag. The greater the difference in pressures, the greater the compacting force. When the layup is compacted, the different layers of fiber are pushed closer together, thus making a stronger laminate.

Vacuum-bag material

Vacuum-bag materials vary in quality and application. Ensure the bagging materials, including the sealant or tacky tape, being used are those specified in the weapon system technical manual (TM) or engineering authorization documentation. Consideration should be given to the bagging material capability at the cure temperatures required and the time at this temperature. Rehearse the repair procedures to discover trouble before the actual process starts. Rehearsal is important for placement of the bagging materials and placement of the TCs in close proximity to the patch.

The key to any successful vacuum bag process is to ensure the following:

- The proper level of vacuum is maintained.
- A tight vacuum seal exists.
- A good air path exists from the repair material to the vacuum source.

Determining bagging system

When fabricating a laminate or patch, the resulting structural properties will be based on having a certain amount of resin within the cured material. The two types of systems that you will use are bleed and no-bleed systems. The material type, cure schedule, and bag layup sequence provided by the weapon system-specific TM or the material manufacturer will dictate which system to use.

Bleed system

Pre-pregs with resin content above 45 percent are typically bleed systems. These pre-pregs contain excess resin, which is normally removed during the curing process, to achieve the desired structural properties. The process of removing the resin during cure is called bleeding. In addition to removing excess resin, entrapped air or other volatiles from the laminate are removed along with the resin. Bleeders can be made with single or multiple layers of fiberglass cloth or polyester breathers; the quantity and type of bleeders used affects the final resin content and structural properties of the laminate. Using too many bleeders can result in resin-starved areas and poor strength.

No-bleed system

Pre-preg systems with 32–35 percent resin content are typically no-bleed systems. These pre-pregs contain exactly the amount of resin needed in the cured laminate; for this reason, resin bleed-off is not desired. The majority of pre-pregs in use today are no-bleed systems. No bleeder is used, and the resin is trapped/sealed so that none bleeds away.

Vacuum-bag procedures

Figure 1–8 shows the complete setup to be followed when applying vacuum pressure to a composite repair.

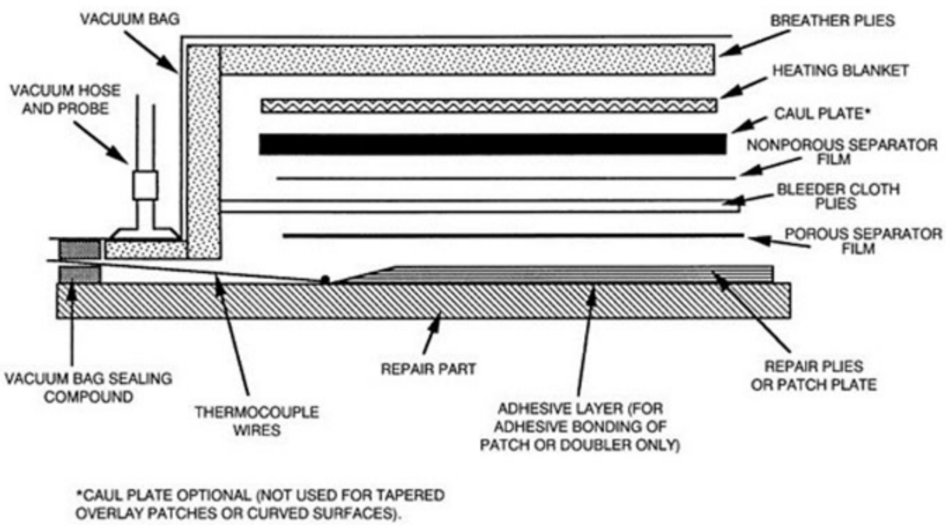


Figure 1–8. Vacuum bag pressure curing.

The steps within the following table describe the process of setting up this method to obtain a void-free repair:

Step	Description
1	Make a vacuum barrier at least 3 inches larger than the outer ply of the repair area. Some common vacuum barrier materials are Tacky Tape and Duxseal.
2	Place a breather strip made of felt ¼ inch thick and 1 inch wide around the entire repair. Place it about 1 inch from the wet laminate. Clothesline rope, rolled gauze, or cheesecloth can also be used.
3	Cut a piece of polyvinyl acetate (PVA) film that conforms to the repair area and extends about 1 inch beyond the strip of Duxseal.
4	Place the open end of the aluminum tubing (which is attached to the vacuum hose) beyond the vacuum barrier to the edge of the felt strip.
5	Pack the vacuum-barrier material around the tubing. When the vacuum line does not have a moisture or resin trap, place several layers of cheesecloth over the open end of the aluminum tubing. This prevents resin from entering the vacuum line to the pump.
6	When using heat to cure a repair, place a TC wire (peel the covering from the wire about ½ inch from the end) about ½ inch from the wet laminate (to get an accurate indication of the surface temperature). Tape the wire to the surface with Mylar or cellophane tape. Embed the wire into the vacuum barrier to prevent air leakage along the wire. Hook the TC wire to a heat indicator (e.g., a digital thermometer).
7	Apply a vacuum slowly to the repair. The PVA film will collapse or flatten over the repair area. Check for leaks around the vacuum barrier. Stop any leakage of air to prevent loss of the vacuum.
8	Work out the wrinkles in the PVA film with a squeegee. Using the radius end, wipe out all air bubbles and excess resin. Start approximately at the center and sweep toward the edge of the repair. Use a slow motion to sweep out the bubbles along with the resin. Squeegees made from Teflon material or flexible rubber is recommended. The dimensions of the squeegees will vary, depending on the size and contour of the work surface. Rubber squeegees approximately 4 inch × 6 inch × ½ inch are satisfactory for most applications. If rubber squeegees are used, coat the PVA surface with a light film of lubricating oil to the outer surface of the PVA so that frictional drag is reduced. When Teflon squeegees are used, lubrication of the PVA is not necessary.

Step	Description
9	When all air bubbles and excess resin are removed, stop; further wiping will create air or vapor voids. This is indicated by a whitening or loss of transparency.
10	If you puncture the film while wiping, repair the puncture with transparent tape. Remove all trapped air from the repair again by wiping the surface.
11	Maintain the vacuum pressure until the repair is cured. Maintain a vacuum pressure between 15 to 28 inHg. Too much vacuum pressure squeezes too much resin out of the wet laminates. Drawing too little vacuum will not produce the desired pressure to force the wet laminates tightly against the structure. If sufficient vacuum pressure is not maintained, ply separation or delamination results.

Vacuum materials

When selecting materials, especially the parting agent film, the temperature at which the repair is to be cured must be known. PVA film is ideal when the bonding temperature does not exceed 250°F. PVA film has very high tear resistance and can be heat sealed effectively. When the bond temperature is *not* above 180°F, use polyvinyl chloride (PVC) film; for temperatures up to 400°F, a polyvinyl fluoride (PVF) film is used. These three types of films are available in a variety of weights and widths.

Moisture removal from composites

Composite skins and sandwich structures inherently absorb water and moisture during use. This water and moisture intrusion may not be obvious by a visual inspection of the structure. The structure may look dry to you, but it is not. Some composite materials, including resin, fiber, and core, have inherent water absorption characteristics. Sandwich or honeycomb panels are particularly prone to water absorption and retention due to the increased air volume in these panels. Cracked coatings, impact damage, and loose fasteners all provide paths for moisture intrusion. It is very important to always refer to the weapon system-specific TO for the drying requirements of your particular situation.

It is also extremely important to ensure water and moisture is removed before performing any bonding, especially one incorporating a heated curing process. Standing water, water vapor, and absorbed moisture in laminates and honeycomb can produce the following damaging effects:

- Blistering.
- Delamination.
- Micro-crack damage.
- Porosity.
- Weak bond-line strength.

Laminates

Composite laminates absorb moisture when exposed to the environment for extended periods of time (several months). The absorption process is reversible and time, temperature, and humidity dependent. The moisture content of a laminate varies through the thickness, with the moisture content being highest at the laminate surfaces. Painted laminates could have higher moisture content than unpainted laminates as the paint tends to inhibit the moisture egress from the laminate.

Absorbed moisture in composite laminates can cause problems when heat is applied during the curing process. It is, therefore, necessary to dry the part before curing using drying temperatures that do not allow the moisture vapor pressure to exceed the matrix strength. Generally, the part is not dried at a temperature higher than the service temperature of the material used to manufacture the part and the phase shift (water to steam) temperature of water (at sea level, this would be 212°F and decreases with increasing altitude, about 190°F at 5,000 feet).

Honeycomb sandwich assemblies

Moisture can enter into honeycomb sandwich assemblies through damaged edge closeouts, core vents, skin punctures, or other defects that expose the core to the environment. Once inside, the moisture can then travel by way of vented cell walls or skin to core delaminations. This moisture can collect and become trapped after traveling through the core. Liquid moisture present in honeycomb sandwich assemblies is usually detectable by x-ray.

Water present in the honeycomb core, either visually apparent or detected by x-ray, must be removed to prevent the corrosion of metallic core or moisture-related degradation of nonmetallic core. Areas containing water will appear lighter than adjacent areas in an x-ray film. However, the presence of cured liquid adhesive from a previous disbond or delamination repair can give a similar appearance.

If the water indication is in proximity to a previous repair, obtain assistance from an NDI technician to determine if water is present. Water must be removed before using a cure temperature of 200°F or higher. Generally, water removal is performed at a lower temperature than the laminate-drying temperature to prevent damage to the honeycomb sandwich assemblies due to steam pressure.

Field repair issues

Composite parts must be dried as much as possible, and this can be a lengthy process. However, in the field environment, repair time and equipment available to you may be limited. These limiting factors can cause problems during the repair process. To mitigate the effects of any moisture not removed during the drying process, cure temperatures of 210°F or below should be used if authorized by the weapon system-specific technical data or manufacturer’s specification. The problem with curing at less than the optimum temperature, even when authorized, is that it will prevent adhesives from reaching their ultimate properties. In this situation, however, loss of adhesive strength is more desirable than inducing damage from water vapor pressure during the cure cycle.

Drying verification

To ensure the repair area is dry, a desiccant can be installed into the vacuum bag to monitor the moisture removal. A moisture indicator is used to determine if a part is dry following a drying cycle; it uses a color-changing desiccant to indicate the presence of moisture. The verification process involves inserting a tube, which will be used to hold the color-changing desiccant, in-line between the vacuum bag and the vacuum pump. The part is heated in an oven (if possible) or in an envelope bag with heat blankets. The temperature is held at the drying temperature for several hours. At the end of the drying cycle, a fresh supply of desiccant is placed in the tube. If the desiccant picks up moisture over the final hour (which will be indicated by a change in color of the desiccant), the part is not dry; continue drying and repeat the drying verification.

General drying procedures

Always refer to the system-specific TM for any peculiar drying procedures. When the service temperature of the part is unknown or no system-specific drying information is given, a commonly used method is to heat the part to 180°F and hold it at that temperature until dry. Drying a composite laminate can be a very lengthy process, depending on the thickness of the laminate.

A vacuum chamber or a vacuum bag placed over the repair area will significantly decrease drying time. The time required to completely dry the skin varies with skin thickness, initial moisture content, and drying temperature. Fortunately, it is not necessary to completely dry the skin to prevent laminate blistering and/or bond line porosity as completely drying thin skins (4–10 plies) may take more than 10 hours; completely drying thicker skins (12 plies and up) can take more than 30 hours. It is only necessary to reduce the near-surface moisture content by using the appropriate drying procedures.

404. Developing repairs

Developing a layout for a composite repair is a multi-step process that begins after the extent of damage has been determined and classified. You will first need to mark the damage orientation; afterwards, you will construct various templates to aid you in the development of your repair.

Orientation markings

Orientation markings are essential to proper repair ply layup. When the repair information calls out the orientation angle of each ply, you must use the same coordinate system used by the engineers to design the repair; this information is found in the system-specific TM, repair drawings, or original equipment manufacturer (OEM) drawings. If you are reading the laminate to determine the orientation angle of each ply, you should orient the 0° direction of your coordinate system along one of the fiber directions, usually the fiber direction running the length or width of the part.

When you are orienting your markings, it is very important to utilize the standard industrial laminate orientation code (SILOC) (fig. 1–9). It is imperative to follow the code to ensure replacement of as much strength to the component as possible.

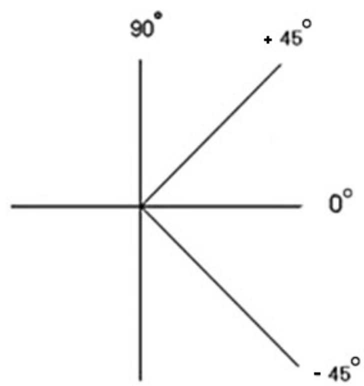


Figure 1–9. Standard industrial laminate orientation code (SILOC).

As a technician, you must pay close attention to the SILOC to translate the engineer’s angles to the repair site. The number of plies and their individual layup angles (in relation to the first ply laid up) determines the strength and stiffness of a composite structure. Using the SILOC, each ply will be laid in sequence from first to last ply. There are many types of ply orientation layups, a few of which are cross ply, angle ply, and quasi-isotropic.

Cross ply

Cross ply is a ply layup in which the laminates are at right angles to one another (0°, 90°).

Angle ply

Angle ply is a ply layup containing plies alternately oriented to any angle to the reference axis not including 0°, 90° plies (e.g., 45°, 53°, –45°, –45°, 53°, 45°).

Quasi-isotropic

Quasi-isotropic is an orientation that designates approximately equal strength in virtually all directions. A simplified version of this would be 0°, 90°, +45°, –45°. By varying the number of layers and ply-direction sequences in each of these four directions, the strength and stiffness of a part can be tailored for its particular structural requirements. Quasi-isotropic layups are balanced/mirrored (0°, 90°, +45°, –45°, –45°, +45°, 90°, 0°) or unbalanced (0°, 90°, +45°, –45° 0°, 90°, +45°, –45°).

Layout development procedures

To begin your layout, you will need template film, a pencil or permanent marker, a straightedge, and a compass or circle template. When you are drawing on composite materials, be sure not to use wax, grease, or oil-based markers, and do not use graphite pencils on aluminum. Continue your layout using the procedures presented within the following paragraphs.

Reading the laminate

Reading the laminate is required when structural technical data showing ply orientation at the damaged area is not available. While the light reflecting from a sanded surface can reveal the presence of plies of different orientations, accurately determining the directions of these plies is fairly difficult. The use of a magnifying glass (8–12 power) is helpful. Using a needle to pick out individual fibers should be used only as a last resort. The ply direction in a scarfed surface can also be read when the damaged material is being removed; that is, the removed pieces can be split apart to observe the direction of the fibers. A group of plies lying together in the same direction are not easily distinguished, but the length of the scarf through each group of plies will reveal the number of plies in the group. Wet sanding with 400-grit sandpaper eases the reading of the ply orientation. Document the ply and reference orientation using the SILOC.

Templates

Templates are used to define patch layouts and aid in constructing and laying up repair patch plies. Ply orientation and stacking sequence are essential in achieving the designed repair strength required by the system-specific TM or engineering authority. Failure to maintain proper orientation throughout the template construction, ply cutout, and ply layup procedures will reduce the strength of the repair.

Patch drawing

The first element of patch preparation is generating a visual aid in the form of a patch drawing or sketch. It should include a coordinate system showing ply orientation and shape, nearby fasteners, prominent aircraft features, and overall dimensions of damage cutout, scarf, and repair plies. An example is shown in figure 1–10.

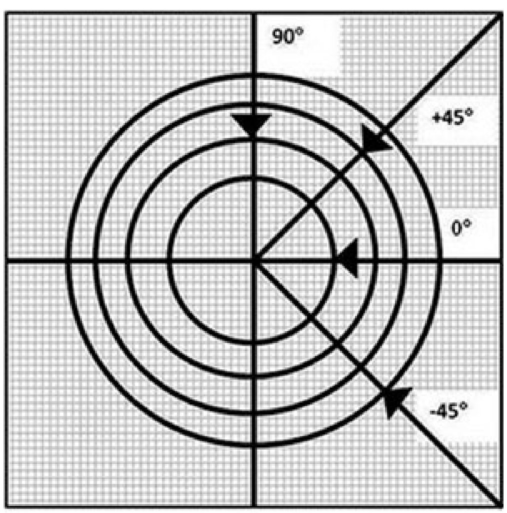


Figure 1–10. Patch drawing.

Stacking template

After the patch drawing has been completed, a stacking template (fig. 1–11) should be constructed. A Mylar or other wax-free material should be used for the template. Remember to include ply orientation and stacking sequence on all drawings and templates. Ensure patch templates used for layup and alignments match the orientation and reference lines on the structure being repaired.

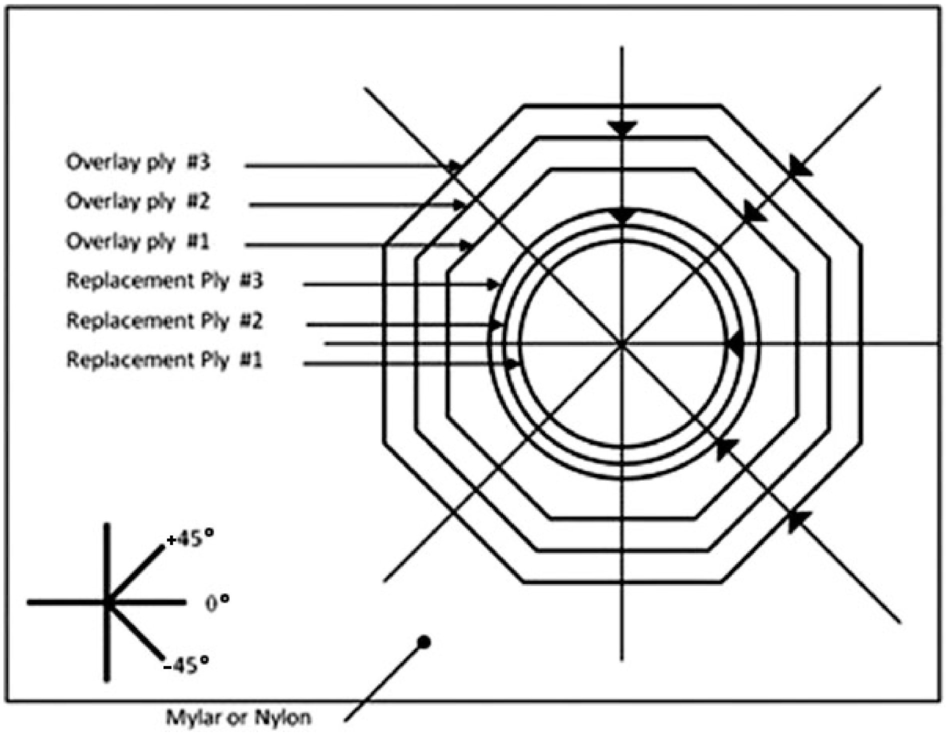


Figure 1–11. Stacking template.

The stacking template is used to mock up the actual patch and should be sized to the actual dimensions. Draw arrows for each ply pointing inward toward the ply, indicating ply orientation. When stacked correctly, these arrows should line up with the actual fiber direction of each ply. For an overlap repair, the ply sequence is generally arranged from largest ply toward the part to smallest ply away from the part. For a scarf or step repair, the patch ply sequence is reversed.

Cutting template

Construct a cutting template from a sheet of Mylar or nonperforated (NP) parting film (nylon). Include ply number, orientation, and zero fiber reference. A Mylar cutting template can be used when performing pre-preg repairs. This template looks similar to a stacking template, but the drawn arrows indicating ply orientation will be pointing outward. The arrows pointing out are important because as you cut each ply off the template, the arrows remain on the other plies. In other words, you place the template on the pre-preg, line up the arrow with the fiber direction, and trace the ply. Next, you would take the template and cut off that ply from the template; you would then place the smaller template back on the material with the arrow pointing in the correct direction, and keep repeating the process until all plies have been traced. Be sure to number each ply on the template and the material so you know the order to put them together.

A nylon-parting film-cutting template will be used when performing a wet layup repair. This will take the shape of a vacuum bag that will be used to vacuum saturate the dry plies and, at the same time, function as a cutting template. The purpose of vacuum saturation is to impregnate dry repair fabric with a two-part resin, reducing the level of entrapped air within the fibers. This process offers a more controlled and contained configuration for completing the saturation process.

Before saturation, mark all plies on the nylon vacuum bag using the cutting template as a guide. Slide the stacking template under the bag, and trace each ply to the top of the cutting template. Indicate ply orientation on each ply. Once all plies are transferred, vacuum saturate the dry cloth. When complete, the saturated repair material will be sandwiched between the cutting template/vacuum bags. This will make the material easier to handle when cutting. Using sharp cutting shears cut out the repair and overlay plies. Refer to figure 1–12 for an example of a cutting template for a wet layup.

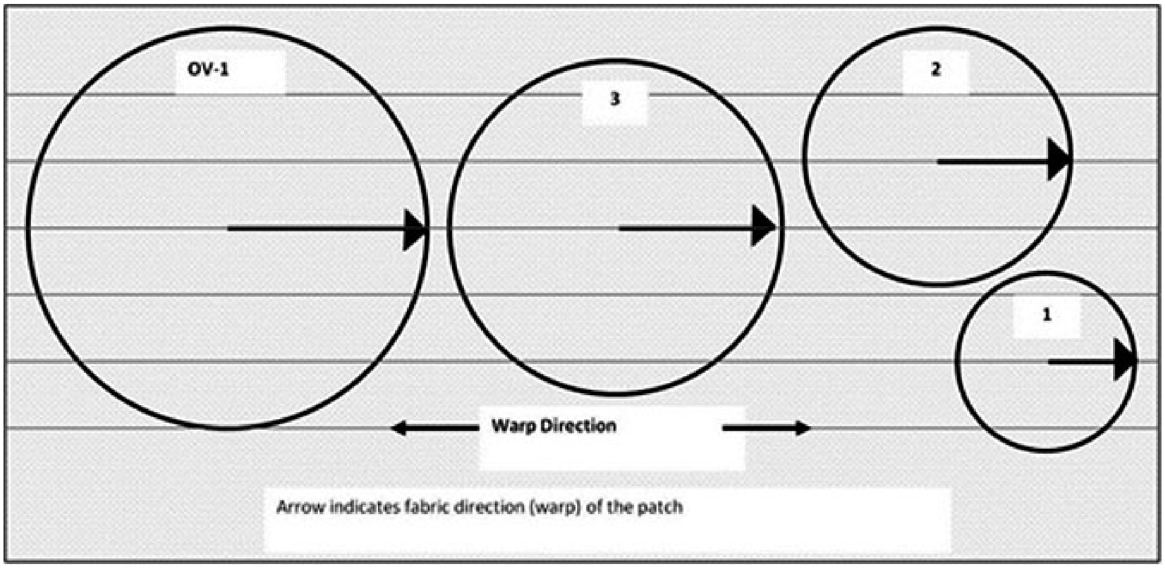


Figure 1–12. Cutting template for a wet layup.

Patch construction

Once your templates are complete and your repair plies are drawn out using your cutting templates, you will cut your repair plies. Next, you will construct the patch by placing each repair ply directly on the stacking template, noting proper order and orientation. Once the stacking of the individual plies is complete, place a layer of nylon-peel ply over the stack-up. This peel ply must be on the outer mold line (OML) of the repair stack-up and will be removed once the curing of the patch is complete.

Sanding template

One more template that you will use during the repair process is the sanding template. The purpose of a sanding template is to protect the undamaged material and to aid in making the repair the desired shape and size. Construct a sanding template using Mylar, flash tape, or masking tape.

405. Machining composite materials

Machining composites is a critical part of your job. You will be called on to cut, drill, and countersink composite components. In addition, you may be called to trim and fit panels on an aircraft. If you don't follow the correct procedures, you could damage the part beyond repair. This section is designed to teach you the necessary procedures needed to machine composite materials.

Tooling selection, type of material, speed rate, and feed rate all have to be considered when removing material. Using the correct tooling and procedures to remove damage from composite aircraft structure provides a satisfactory bonding surface for subsequent repair. However, the use of improper tools and equipment will further damage the repair area.

Composite materials are uniquely different from their metallic counterparts. When machining, it's easy to exhaust the entire shop supply of cutting tools. Each composite material, whether it be fiberglass, boron, graphite, aramid, woven, or UD fabrics, behaves differently when being machined and not knowing or understanding their characteristics can result in loss of equipment, damage to the structure, or personal injury.

Remember when machining composite materials, remove only enough of the good material necessary to accomplish the repair. Avoid breathing the dust from cutting or machining operations. Wear a dust respirator as directed by the bio-environmental engineer and collect dust with vacuum equipment. Wear eye protection during all material removal operations. Adequate ventilation is required as specified by bio-environmental engineering.

Trimming

Trimming operations are somewhat similar to sheet metal work. Trimming composite panels to fit can be very easily done with the proper tooling and techniques. However, it is easy to damage composite structures because of improper tool selection or by using the wrong cutting blades. The fibers within the composite can be pulled or torn out of the matrix, which can cause delaminations/moisture intrusion problems. The tool speed and feed will vary, depending on the type of filaments being cut. Some examples of the equipment used are files, cast saws, kett saws, routers, and band saws fitted with appropriate blades. It is very important that you refer to the weapon system-specific TO concerning proper tool selection.

Boron

Trimming or machining operations should always be accomplished using diamond charged, chipped, or dusted tooling. Coolant use is mandatory when machining boron fiber–reinforced materials. Use non–oil-based lubricants, such as Boelube®, cetyl alcohol, and oil-free Freon™ when authorized by the system-specific TM. The composite should not exceed 140°F during drilling or machining. Low to moderate speed and light feed are used when cutting/machining boron. Do not use coolant when cutting or drilling honeycomb structures.

Graphite

Trimming or machining operations should be accomplished using conventional carbide, continuous chip tungsten carbide, or diamond-charged saw blades. Band-saw blades with a straight or raker set will trim fibrous panels satisfactorily (fig. 1–13). Also, running the blade in reverse lessens the likelihood of pulling the fibers out of their plane, resulting in delaminated edges or fraying. As a safety precaution, use a vacuum exhaust system with all sawing equipment.

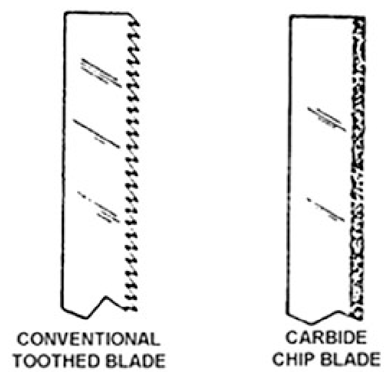


Figure 1–13. Band-saw blades for cutting graphite.

Routers with a helical flute or diamond-cut router bit can also be used to trim graphite components; use a template with this operation. This technique is used to give a smooth, finished cut to a graphite panel. Finish the operation by sanding the trimmed edge smooth.

Aramid

The unique physical properties of aramid fibers call for different cutting tools than those used to drill or machine carbon or glass composites. Sawing, drilling, or machining of any kind generally cannot be accomplished using diamond or carbide abrasive or resin-coated abrasive cutting tools. The relatively low compressive strength of aramid allows deformation to occur at relatively low machining loads. Consequently, the fibers have a tendency to move away from the cutter within the laminate. Laminate structure, fiber orientation, fiber content, and material process can significantly affect machining quality and tool life.

Fiberglass

Fiberglass tends to be easier to work with than some of the other composite materials. As a general rule, you will typically get satisfactory results if you use the same tooling and working techniques that you use when trimming graphite materials.

Drilling procedures

The preferred method for drilling holes in laminate materials is to use a drill bushing and guide to stabilize drill bits so as to prevent wobble and ensure holes are drilled perpendicular to the surface. Also, firmly clamped backup material on the exit side must be used. Do not force feed the drill bit through the composite as damage (delaminations and splintering around the hole) may result when the drill bit breaks through the exit side of the structure. The drilling process must also be performed incrementally, beginning with a pilot hole. Thus, several sizes of drill bits are required for a drilling operation (e.g., pilot holes, $^{1}/_{64}{}^{th}$ undersized, and final hole size). Do not continue to use a drill bit that has become dull. When this happens, the drill motor will slow down, much more force and energy is required, and the drill bit will most likely snap, and the resin can overheat. All of these symptoms can damage, sometimes severely, the composite structure. As soon as any of these symptoms begin, stop and replace the drill bit with a sharp one.

To obtain good quality holes, portable drill stands or drill guides should be used. Drill motors equipped with feed-rate–limiting surge controls are recommended. Maintain a steady pressure to keep the drill cutting at a constant rate. Generally, a high-speed, slow-feed method works best. If too much pressure is applied at high speeds, the excessive heat generated can damage the resin, causing delamination or fracturing.

When drilling without depth sensors, extra care is needed to control hole depth. The drill should be turning before it comes in contact with the laminate and also as it is being withdrawn from the completed hole. Reduce pressure and avoid tilting the drill, driving the drill chuck into the work or ramming the drill point into hidden material. Just before the drill breaks through the back of the material, pressure must be reduced to prevent splintering or fuzzing of fibers on the back face of the laminate.

When drilling or reaming, backup material should always be used to prevent delamination, splintering, or fraying. Several backup materials have been used successfully, including fiber-board, wood, and fiberglass laminates. Clamp the part securely to prevent gaps between the laminate and the backup material or between multiple layers being drilled.

Boron

Boron structures require diamond-charged tooling, and coolant (water-base) use is MANDATORY. Consult your weapon-specific TO for coolant requirements. The use of coolant when drilling through the sandwich structure is not recommended due to honeycomb core contamination and cleaning problems. You must perform a moisture removal process after cleaning is complete.

Graphite and fiberglass

Use carbide-tipped or solid carbide, carbide brad point, or diamond-charged bits to drill graphite and fiberglass parts. Just like when you work with metallic parts, the design and type of drill bits used to drill composites vary. Cobalt high-speed–steel drill bits are not recommended because sharpening is required more often. Carbide spade/flat flute bits (fig. 1–14) are recommended for drilling through laminates. A straight-fluted carbide drill reamer, such as the ST1257B shown in figure 1–15, has been found to cut high-quality holes, with minimum backside breakout, in graphite/epoxy and fiberglass materials. These last significantly longer than any other bit, except for diamond-coated drills and countersinks. Also, the straight-fluted carbide drill reamer cuts with a shearing action that will not pull filaments from the laminate. If a flat flute drill bit is used, a drill guide is required. Remember to change to a twist drill when drilling through a metal substructure.

Observe the following guidelines when drilling composites:

- Use backup material on the exit side of the composite to prevent delamination, splintering, or fraying.
- Use a high-speed, low-feed, in/out drill operation for best results.
- Use a steady, even force.
- Reduce pressure just before the drill breaks through the back of the material to prevent splintering or fuzzing of fibers on the back face of the laminate.
- Use a vacuum to clear the chips.

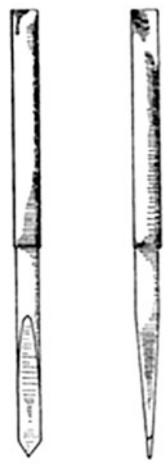


Figure 1–14. Spade (flat) bit for drilling graphite.

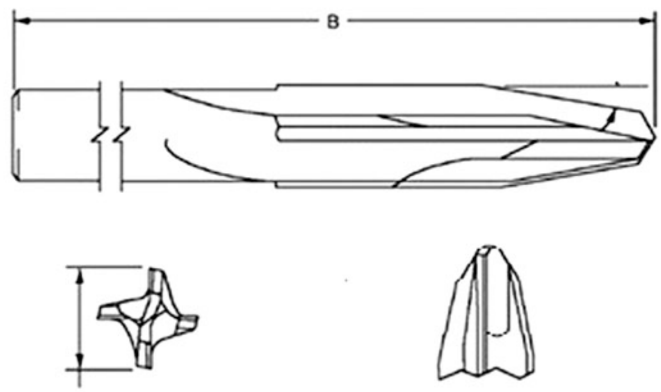


Figure 1–15. Straight-fluted carbide drill reamer.

Aramid

Woven aramids are generally easier to drill or machine than UD laminates, and plain-weave laminates are easier to drill or machine than satin-weave laminates. Physical properties of aramid fibers call for different cutting tools than those used to drill or machine graphite. Hybrid structures where aramids are combined with other materials require special considerations. For hybrid structures, combine characteristics and tool up for the hardest material. For tooling, select carbide, carbide-tipped, or cobalt/high-speed steel. Bit geometry, such as the spade bit, is recommended because it will shear and not lift the fibers. Dagger bits and brad point bits also work well. Conventional twist drill bits should never be used on aramid laminates as unacceptable hole quality and damage will result.

Countersinking

Aramids require a special grind on the carbide to shear the fibers and prevent fuzzing. The countersinks used for aramids would be composed of two very sharp flutes with sickle-shaped cutting edges. For all other composites, carbide tipped, four-fluted solid carbide, and polycrystalline diamond inserted countersinks can be used.

Always use micro-stop countersinks to maintain consistent results. Maintain steady pressure throughout the operation and avoid rocking the micro-stop back and forth to prevent elongation and fuzzing when working with aramid fibers. Make sure the tooling is rotating before contact. When countersinking is complete, inspect for splintering, delamination, fraying, and elongation.

Trimming and fitting replacement components

Excess material on spare or replacement panels will require trimming. Always consult the system-specific TM for gap tolerances. Panels should never butt up against one another. A gap of at least .010 inches is required. This gap allows for the stresses of flexing and heat expansion during flight.

406. Repairing composite structures

There are several types of repairs for solid laminate composites. We will go over some general types in this lesson; the other methods will be discussed in more detail in the following lessons. More repairs can be found in TO 1–1–690, *General Advanced Composite Repair Processes Manual*.

Minor repairs

Class I repairs (e.g., scars, scratches, surface abrasions, or minor rain erosion not penetrating through the first ply facing or fiberglass cloth) are repaired as described in the following table:

Step	Description
1	Clean the damaged area thoroughly and carefully using a clean cloth saturated with an approved solvent.
2	Lightly sand the damaged area using a fine grit sandpaper, such as 280-grit. Clean the sanded area thoroughly using a solvent. Ensure the moisture and solvents are completely removed to prevent their inhibiting the cure of the resin.
3	Mix the resin according to the applicable TO specifications, and apply one or two coats of catalyzed resin to the abraded surface, filling to the level of the surface.
4	Cut a piece of cellophane or PVA film about 2–3 inches larger than the resin-coated surface and lay it on the repair area. The film prevents exposure to the air and provides a smooth surface against which the resin can cure.
5	Tape the film in place and work out all air bubbles and excessive resin. You can vacuum bag the area if you so desire. Cure the repair as given in the specific TO.
6	After the resin cures, remove the PVA film from the repair area and sand the excess resin to the surface level.
7	When a rain erosion coating is removed to complete a repair, replace the coating IAW the TO procedures.

Skin delamination

A skin delamination is a separation between two or more plies of laminate. Delamination is caused by improper bonding, the part being dropped, or the part being struck by a heavy object. Repair of a skin delamination is shown in figure 1–16 and is described in the following table:

Step	Description
1	Drill a hole into the delamination area using a No. 60 (maximum size) drill bit.
2	Inject the resin slowly into the delaminated area using a syringe and needle. If air entrapment occurs when injecting the resin, drill more holes. Inject the resin until it flows freely from the drilled holes.
3	After the void is completely filled, bring the delaminated area down to the proper thickness. Work out the excess resin from between the layers of laminate. Cover with cellophane or PVA film.
4	Apply pressure to the area using C-clamps or vacuum bag, and cure delaminated area according to the applicable TO.

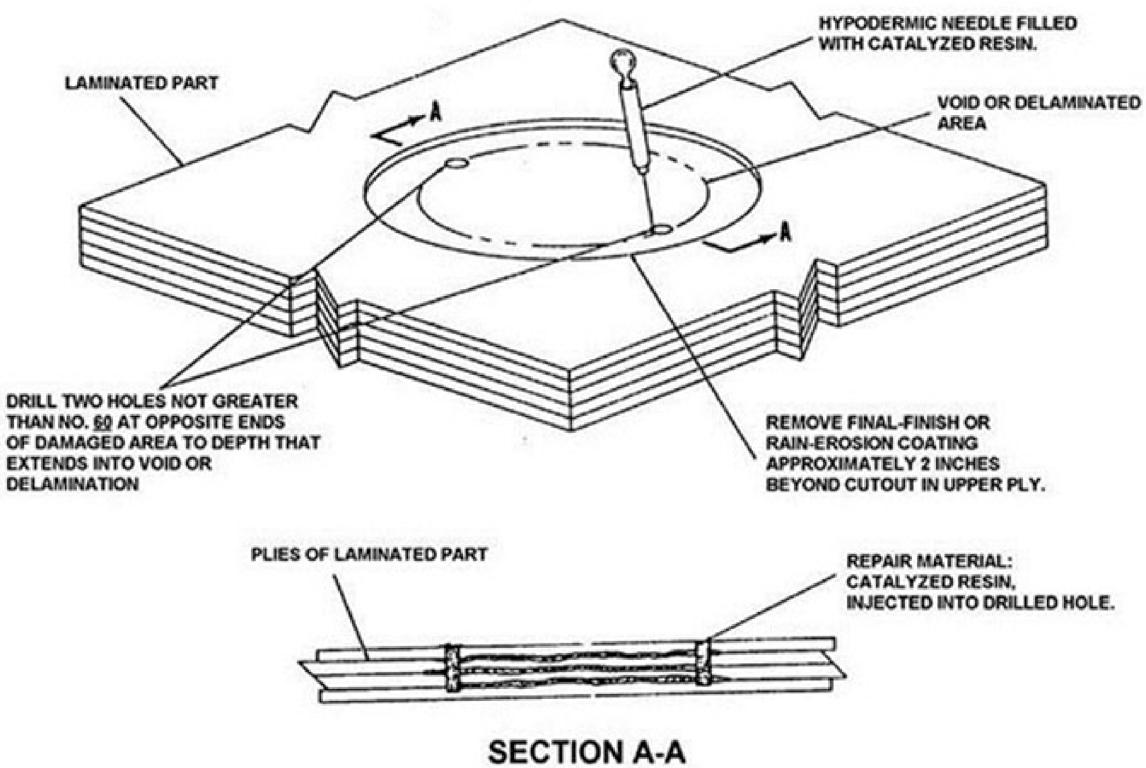


Figure 1–16. Delamination repair procedures.

Step-joint method

Generally, step joints are used in field repairs only on laminates made from woven materials. This is because woven material, unlike plies of UD material, has a greater tendency to separate between plies than within a ply. The step-joint method is accomplished in the manner described in the following table:

Step	Description
1	Outline the damaged area in the shape of a circle, square, or rectangle (round all corners of a square or rectangle).
2	Count the number of damaged skin plies and subtract one ply, then multiply by 1 inch to determine the side to outline around the repair. For example, let's say we have four damaged skin plies. In this case, we would employ the following equations to obtain our required result: 4 plies – 1 ply = 3 plies. 3 × 1 inch = 3 inches. Therefore, we would extend the side we have outlined around the repair (3 inches).
3	Use a sharp knife or specially prepared cutter and cut along the outer line. Cut through the first ply only. Do not cut into the second ply as it can weaken the repair.
4	Remove the cut's outer ply by inserting a knife or putty knife under a corner, prying it loose until it is removed.
5	Scribe on the exposed ply a similar outline reducing the dimension by 1 inch. Remove the ply as you did the first ply.

Step	Description
6	Repeat the procedures until all damaged plies are removed.
7	Lightly sand the exposed plies and clean the surfaces with an approved solvent; afterwards, thoroughly dry the surfaces.

Figure 1–17 shows a side view of how the cutout should look after removing the damaged plies from one side. After all the damaged plies have been removed, the plies around the cutout are then stepped off as earlier described. From an electrical standpoint, the step-joint method produces a more nearly homogeneous patch and is normally the preferred technique of ply removal.

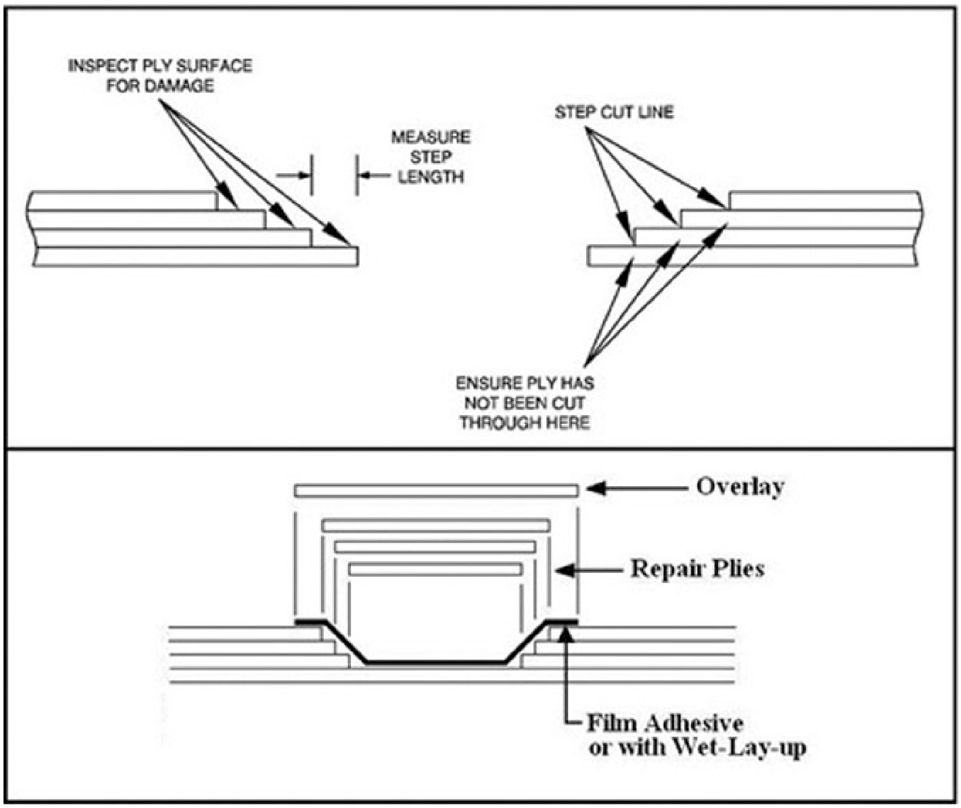


Figure 1–17. Step-joint repair.

When you have removed the damaged plies using the step-joint removal method, accomplish the steps in the following table to restore the structural and electrical qualities of the part being repaired:

Step	Description
1	Lightly sand the exposed plies and clean their surfaces with a solvent. Allow them to dry thoroughly before starting the replacement.
2	Cut the replacement plies from glass cloth that matches each ply of the original material (e.g., the same thickness, warp, fill direction, and style). Make them larger than the area they are to fit. Cut two pieces of cellophane or PVA film about 2 inches larger than the replacement plies for each step.
3	Starting with the smallest or innermost ply, impregnate the glass cloth with catalyzed resin that is 45–50 percent resin (weight of the resin equal to weight of the dry glass cloth comprises 50 percent resin content). Place it between two sheets of cellophane or PVA film. Cut the cloth with scissors to the exact size you need for this step in the repair. This method prevents the fraying of cloth edges. Templates can be made from cardboard to the correct size for each step in the repair.

Step	Description
4	Fit the innermost patch (smallest) to the area. Lay the pieces of fabric in place by first removing the PVA film from one side of the fabric. Place the exposed fabric in position on the repair. Then, remove the second piece of PVA film. Now, butt the edges to the existing bond ply. Be sure the weave direction of the replacement ply runs in the same direction as the existing plies; otherwise, the strength of the structure is reduced.
5	Place a sheet of cellophane or PVA film over the replacement ply. Work out all of the air bubbles with a squeegee or phenolic block. When the ply is void-free and smooth, cure the repair IAW the manufacturer's instructions before applying the remaining plies.
6	Lightly sand the cured repair ply surface to match the contour of the repaired part. Then, place the next cloth ply in the same manner as the first.

NOTE: When the repair has cured, lightly sand the surface as much as necessary to obtain a smooth surface and remove excess cured resin. On solid laminates, when damage extends completely through all plies, remove one-half of the damaged face plies from one side and complete the replacement; then, repeat the same procedures on the opposite side of the damaged area.

Scarf repair

The scarf method requires the damaged plies to be feathered as far back as possible. It is normally used for a small repair up to three or four inches, especially if the facing is constructed of a thin weave of glass cloth that would make it difficult to peel off.

The scarf method (fig. 1–18) consists of sanding out the damaged face plies into a circular or oval disk-shaped cutout. To remove damaged plies, first remove any paint or coating from the repair area by sanding with 180-grit or finer sandpaper. Then, lay out the dimensions of the scarf and patch overlaps IAW the procedures in the TO. Mask the outline of this area and scarf to within ½ inch of the masking tape. This ½ inch border should be lightly abraded to remove any coating or contaminates because it's used for the last ply overlap. You can use a drill motor with a flexible disk to scarf out the damaged area of an aramid panel. Exercise caution to avoid damage to the opposite facing.

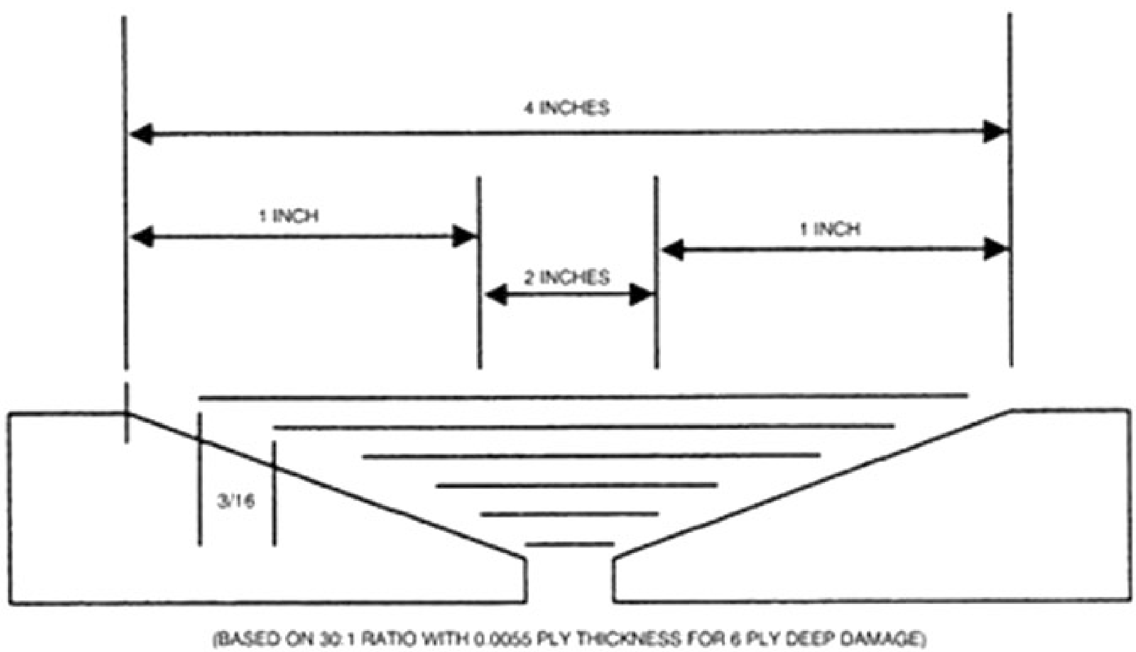


Figure 1–18. Scarf ratio.

The method used to replace plies into the scarfed cutout area affects the sequence of ply replacement. One method is similar to the step-joint method where smaller plies are inserted first with increasingly larger plies being inserted (fig. 1–19). The other method is directly opposite in the largest ply is inserted first, then the smaller plies.

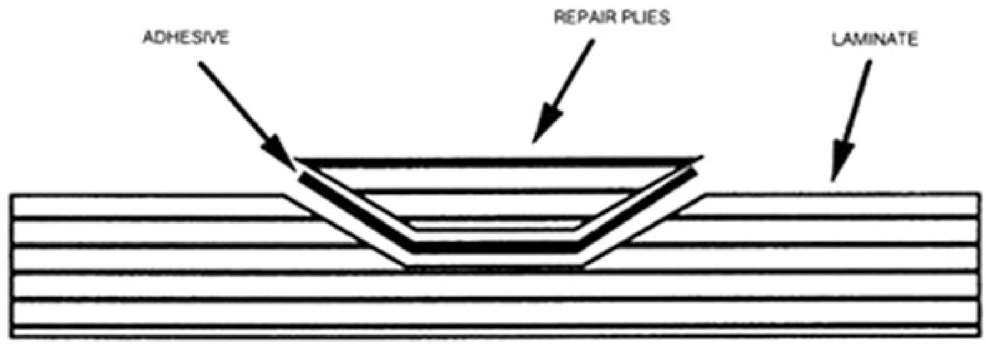


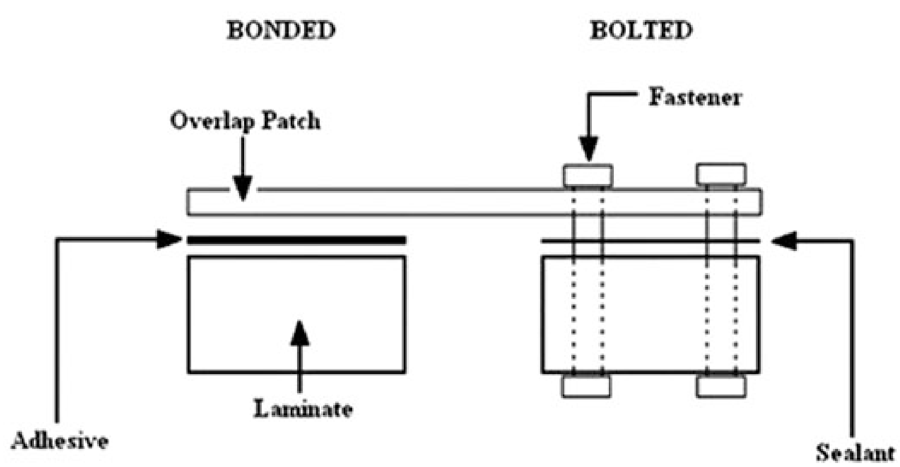
Figure 1–19. Scarf repair.

When using the replacement method of smaller ply to larger ply insertion, overlay the first ply to the smallest area of the cutout by at least ½ inch. Adding an additional ½ inch overlap to the next ply, fit the next larger ply and so on, until the buildup is complete. When using the opposite method, cut the first ply so that at least ¼ inch overlaps the outer edges of the cutout area. Make each additional ply ½ inch smaller, until the necessary buildup is completed.

Regardless of the method used to insert replacement plies, prepare the plies as stated in the step-joint method, step 3. When all of the replacement plies are prepared, lightly sand the exposed plies on the repair part and clean with a solvent, allowing the surface to dry before starting the ply buildup. Once the solvent dries, coat the sanded surfaces with a coat of catalyzed resin. Having brushed the sanded surfaces with resin, fit the replacement plies based on the replacement method being used. At this point, follow the techniques covered for the step-joint method in steps 5 and 6. When the repair has cured, sand the surface of the repaired area to match the contour of the part being repaired.

Overlap repair

Overlap repairs are typically called a scab patch. These repairs simply cover the damaged area with patch material. Overlap repairs can be bonded, mechanically fastened, or both (fig. 1–20).



Typical Bonded and Bolted Overlap Repair

Figure 1–20. Overlap repair.

Bonded overlap repairs work well on most structures. They consist of solid patch materials, such as metal, procured laminates, pre-preg, or wet layup material co-cured in place. Paste adhesives can be used to either co-bond repair patches or to bond a procured repair patch to the structure. The steps in the following table describe procedures for an overlap repair:

Step	Description
1	Remove damage and clean part IAW the applicable aircraft TO or TO 1–1–690.
2	Mix paste adhesive IAW the manufacturer's instructions.
3	Use a trowel or sweep to apply a uniform coat of adhesive to the bonding surface in the repair area. A sweep from the center out (a sunburst pattern) is recommended to minimize trapped air inside the patch.
4	If a scrim or other bond line thickness control measure is used, cut it as required and place it on the adhesive layer. Ensure there are no wrinkles in the scrim cloth.
5	Install the patch, vacuum bag, and cure IAW TO specifications.

407. Repairing bonded honeycomb cores

The repairs in this lesson are general repairs for bonded honeycomb structures. There are small variations for the different materials, such as fiberglass and metal; therefore, consult the aircraft-specific TO for more detailed repair information.

Minor skin delamination repair

Skin delamination occurring in the bonded structures is the separation of the facing(s) from the honeycomb core structure or the splitting apart of the skins or facings. You can repair minor delaminations by drilling a series of holes in the delaminated area and injecting a liquid adhesive into the void. Refer to the steps in the following table and compare them with figure 1–21:

Step	Description
1	If possible, tilt the damaged assembly to an inclined or vertical position. This aids in the flow of the adhesive when injected between the skin and core material.
2	Drill No. 40 holes through the skin at the top and bottom of the delaminated area. Holes should just penetrate the skin. Use a drill stop to avoid core damage to the honeycomb core.
3	Layout and drill the remaining additional holes between the first two existing holes. Holes must be spaced a maximum of 2 inches apart.
4	Deburr the holes and remove all drill cuttings.
5	Mix the adhesive and load the sealant gun, which must have a tip smaller than the No. 40 holes in the skin.
6	Insert the tip of the sealant gun in the lowest hole and inject the adhesive into the void until it flows from the next hole above. Do not apply pressure to the skin during the injection process. If external pressure is applied to the skin, the void closes, making it impossible to inject the adhesive for maximum bonding. Inject the adhesive slowly to allow air to rise above the adhesive. If necessary, the tip of the sealant gun can be heat-formed for angle delivery, if more convenient.
7	Seal the bottom hole with tape, and slowly inject the adhesive into the second hole until it flows from the third hole.
8	Repeat step 7 progressively from hole to hole until the adhesive flows from the top hole.
9	Clean off any excess adhesive at all holes.
10	Cure the adhesive using heat and pressure.

Step	Description
11	Once the adhesive has cured, inspect the repair for effective bonding.

NOTE: Some TOs require the use of an outer overlay to prevent moisture penetration.

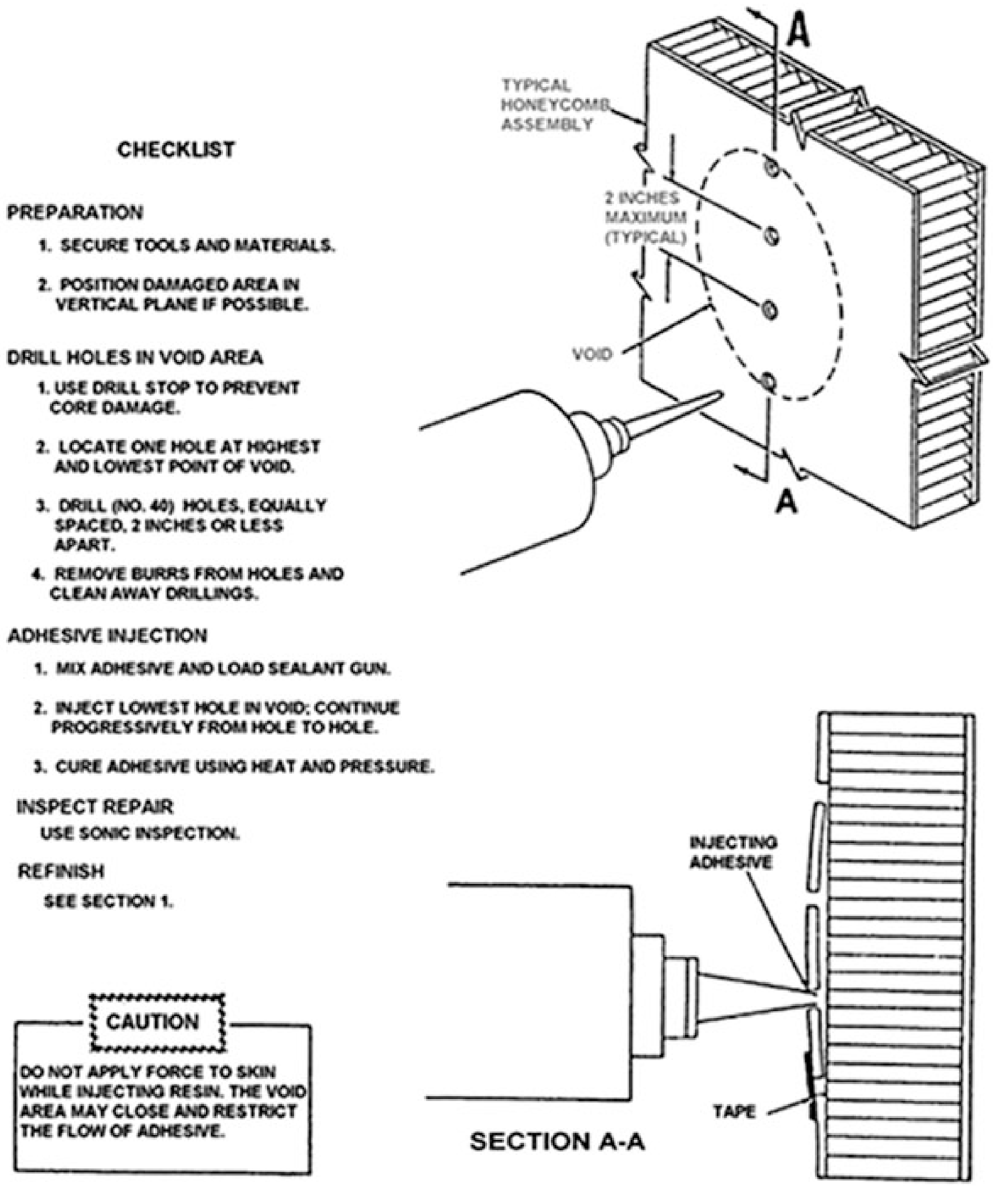


Figure 1–21. Minor skin delamination repair.

Minor skin crack repair procedures

What appears to be just a small scratch or defect may, in fact, be an actual crack, especially on the thinner materials. Minor cracks can be repaired by two methods:

- The first consists of stop drilling the cracks with a suitable diameter twist drill to eliminate stress concentrations at the ends of the crack. Then, you bond fiberglass cloth overlays or a metal overlay over the cracked area, depending on TO specifications.
- The second method is basically the same, except you route the cracked area and insert filler, applying the overlays after. For purposes of our discussion, this is the method we will use.

Prepare the damaged areas requiring the fiberglass cloth overlay repair by cleaning the surfaces, removing the damaged area using a template with router equipment, and cleaning out the damaged and surrounding area. After the damaged area has been completely removed and cleaned, prepare the fillers and overlays. Use two layers of fiberglass cloth, No. 181, impregnated with a suitable resin as filler and overlay material. Cut the filler layers $^{1}/_{16}$ inch smaller in diameter than the damage cutout. Cut the laminated glass cloth overlays at least 3 inches larger than the cutout. This provides at least a 1½ inch overlap around the entire cutout. Before any laminated fiberglass cloth overlays are applied to a repair area, clean the faying surface until no trace of foreign materials exists. Apply a thin, continuous film of adhesive primer to the faying surface, and let it dry at room temperature or an accelerated temperature as recommended. Afterwards, place the overlays evenly over the repair area. Finally, cure, test, and surface finish the repair.

One-skin facing and core damage repair

There are two methods for repairing damage to a one-skin facing and honeycomb core. The first, and most preferred method, utilizes a replacement core plug to replace the damaged honeycomb. The second method involves replacement of the core with a potting compound. This method is used for small holes only and subject to approval of the responsible engineering authority or as authorized in the applicable aircraft TO.

This lesson concentrates on the first repair method only due to its preference. Depending on the depth of damage, all or only partial core will need to be removed. A cross sectional view of each of these repairs is shown in figure 1–22.

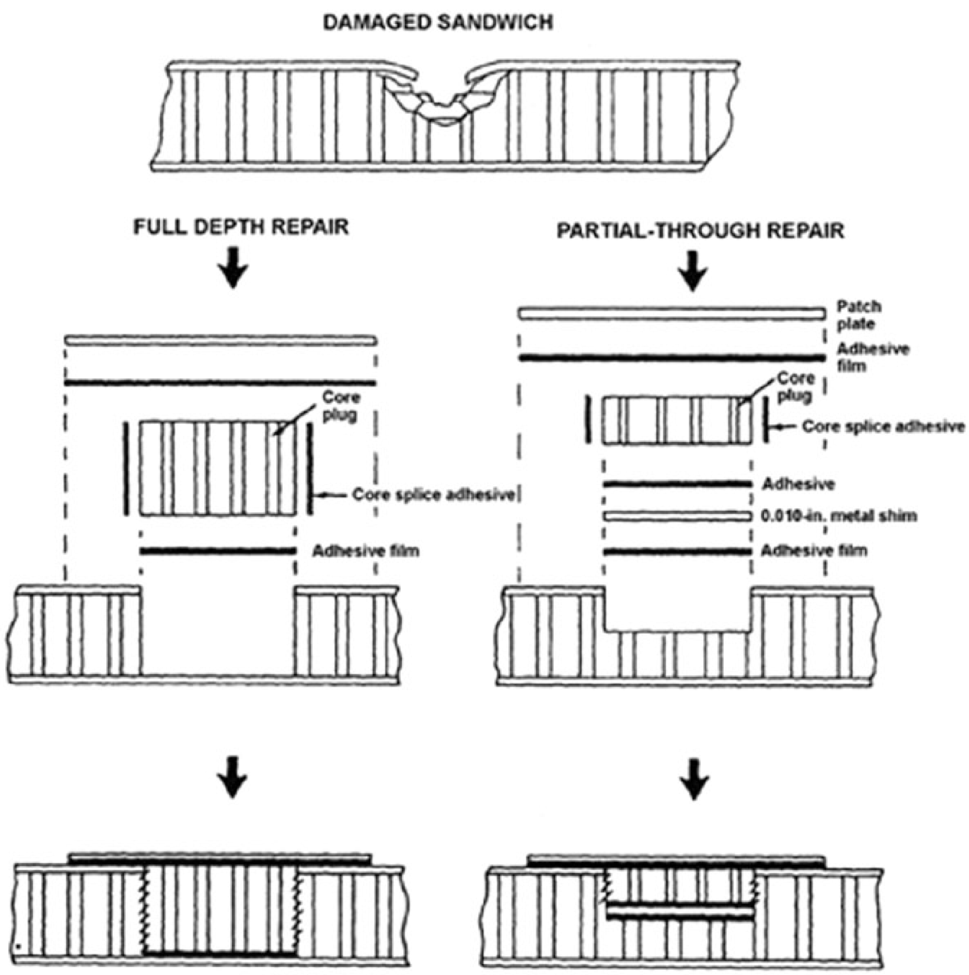


Figure 1–22. Repair for damage to skin and core.

Damage removal

Apply masking tape around the repair area to prevent further damage during rework, and be sure to isolate and contain chemicals or acids. Use aluminum foil or polyester tape for aluminum and lead foil or polyester tape for titanium. Using an ink pencil, draw coordinates, which if extended would pass through the center of the damaged area. Determine the best tool to use and remove the damaged core. Once the damage is removed, use an aluminum oxide disc to remove core ends and adhesive fillets to a smooth finish. Remove the sanding dust and debris with a vacuum cleaner, and wipe the area with clean dry cheesecloth.

Core plug fabrication

Select a core plug with the same density, cell size, and alloy used in the original construction. Consult specific aircraft TOs for any substitutions. Cut and trim the plug to a loose fit in the routed cavity. Trim the core surface to be flush with the surface of the skin. Carefully remove the trimmed core plug and clean it using an approved degreaser. Heat the core plug to thoroughly dry it out; after you accomplish this, wrap the core plug in clean, wax-free Kraft paper until needed for assembly.

Patch plate fabrication

Select the same material as the sandwich face material being repaired. Cut the patch plate to the diameter of the hole, plus the allowance for overlap. The overlap should be a minimum of 1 inch or as designated by the specific aircraft TO. If the patch plate exceeds 0.025 inch in thickness, bevel the edge of one side.

Adhesive preparation and metal shim

Select the appropriate adhesive film listed in the applicable aircraft TO. Observe precautionary notes when removing refrigerated material from storage. Cut one disk of adhesive to the same size as the repair cutout (cut out two disks if a partial-through repair is being made). If a partial-through repair is being made, cut a 0.010 inch thick aluminum shim the same size as the cutout. Preassemble the parts to ensure proper fit. Prepare the metal shim (if used) for adhesive bonding IAW the applicable TO. Wipe the bottom and sides of the cutout area with solvent and allow the area to dry.

NOTE: Different manufacturers use different methods to make the shim; this is only one method of many. Metal type and thickness may vary; also, some manufacturers call for layers of fiberglass cloth instead of metal. Always go by the specific aircraft TO.

Initial bonding procedures

Remove the separator film from one of the adhesive disks, and position it in the bottom of the cutout. If a partial-through repair is being made, place the 0.010 inch metal shim on top of the adhesive and cover with the second adhesive disk, being sure to remove the separator film. After this is done, position a layer of core splice adhesive foam tape around the inside edge of the cavity (fig. 1–23). Insert the core plug into the cavity, making sure the ribbon direction of the plug matches that of the sandwich core. Be careful not to push the core splice adhesive out of position. Fill any voids with additional foam-type adhesive. The core plug should extend slightly above the facing surface. Equally space the TCs around the core plug, fasten in place with nylon or polyester tape, prepare the area for initial bonding (vacuum-bag setup), and cure this portion of the repair. One very important step to remember is once the cure cycle has started, continue until it is complete. Figure 1–23 shows a cross section of a repair bagged for cure.

Remove the bonding equipment after the cure cycle is complete. Visually inspect the core plug for a homogeneous bond. If voids are present in the bond line, fill them with a core splice adhesive paste and cure at the required temperature. Sand the core flush and remove any debris with a vacuum. Wipe the surface of the core with solvent, and dry with clean, dry cheesecloth and dry, compressed air to remove all solvent. Mask the core plug surface to prevent contamination during the skin preparation.

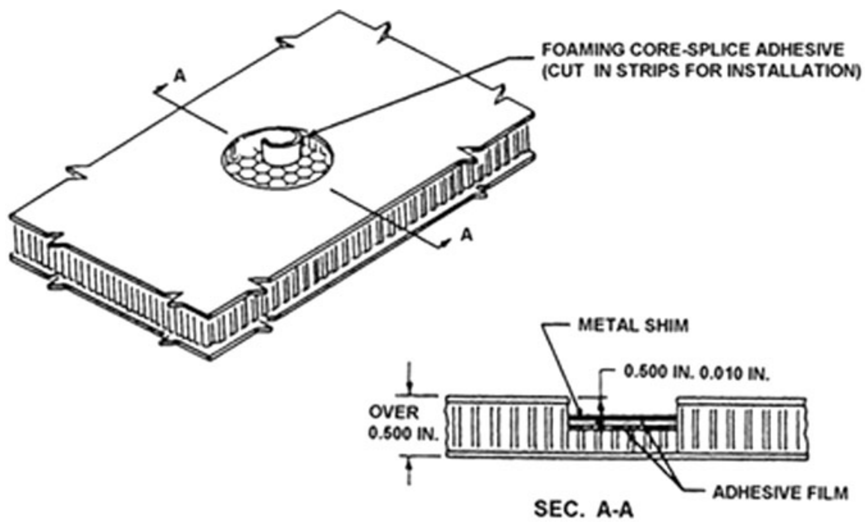


Figure 1–23. Partial through repair.

Patch plate installation

Chemically prepare the skin surface and surface of the patch for bonding. After the surface preparation is complete, apply the adhesive primer. Using the patch plate as a template, cut an adhesive disk to the patch plate size; apply the adhesive disk and the patch plate over the cutout area, and secure them with nylon or polyester film tape. Prepare the area for bonding and cure this portion of the repair. Once the cure cycle is complete, remove the bonding equipment and excess resin. Seal around the edge of the patch plate with sealing compound.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

403. Bonded repair preparation

1. How can you ensure quality materials are being incorporated into a repair?

2. Who specifies a material's storage life and maximum time out of the freezer?

3. How should you store pre-preg materials?

4. What is kitting?

5. What will happen if you don't allow the frozen materials to come to room temperature before opening?

6. In a two-part liquid matrix, which part contains the resin and which part contains the curing agent?

7. What is the result of adding too much catalyst when mixing liquid adhesives?

8. How can you prevent air from being mixed into your liquid matrix?

9. What is the portable, self-contained HB–2 hot-bonding system designed to do?

10. How can you discover trouble spots in the vacuum process before the process starts?

11. List three key points to a successful vacuum-bag process.

12. How is the Duxseal positioned during a vacuum pressure setup for a composite repair?

13. What do you do after you place a breather strip around the entire repair?

14. How should the TC wire be placed to ensure an accurate indication of surface temperature?

15. Once the vacuum pressure is applied, how do you remove air bubbles and excessive resin from the repair area?

16. How can you prevent ply separation or delamination results when applying vacuum pressure?

17. How do you determine the type of parting agent film to use?

18. List five damaging effects that standing water, water vapor, and absorbed moisture can produce in laminates and honeycomb structures.

19. How can you tell if water is present in a honeycomb structure by looking at an x-ray film?

20. How can you mitigate the effects of any moisture not removed during the drying process when doing a field repair?

404. Developing repairs

1. What must you use if the repair information calls out the orientation angle of each ply during a repair ply layup?

2. Why is it very important to use the SILOC?

3. What tool can you use to help you read the ply orientation of a sanded laminate?

4. What should you include in your patch drawing?

5. What do you do after you create a patch drawing?

6. When using a cutting template, what do you do after you trace the first ply onto the repair material?

7. What do you do before you vacuum saturate the dry cloth during a wet layup repair process?

8. What do you do after the stacking of the individual plies on the stacking template is complete?

405. Machining composite materials

1. What are four things you must take into consideration when removing material from composites?

2. What will the tool feed and speed be dependent on during trimming operations?

3. What tool speed and feed should you use when cutting or machining boron?

4. What type of saw blade would you choose to trim a graphite component?

5. What technique would you use to get a smooth, finished cut to a graphite panel?

6. How do you prevent wobble and ensure holes are drilled perpendicular to the surface when drilling holes in laminate materials?

7. What happens if you apply too much pressure at high speeds when drilling composites?

8. What do you have to do just before the drill breaks through the back of the composite material and why?

9. When drilling a composite, how can you prevent splintering or fuzzing of fibers on the back face of the laminate?

10. How can you maintain consistent results when countersinking composites?

406. Repairing composite structures

1. Match the proper sequence in column B with the abbreviated work procedures for a minor repair to a laminated fiberglass part in column A by placing the letter of the item in column B beside the procedure in column A. Each item in column B may be used only once.

Column A	*Column B*
____ (1) Sand the excess resin to the surface level.	a. Step 1.
____ (2) Cut the PVA film to about 3 inch larger than the repair area.	b. Step 2.
____ (3) Clean the damaged area using an approved solvent.	c. Step 3.
____ (4) Remove the PVA film from the repair area.	d. Step 4.
____ (5) Mix the resin according to the applicable specifications.	e. Step 5.
____ (6) Lightly sand the damaged area using 280-grit sandpaper.	f. Step 6A.
____ (7) Replace the rain erosion coating.	g. Step 6B.
____ (8) Work out excessive resin and air bubbles.	h. Step 7.

2. Match the proper sequence in column B with the abbreviated work procedures for repairing a delaminated facing on a laminated composite part in column A by placing the letter of the item in column B beside the procedure in column A. Each item in column B may be used only once.

Column A	*Column B*
____ (1) Apply pressure and cure the delaminated area.	a. Step 1.
____ (2) Inject resin into the delaminated area.	b. Step 2.
____ (3) Drill a hole using a No. 60 drill bit in the delaminated area.	c. Step 3A.
____ (4) Cover the area with the PVA film.	d. Step 3B.
____ (5) Work out excess resin from between the layers of laminate.	e. Step 4.

3. When performing a step-joint repair, what do you do after you have removed all the plies?

4. How do you cut replacement plies for a step-joint repair?

5. What should you do when fitting the repair patches in a step-joint repair?

6. What do you do before removing damaged plies for a scarf repair?

7. What step do you take after the scarf repair area is cured?

8. How can an overlap repair be installed on a composite panel?

407. Repairing bonded honeycomb cores

1. How can you aid the flow of adhesive when it’s injected between the skin and core material to repair a minor skin delamination?

2. What do you do after you have drilled the remaining holes to fix a minor skin delamination?

3. What must you do before applying any laminated fiberglass cloth overlays to a minor skin crack repair?

4. How do you determine what types of replacement core to use when repairing core damage?

5. What additional step must be done for a partial-through repair that is not done for a full core replacement repair?

6. What must you ensure when installing the core plug into the repair cavity?

7. In addition to wiping the surface with dry cheesecloth, what else do you do to be sure all cleaning solvents are removed?

Answers to Self-Test Questions

401

1. A combination of matrix type, fiber type, ply orientation, and processing method.
2. They are bundled into groups called strands for fiberglass and tows for graphite.
3. It affects bond strength and durability, depending upon the resin type to be used.
4. Aramid fibers have very good energy absorption characteristics.
5. High tensile and compressive strength plus its lack of galvanic corrosion potential.
6. They are normally clear but appear white, and any color may be added during manufacture.
7. Two or more layers of fiberglass cloth saturated with a catalyzed resin and bonded together under heat and pressure.
8. To separate the outer facings and give the assembly a high degree of stiffness.
9. By their high to ultra-high stiffness, high tensile strength, and low density.
10. The high stiffness-to-weight ratio.
11. A material that is constructed by interlacing yarns, fibers, or filaments to form a fabric with specific structural and workability characteristics.
12. By interlacing of warp (0°) fibers and weft (90°) fibers in a regular pattern or weave style.
13. A fabric in which the majority of the fibers run in one direction only.
14. The ability to place strength in the component exactly where it is required and in the optimum quantity desired.
15. Hexagonal.

402

1. A uniform resin material in which layered fibers of a high-strength material are imbedded to create a composite structure.
2. Stabilizes the slender filaments against compression instability, carries transverse and laminar loads in the individual layers, provides the body to the composite in its cured state, prevents the filaments from drooping, and protects the filaments from abrasion and erosion.
3. Viscous materials that undergo a chemical reaction to generate a rigid structure.
4. To prevent tearing during handling and to aid in bond line thickness control.
5. A high-temperature cure cycle, often 250°F or higher.
6. As lightweight splice material for splicing honeycomb core repair sections.

7. Sheet, roll, tape, and mat.
8. Exact resin mix ratio, exact resin-to-fiber content ratio, and ease of handling/cutting the material.

403

1. Implement and follow a comprehensive material shipping, receiving, storage, and tracking program.
2. The manufacturers.
3. In sealed, moisture-proof bags IAW the applicable technical data.
4. Cutting large batches of material into smaller sections the first time it is thawed.
5. It will result in moisture absorption, which will degrade the resin.
6. Part A contains the resin, and Part B contains the curing agent.
7. It creates a hot mixture, which cures too quickly and becomes brittle, reducing the strength of the matrixes by as much as 65 percent.
8. Fold or blend the mixture into itself slowly.
9. Monitor and control cure temperatures, and monitor vacuum pressures.
10. Rehearse the repair procedures.
11. Ensure the proper level of vacuum is maintained, a tight vacuum seal exists, and that a good air path exists from the repair material to the vacuum source.
12. Should be placed at least 3 inches from the outer ply of the repair area.
13. Cut a piece of PVA film that conforms to the repair area and extends about 1 inch beyond the strip of Duxseal.
14. About ½ inch from the wet laminate.
15. Use a squeegee made from Teflon material or flexible rubber, and slowly sweep out the bubbles along with the resin.
16. Maintain a vacuum pressure between 15 to 28 inHg until the part is cured.
17. It is determined by the bonding temperature. PVC film is used up to 180°F, PVA film is used up to 250°F, and PVF film is used up to 400°F.
18. Blistering, delaminations, micro-cracks, porosity, weak bond line strength.
19. The areas containing water will appear lighter than the adjacent areas.
20. Use cure temperatures of 210°F or below.

404

1. The same coordinate system used by the engineers to design the repair.
2. To ensure replacement of as much strength to the component as possible.
3. An 8–12 power magnifying glass.
4. Ply orientation and shape, nearby fasteners, prominent aircraft features, and overall dimensions of damage cutout, scarf, and repair plies.
5. Construct a stacking template.
6. You would take the template and cut off that ply from the template; you would then place the smaller template back on the material with the arrow pointing in the correct direction, and keep repeating the process until all plies have been traced.
7. Mark all plies on the nylon vacuum bag using the cutting template as a guide.
8. Place a layer of nylon peel ply over the stack-up.

405

1. Tooling selection, type of material, speed rate, and feed rate.
2. Type of filaments being cut.
3. Low to moderate speed and light feed.
4. Conventional carbide, continuous chip tungsten carbide, or diamond-charged.
5. Use a router with a helical flute or diamond-cut router bit and a template.

6. Use a drill bushing and guide to stabilize drill bits.
7. Excessive heat is generated, which can damage the resin, causing delamination or fracturing.
8. Reduce pressure to prevent splintering or fuzzing of fibers on the back face of the laminate.
9. Reduce pressure just before the drill breaks through the back of the material.
10. Always use micro-stop countersinks.

406

1. (1) g.
   (2) d.
   (3) a.
   (4) f.
   (5) c.
   (6) b.
   (7) h.
   (8) e.
2. (1) e.
   (2) b.
   (3) a.
   (4) d.
   (5) c.
3. Lightly sand the exposed plies and clean the surfaces with an approved solvent; afterwards, thoroughly dry the surfaces.
4. Cut them from glass cloth that matches the same thickness, warp, fill direction, and style of the original material.
5. Ensure the weave direction of the replacement ply runs in the same direction as the existing plies.
6. Remove any paint or coating from the repair area by sanding with 180-grit or finer sandpaper.
7. Sand the surface of the repaired area to match the contour of the part being repaired.
8. They can be bonded, mechanically fastened, or both.

407

1. Tilt the damaged assembly to an inclined or vertical position.
2. Deburr the holes and remove all drill cuttings.
3. Clean the faying surface until no trace of foreign materials exists. Apply a thin, continuous film of adhesive primer and let it dry at room temperature.
4. Select a core plug with the same density, cell size, and alloy used in the original construction. Consult specific aircraft TOs for any substitutions.
5. A 0.010 inch thick shim must be made the same size as the cutout.
6. That the ribbon direction of the plug matches that of the sandwich core, and take care not to push the core splice adhesive out of position.
7. Use dry, compressed air.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) High strength and stiffness in composite-bonded materials is a result of the
   a. thickness of the improved matrix.
   b. increased diameter of the filaments.
   c. concept of the cross-plied lamination.
   d. different directions of the filaments within each ply.

2. (401) What is the identifying color for aramid materials?
   a. Black.
   b. White.
   c. Yellow.
   d. Translucent green.

3. (401) What is a characteristic of graphite materials?
   a. Ultra-high stiffness.
   b. Low tensile strength.
   c. High-density qualities.
   d. Low compression strength.

4. (401) Unidirectional (UD) fabrics have the highest possible structural properties in fabric composite construction as a result of having
   a. straight and uncrimped fibers.
   b. twisted and uncrimped fibers.
   c. straight and crimped fibers.
   d. twisted and crimped fibers.

5. (402) What essential function does a resin matrix *not* perform?
   a. Carry transverse and laminar loads in the individual layers.
   b. Provide the body to the composite in its cured state.
   c. Carry the primary load of high-strength material.
   d. Prevent the filaments from drooping.

6. (402) The process where viscous materials undergo a chemical reaction to generate a rigid structure is referred to as
   a. curing.
   b. debulking.
   c. off gassing.
   d. exothermic reaction.

7. (402) What type of adhesive is most often used as a lightweight splice material for honeycomb core section splice repairs?
   a. Film.
   b. Foam.
   c. Liquid.
   d. Laminating.

8. (403) When storing advanced composite materials in cold storage, what is the *maximum* temperature permitted?
   a. 0ºF.
   b. 32ºF.
   c. 60ºF.
   d. 72ºF.

9. (403) Cutting large batches of material into smaller sections the first time it is thawed is a process known as
   a. kitting.
   b. scoring.
   c. bagging.
   d. packaging.

10. (403) Adding too *much* catalyst to your matrix produces what is known as a
    a. hot mixture.
    b. cold mixture.
    c. slow mixture.
    d. flexible mixture.

11. (403) When mixing a liquid matrix, the components should be
    a. whipped together quickly.
    b. blended together quickly.
    c. whipped together slowly.
    d. blended together slowly.

12. (403) What *must* you do *prior* to using the triple-beam scale?
    a. Zero the scale.
    b. Adjust the platform.
    c. Center each poise assembly.
    d. Align the poise assemblies to the right side.

13. (403) The *recommended* vacuum pressure, measured in inches of mercury (inHg), for curing a repair is
    a. 10 inHg – 23 inHg.
    b. 15 inHg – 28 inHg.
    c. 20 inHg – 33 inHg.
    d. 25 inHg – 38 inHg.

14. (403) Liquid moisture present in honeycomb sandwich assemblies is usually detectable by
    a. x-ray.
    b. eddy current.
    c. visual inspection.
    d. ultrasonic inspection.

15. (403) In a field environment, mitigate the effects of any moisture not removed during the drying process by using cure temperatures of or below
    a. 190°F.
    b. 200°F.
    c. 210°F.
    d. 220°F.

16. (404) What kind of ply lay-up would a laminate with a ply orientation of 45°, 53°, –45°, –45°, 53°, 45° be considered?
    a. Cross.
    b. Angle.
    c. Mixed.
    d. Quasi-isotropic.

17. (404) What type of orientation would you choose to obtain approximately equal strength in virtually all directions when developing a ply lay-up?
    a. Cross.
    b. Angle.
    c. Mixed.
    d. Quasi-isotropic.

18. (404) What can you do to help ease the reading of the ply orientation in a graphite repair site?
    a. Wet sand with 280 grit sandpaper.
    b. Dry sand with 280 grit sandpaper.
    c. Wet sand with 400 grit sandpaper.
    d. Dry sand with 400 grit sandpaper.

19. (404) The first element of patch preparation is generating a
    a. patch drawing.
    b. model drawing.
    c. cutting template.
    d. stacking template.

20. (405) You would use a drill bushing and guide when drilling advanced composite laminates to ensure holes are drilled perpendicular to the surface and prevent
    a. wobble.
    b. disbond.
    c. drill fatigue.
    d. embrittlement.

21. (405) To compensate for the stresses of flexing in flight, the *minimum* required panel gap is
    a. 0.004.
    b. 0.006.
    c. 0.008.
    d. 0.010.

22. (406) Which work procedure do you *normally* perform *first* when making a *minor* repair to a laminated fiberglass panel?
    a. Sand off any excessive resin.
    b. Lightly sand the damaged area using 280-grit sandpaper.
    c. Mix the resin according to the applicable technical order.
    d. Clean the damaged area thoroughly with an approved solvent.

23. (406) When making a *minor* repair to a laminated fiberglass panel, what is *normally* the *third* work procedure you use?
    a. Lightly sand the damaged area using 280-grit sandpaper.
    b. Mix the resin according to the applicable technical order.
    c. Clean the damaged area thoroughly with naptha.
    d. Sand off any excessive resin.

24. (406) What is the *first* step in a scarf repair?
    a. Find the center point of the damage.
    b. Find the edges of the damage.
    c. Remove any paint or coating.
    d. Remove the top damaged ply.

25. (407) When repairing a *minor* metal-bonded honeycomb assembly skin delamination, you can prevent core damage when drilling holes for the resin injection by using a
    a. drill stop.
    b. core stop.
    c. hand drill.
    d. core detector.

26. (407) How are the thermocouples positioned when repairing a metal-bonded honeycomb repair?
    a. Next to each other.
    b. On the honeycomb.
    c. Equally spaced around the repair.
    d. On the top and bottom of the panel.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Low Observable History, Fundamentals, and Aircraft Signatures

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2–2. Aircraft Signature Basics 2–7
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- 412. Signature reduction techniques 2–8
- 413. Inspection principles 2–12

THE AGE OF "STEALTH" aircraft has become the new era of thinking. Stealth technology gives you the ability to blend the aircraft into the background and make it so difficult to detect that the enemy can't "see" you and, therefore, can't stop you from completing your mission and returning safely.

Within this unit, we will address low observable (LO) fundamentals, including how it is defined, as well as the basics of radar and how it is used to measure the radar cross section (RCS) of aircraft being tracked. In addition, we will provide a more in-depth view of aircraft signatures, including what causes them. We will also discuss reduction techniques and inspection principles.

2–1. Low Observable Fundamentals

For decades, camouflage has been the primary means used on aircraft to attempt to avoid detection. The introduction of RAdio Detection And Ranging (RADAR) during World War II (WWII) drastically changed combat tactics. With today's technological battlefields, camouflage is still important, but avoiding radar detection has become the primary concern.

This section will provide you with basic LO building blocks, along with its definition and a bit of its history. Afterwards, the section will focus on radar, its definition, and basic facts. Lastly, we will discuss measuring LO with radar or the cross section of an aircraft.

408. Low observable defined

Within this lesson, we will define LO (or rather, LO technology), provide a brief history of LOs, and describe its purpose.

Although making an aircraft visually invisible is impossible, applying LO technology gives us the ability to avoid radar detection and increase our surprise attack capability. Our adversaries use multiple techniques to identify potential threats including radar, thermal, acoustical, and visual detection. An object is given the ability to defeat these very same threats through a series of processes which make up LO technology, also referred to as stealth technology. The ability to defeat various detection methods increases aircraft survivability.

Exploring the history of LOs

One of the earliest uses of radar-absorbent material (RAM) was actually discovered by mistake. RCS of an aircraft was theorized by British radar engineers in the late 1930s. Due to the Allied Forces taking catastrophic losses during daylight bombing in WWII, the decision was made to begin nighttime raids. This paid off until the Germans introduced the first airborne radar. With resources becoming scarce, the British built wooden skin fighters known as "Mosquitoes." Because the German radar was new and very basic, the Mosquitoes were able to avoid detection. With this surprising discovery, the Mosquitoes became the primary nighttime fighters.

The brothers Reimar and Walter Horten, pioneers of flying wing aircraft, conceived the Horten HoIX, also known as the Go 229. In 1943, they started to design a twin-engine, jet-powered flying wing called HoIX. At the beginning of 1944, the Reichsluftfahrtministerium (RLM) realized the importance of the design, as did Hermann Goering, who gave all his support to the Horten brothers and their novel aircraft.

Using the previous design of the German Horten HoIX, Northup Grumman established a program to put the stealth technology to work. They manufactured the YB–49, which flew from 1941–1950, but the program was cancelled for 40 years before being brought back online. This design of the YB–49 evolved into the B–2 Stealth Bomber we have today.

During the 1950s, Lockheed Martin designed the very stealthy U–2 with reliable high-altitude intelligence, surveillance, and reconnaissance (ISR), and which is still flying today. In the late 1950s and early 1960s, Lockheed Martin developed the SR–71 Blackbird, which relied on shaping, altitude, and speed to help with its stealth capabilities. While the SR–71 Blackbird is now retired from use in the Air Force, it was capable of flying in the earth's atmosphere at altitudes of 85,000 feet and faster than Mach 3.

With the future of aircraft getting smaller and faster, Lockheed Skunk Works developed an aircraft in the late 1970s to adapt to changes in radar. They designed and built a small state-of-the-art fighter called Have Blue. The Have Blue was made a bit stealthier, thus evolving into the F–117A Nighthawk.

As radar systems became more advanced, stealth technology lagged behind. A major advancement in stealth technology wasn't made until the B–1B bomber utilized advanced composite materials in the late 1970s. The fuselage and empennage sections of the B–1B use an extensive amount of advanced composite material. These advancements in technology led to a more widespread use and are becoming the standard in modern aircraft, such as the B–2 bomber, F–22, and F–35 tactical fighters.

The purpose of LOs

The main purpose of LO technology is to increase the survivability of the weapons platform. The biggest advantage LO aircraft bring to the fight is high survivability. That means an aircraft with LO technology has a high probability to successfully complete its mission and be available to fight again. In addition to having a high-survivability rate, stealth aircraft are also highly lethal platforms. They are capable of destroying many intended targets on their first attempts. The combination of survivability and lethality means one of these aircraft can do the job that required multiple legacy aircraft in past conflicts. This capability makes LO aircraft force multipliers. Stealth systems can penetrate defenses to attack targets denied to conventional aircraft or sustain far fewer combat losses in performing their designated missions. Additional specific advantages of LO technologies including the following:

- Reduced range at which an enemy can detect or track our weapon systems.
- Ability to see our enemies before they see our weapon systems.
- Reduced amount of time the enemy has to react to our weapon systems.
- Allows engagement and destroying of enemy targets before they are able to threat lock-on or launch.
- Permits evasion or deception of hostile forces through covert operations.
- Leads enemy to misidentify our weapon system as a nonhostile platform.
- Increased effectiveness of electronic countermeasures.

409. Radar basics

Most weapon systems are designed to track using either radar or heat, and in some cases, both. Being able to avoid detection greatly increases combat survivability. The way this is accomplished is still highly classified**.** The basic information, however, is not. As LOASM, you will need a basic understanding of radar to successfully defeat it.

Radar definition

As stated earlier, RADAR stands for RAdio Detection And Ranging. RADAR is defined as a system made up of a transmitter and receiver designed to detect and locate a target. RADAR is often called the weapon that won WWII and the invention that changed the world. RADAR was a major development and proved to be one of the most amazingly useful advances of the twentieth century and continues to be vital to aviation in the twenty-first century.

Radar uses

The main use of radar has been the detection and location of objects. The military uses of radar are extensive and cover virtually all aspects of the battlefield. On aircraft, it is used to locate and identify both airborne and ground forces, monitor weather, and to guide precision weapons.

Radar systems use either microwaves or radio waves to gather information. These waves pulse from an antenna, and that pulse travels at the speed of light until it strikes an object. The frequency of the radar wave will determine what type and how much information is collected and processed. The rate at which the radar wave fluctuates is called the *carrier frequency*.

Once the traveling wave strikes an object, it bounces back and is received by the antenna. The wave is then amplified and processed by a computer to determine information about the target. The reflected target energy is called *skin return*, and the amount of energy returning back to the originating radar or other receiver is directly proportional to the cross-sectional area of the target. Basic radars present the target information on a display, and displayed targets are referred to as *blips*. Based on the relative size of the blips on the display, a radar operator can determine many factors. The more energy bounced back to the antenna, the more information that can be processed. RCS, speed, location, and direction are some examples of information that can be obtained about a target.

Kill chain

All defense systems must complete a chain of events called an *engagement sequence* or “kill chain,” which includes target detection, target acquisition, tracking, and weapons launch. Figure 2–1 shows a kill chain example for a legacy aircraft. As you can see, the radar detection systems overlap, making it difficult for the aircraft to move through the radar field undetected. Figure 2–2 shows how a stealth aircraft evades the kill chain. By reducing the effectiveness of the radar detection, the aircraft is able to fly through the radar net undetected.

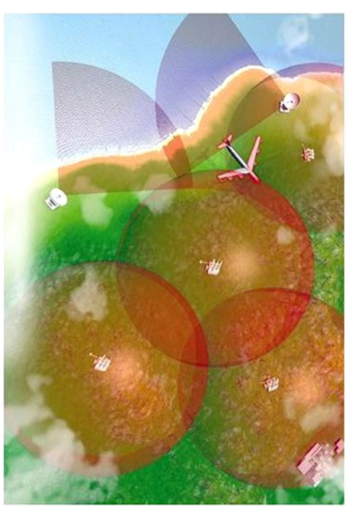

Figure 2–1. Legacy aircraft kill chain.

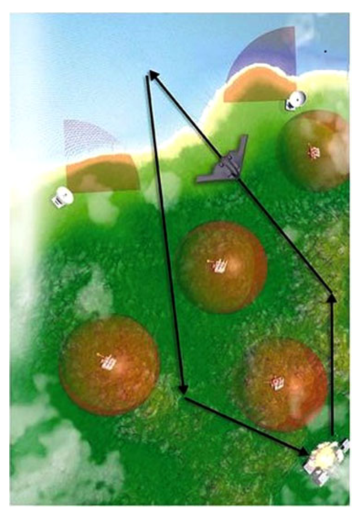

Figure 2–2. Stealth aircraft kill chain.

Carrier frequencies

Radio carrier frequencies vary dependent on the radar's function. Frequencies are usually measured in megahertz (MHz), which is millions of cycles per second. Higher frequencies are measured in gigahertz (GHz), which is billions of cycles per second. The most common radar frequency carriers are low-frequency (long-range tracking), mid-frequency (long-to-medium–range tracking), and high-frequency (short-range tracking). Refer to the following table for radar frequencies.

Band	Frequency	Wavelength	Usage
HF (high frequency)	3–30 MHz	200–33 ft.	Long range
VHF (very high frequency)	30–300 MHz	18–3 ft.	Very long range
UHF (ultra high frequency)	300–1,000 MHz	3–1 ft.	Very long range
L	1–2 GHz	1–0.5 ft.	Long-range tracking
S	2–4 GHz	6–3 in.	Moderate range
C	4–8 GHz	3–1.5 in.	Moderate range
X	8–12 GHz	1.5–0.9 in.	Short-range tracking
Ku	12–18 GHz	0.9–0.66 in.	Fusing (missile)
K	18–26 GHz	0.66–0.45 in.	Anti-A/C artillery
Ka	26–40 GHz	0.30–0.40 in.	Comm. satellites

We need to be concerned about many different types of radar systems, including systems used for surveillance, as well as for tracking/fire control. Surveillance systems use low-frequency radar for early warning detection. Once the system detects an object, it will relay the signal to a tracking/fire control radar system that has a higher resolution. Surveillance systems used for long-range tracking and early warning detection usually operate in the VHF to L band ranges. The tracking/fire control systems use mid-frequency radar (band ranges S, C and X) for moderate- and short-range tracking. Tracking systems will use the medium-frequency S and C band ranges to track objects and relay the signal to the fire control system. Short-range fire control systems use high-frequency X and K bands ranges to obtain high-resolution information.

410. Radar cross sections

RCS is a measurement of the electromagnetic (EM) energy returned to the radar antenna. When radar waves are shot at a target, only a portion of the waves are reflected back. This energy helps to determine the object's RCS. A number of different factors determine how much EM energy returns to the source.

RCS defined

The RCS of an object is defined as the cross-sectional area of a conductive sphere that would reflect as much energy as the object in question. In other words, the RCS is the size of an object as measured by radar; however, the physical size of an object is a secondary RCS determinant. In general, a RCS observation requires you to specify four things, including azimuth, elevation, frequency, and polarization.

Azimuth

Azimuth is the horizontal angle measured around the object's vertical axis and is a measurement annotated in degrees from the object's nose starting at 0º running clockwise to 360º. It is often referred to as the "look" angle in an RCS measurement; for example, if an observer walks around the object clockwise, when he or she is directly on the right-hand side, the observer would be viewing the object at 90º. Once directly behind the object, it would be viewed at 180º as is illustrated in figure 2–3.

Elevation
The angle looking down or up at an object is the elevation. Looking directly at the object's waterline would be referred to as 0º (fig. 2–3).

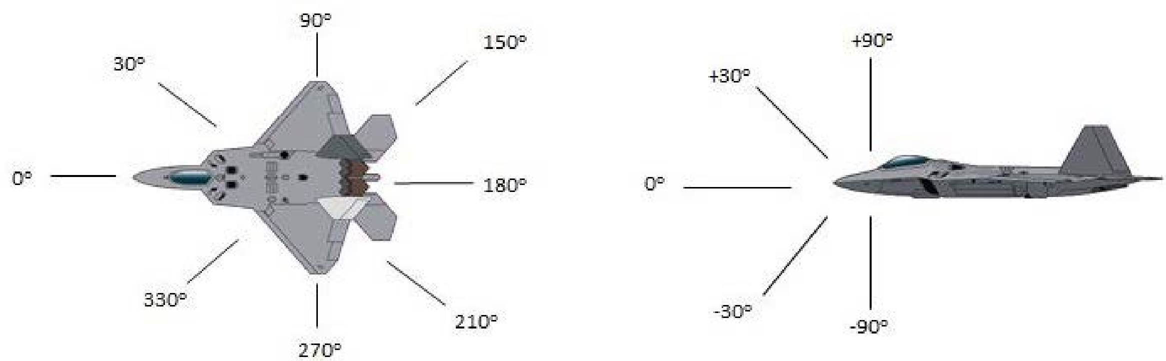

Figure 2–3. Azimuth and elevation.

Frequency
Frequency is the number of amplitude peaks in a wave that passes a given point per second.

Polarization
For an EM wave, polarization is the direction in which the electric field vector is oriented; for an ANTENNA, it is the direction in which the EM field is oriented when it is radiated by the antenna.

RCS measurement
RCS is typically measured in square meters and converted to decibels relative to square meters (dBsm). Decibels (dB) are simply a mathematical transformation of numbers into quantities that can be easily understood. Using dBs gives us the ability to easily understand a range of numbers, from very small numbers up to very large numbers. Because the RCS of similar objects can vary widely (1,000–10,000 times in some cases), using dBs makes it easier to discuss the RCS magnitudes of certain objects.

Although the RCS return of most military aircraft is classified, the respective RCS of various objects have been measured (fig. 2–4). A typical surface ship has an RCS of approximately 10,000 square meters or 40 dBsm. When viewed from the side, an F–14 has the same RCS as the front of a commercial airliner, which is in the range of 1,000 square meters or 30 dBsm. A human being has an RCS measured at approximately 1 square meter, which is 0 dBsm.

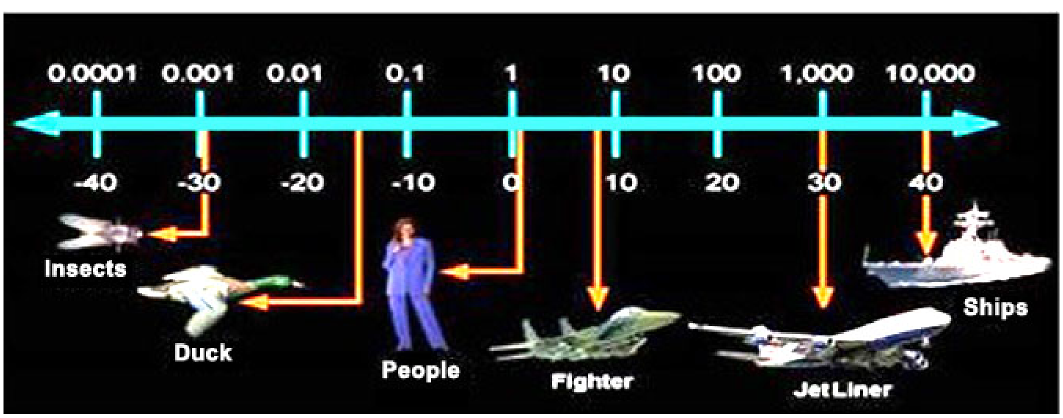

Figure 2–4. RCS of various objects.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Low observable defined

1. What is the definition of *LO* technology?

2. What increases an aircraft's survivability?

3. What major stealth technology advancement occurred in the late 1970s?

409. Radar basics

1. What does the acronym RADAR stands?

2. How is *radar* defined?

3. What has been the main use of radar?

4. What type of waves do radar systems use to gather information?

5. What will the frequency of the radar wave determine?

6. List four examples of information that can be obtained about a target using radar.

410. Radar cross sections

1. What is RCS a measurement of?

2. What is the definition of an object's RCS?

3. What are four things that an RCS observation requires you to specify?

4. How is RCS measured, and what is it converted to?

5. What are dBs?

2–2. Aircraft Signature Basics

Not all signature sources can be controlled. Having a thorough comprehension of the sources that can be controlled and how they are produced is the first step to being able to control them. Through signature-reducing techniques and proper inspection, you can ensure that signature sources remain as low as humanly and mechanically possible.

411. Aircraft signature sources

A *signature source* is a characteristic of an object that can be detected by visual or mechanical means. Knowing the different signatures and what causes them is essential in reducing the signature of an aircraft.

Visual

The visual signature of an aircraft is an important factor in determining overall aircraft detectability. Visual sources are anything that can be seen if not properly controlled. Low visibility is important for military aircraft and essential for stealth aircraft. Aircraft encounter a variety of threats during a combat mission, one of which is anti-aircraft artillery (AAA) that local air defenses use. AAA may come in the form of small-arms fire, light artillery (20 millimeter [mm] through 60mm), medium (60mm through 100mm), and heavy (greater than 100mm) and may be visually directed, especially with low altitude systems. Short range, low altitude surface-to-air (SAM) systems may require visual acquisition before launch. In addition, older airborne interceptors may visually acquire an aircraft at close ranges to fire their cannons and to launch infrared (IR) missiles, while modem detection systems may use automatic optical trackers to detect aircraft at long ranges.

The visual signature is determined by the contrast of the aircraft with the background; however, other things; such as condensation trails (contrails for short), glints, engine smoke, paint scheme, and the shape of the aircraft; may reveal its presence. At night, engine exhaust glow, external lighting, and cockpit lighting may also provide visual cues. Nighttime aircraft detectability is increased if the observer uses night vision goggles.

IR

IR sources occur when the aircraft skin heats up during flight due to friction and engine exhaust. Additional IR sources include internal engine heat and exhaust from the power unit and environmental cooling system.

Acoustic

Because aircraft are loud, they can be tracked by the sound that they make. An aircraft creates various acoustic sounds that can be heard with and without the aid of listening devices. For example, an aircraft’s afterburner, regular engine noise, sonic booms (if supersonic), and the skin of a vibrating airframe during flight are all loud, audible acoustic sources.

Radio frequency emissions

Radio emissions occur when energy is transmitted or escapes from the aircraft’s radar, antenna emissions, avionics bays, communication systems, and static electricity buildup.

RCS

An object's RCS is the measurement of energy a "target" object returns or backscatters to radar. An object's RCS depends on its size, the reflectivity of its surface, and the directivity of the radar reflection caused by the object's geometric shape. An RCS return occurs when energy strikes and scatters from cavities, gaps in the skin, rivets and screws, crew compartment area, tail section, wings, and fuselage.

412. Signature reduction techniques

With today's technology, we can design and manufacture military aircraft to be agile, fast, and LO. When designing an LO aircraft, we need to consider seven main areas: shaping, use of RAM, radar-absorbent structures (RAS), visual, IR, electronic emission, and acoustical reductions. A key determinant of whether an aircraft is LO is the size of its RCS. The larger the aircraft's RCS, the more information the radar system can return; therefore, the larger the RCS, the greater the risk of detection. Every effort must be made to minimize an aircraft's RCS. To attempt to minimize an RCS, you must first have an understanding of the different wave interactions involved.

Wave interactions

RCS reduction is an attempt to make the object look smaller to radar; it is also synonymous with stealth technology or LO aircraft. The RCS of an object is a critical factor that can determine how close you can be to a radar system before the system can detect you. RCS causes a wave interaction (fig. 2–5) in which EM energy encounters something, and a portion of the energy passes through or will be absorbed by the target; the rest of the energy is scattered in many directions.

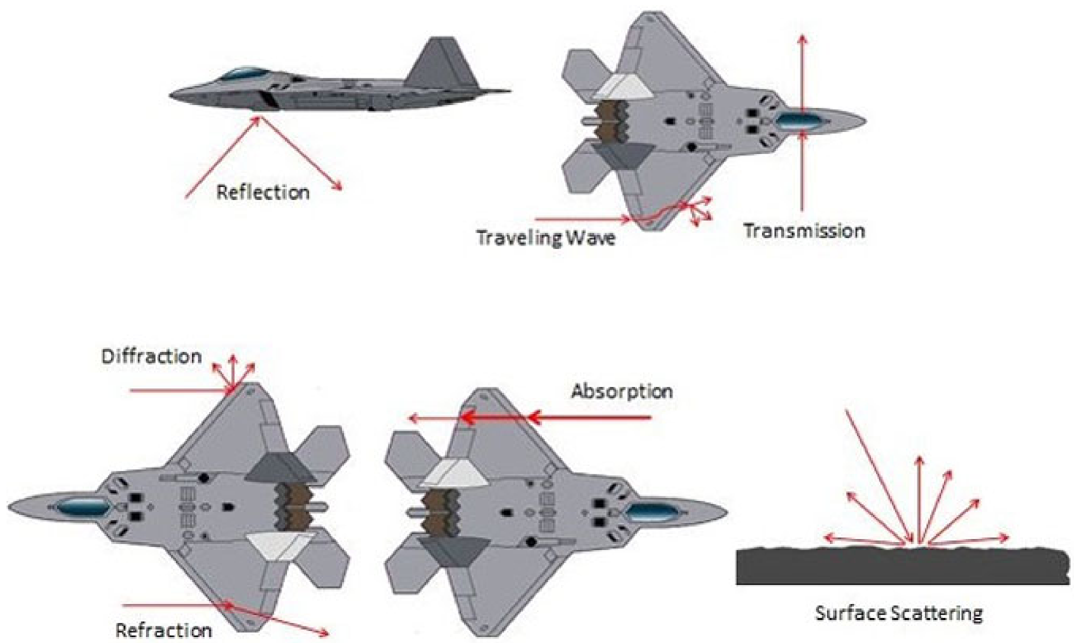

Figure 2–5. Wave interactions.

The six types of wave interactions include reflection, transmission, traveling, refraction, diffraction, and absorption, all of which are discussed in the following paragraphs.

Reflection

A reflective wave occurs when the energy bounces off the object. It is similar to light bouncing off of a mirror. Two primary types of reflective returns are *specular* and *multibounce* returns.

Specular

Specular returns are caused by EM energy returning at or near right angles to where it originated. A specular return can be to either a radar site or a transmitter receiver and is the most dangerous type of return.

Multibounce

Multibounce return occurs when the EM wave bounces off one or more surfaces and is eventually reflected back to where it originated.

Transmission

A transmission wave is a wave that passes through the body and is similar to light passing through a window.

Traveling

Traveling waves are created by EM energy creeping across the surface of the object until the energy dissipates into free space or is diffracted. This type of return is considered a nonspecular return.

Refraction

Refraction is when the direction of the energy wave is changed or bent by going from one media to another. An example is when you put a pencil in a clear glass of water. When you look at it from the side, the pencil appears bent. This is caused by a change in the density of the medium through which the waves are passing. In this case, water is denser than air.

Diffraction

Diffraction is a change in the direction and intensity of a group of waves after the waves pass by an obstacle or through an aperture.

Absorption

Absorption occurs when energy is absorbed by the object and is converted to heat. An example of absorption is a microwave oven that bombards the food with microwaves. The food absorbs and converts the waves to heat, which cooks the food.

Reduction strategies

Engineers use a variety of strategies to help reduce an aircraft's overall signature. As a maintainer, you will need to be familiar with the different strategies so that you can do your part to ensure each approach is adhered to in the maintenance and repair of the aircraft.

Shaping

The most important factor for RCS reduction is the shape of the object. Using RAM and RAS is the most familiar means of RCS reduction; however, it is less important than shaping. The idea behind shaping is to reflect radar energy away from the radar source. Various design characteristics can be used to reduce the RCS of an aircraft.

The design strategies for LO aircraft are to shape the aircraft and components to take advantage of features that have low-radar backscatter potential. Flat surfaces that make 90° corners are called *corner reflectors*; these give off the largest RCS. In most aircraft, the empennage (tail) and wings form corner reflectors with the fuselage. Reduction of corner reflectors is why stealthy aircraft have fewer surfaces that are perfect horizontals and verticals. Once all of 90° corners are eliminated, flat surfaces are oriented to deflect radar energy in a direction other than back to the source. This is called *faceting* and is an important feature that Lockheed Martin incorporated into the design of the F–117 (fig. 2–6).

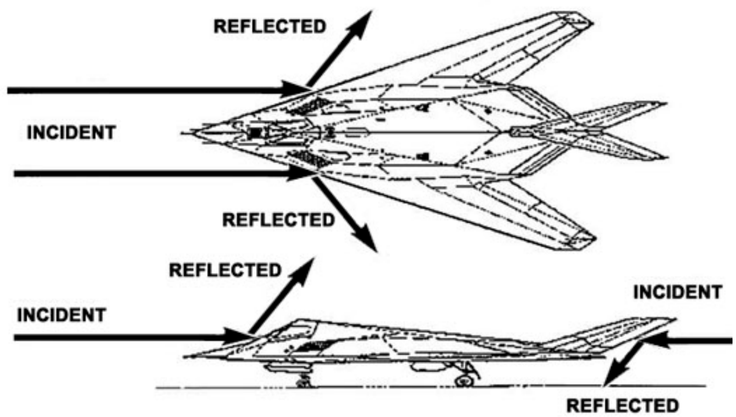

Figure 2–6. F–117 RCS reduction by shaping.

Engineers design aircraft in which they replace straight edges with highly contoured surfaces to redirect energy. This highly contoured approach is an important feature that Northrop Grumman incorporated into the design of the B–2 (fig. 2–7). Stealth-shaping strategy keeps energy concentrated in well-defined areas around the aircraft by aligning all aircraft details with outer-mold lines of the aircraft shape. This is called *planform alignment*, which will be discussed in the next unit.

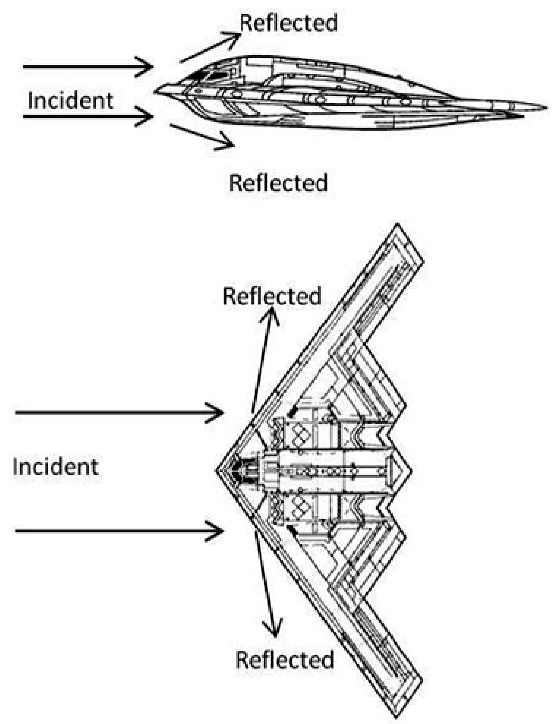

Figure 2–7. B–2 RCS reduction by shaping.

RAM and RAS

The use of RAM and RAS is an important part of reducing the overall RCS of an aircraft. Absorbing materials that have varied electrical properties must have the ability to weaken, absorb, or dissipate different types of radar energy. Different absorbing materials are used not only on the surface of the aircraft but also on the internal components.

Visual reductions

Reducing the visual signature of an aircraft is a multistep process. First, we need to reduce visual contrast. This is primarily accomplished through the use of paint schemes and shaping. Aircraft are painted colors that correspond with their primary missions. If an aircraft flies primarily at night, then the aircraft would be painted a dark or black color. Aircraft that fly primarily during the day would have a lighter paint scheme to reduce contrast with the sky.

Visual contrast is reduced by shaping the aircraft to make it difficult to see from certain angles. A perfect example of this is the B–2, which is very difficult to see if you are looking directly at the nose of the aircraft while it is flying—it has a very thin profile design.

Second, designers need to be concerned with *glint*, which occurs when light reflects off of the surface of the aircraft. To overcome glints, aircraft are painted with nonreflective coatings. To overcome glints off of the aircraft canopies and formation lights, they are covered with special types of coatings. One such coating is indium tin oxide (ITO). Being electrically conductive and optically transparent, ITO helps transfer EM energy without backscatter while still allowing the pilot to see.

Third, contrails and engine smoke give off a significant visual signature. Contrails are formed when warm, moist air drops in temperature below the ambient air temperature. Mixing outside air or bleed air with the engine exhaust can reduce the exhaust temperature, which, in turn, reduces the probability of contrails when flying at high altitudes. Engine smoke has been virtually eliminated through the use of highly efficient engines.

IR reductions

All aircraft emit some IR signature, and it is vitally important to reduce that signature as much as possible. If the IR signature is not masked or diminished, it may be possible to track stealth aircraft using IR equipment or IR guided missiles. The primary IR sources are the engines. Through the use of shielding, active or passive cooling, and special materials and coatings to absorb or reflect and dissipate the emissions, it is possible to diminish the IR signature.

Aircraft shaping can also be used to diminish or reduce the IR signature. On the B–2 and F–22, the engines are buried in the fuselage, and the intakes are specifically designed (fig. 2–8) to help dissipate the heat.

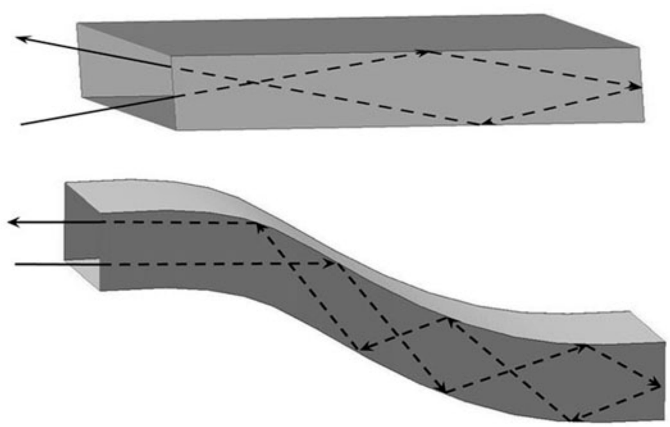

Figure 2–8. Standard and serpentine inlets.

Radio frequency emission reduction

Radio frequency (RF) emissions can be reduced by design and by tactics. The aircrews' operational tactics, such as not using transmitters or lighting unless it is mission essential, play a large role in reducing RF emissions. From a design perspective, unintentional RF emissions can be controlled by shielding onboard electronics, by using fiber optics rather than copper wire, and by using RAM in avionics bays.

Acoustic reductions

Reducing aircraft inlet and exhaust noise is the goal of acoustic reduction. The B–2, for example, has its engines located deep in the fuselage to reduce inlet noise. Additional structural design features are also implemented in LO aircraft to reduce noisy airflow and reduce the amount of vibration given off by the airframe and the exhaust areas. Some aircraft are designed to lower the dBs the engine exhaust produces.

413. Inspection principles

As an LO maintainer, it will be your responsibility to ensure the radar-absorbent coatings and structures are properly inspected and maintained. Various techniques are used to inspect the different LO properties. Inspection techniques range from simple visual inspections to complex electrical testing using state-of-the-art equipment.

Purpose of inspections

The basic purpose behind inspecting an LO process is to ensure all LO coating systems are working as intended. Aircraft inspections are conducted to identify any defects that may affect RCS, as well as defects in structural areas, including corrosion. Inspections are conducted at specific intervals, depending on specific aircraft requirements. For example, the F–22 is inspected after the last flight of the day. Of course, if damage or defects are noted, the aircraft will also be inspected before the specified interval.

Conducting inspections

Visual inspections are used extensively to assess the LO integrity. As an inspector, you will be looking for some of the following things:

- Coating defects.
- Missing material.
- Disbonded material.
- Tip breaks or coating damage along the edge of a panel.
- Cracks in the coatings.

While you will be looking for new damage, you will also look for further deterioration or continued expansion of existing damaged areas. You will mark the damage to allow easy identification during subsequent inspections.

As you locate the damage, you will record information such as the location, length, width, depth/height, orientation, and classification of damage. This information will be loaded into a database that calculates the RCS impact to the aircraft. The database is used to prioritize maintenance actions, based on the biggest RCS deficiency.

Each weapon system has its own LO maintenance assessment system for evaluators to enter material damages; these assessment systems provide feedback on the degradation of the RCS and facilitate the prioritizing of all repairs. It is vital that the evaluator ensures all damage information inputs are precise. The accuracy of the data input by the technician determines if the LO system is mission capable. Refer to the following table for a description of the different systems.

Aircraft	Assessment System	Description
B–2	Inspection management system (IMS)	Used as the maintenance assessment system in assessing the LO discrepancy write-ups, prioritizing maintenance workload, and providing an estimate of the aircraft signature for mission readiness assessments.

Aircraft	Assessment System	Description
		IMS works in conjunction with the MAPPER program/system to calculate how the damage affects the RCS.
F–22	Signature assessment system (SAS)	Used for monitoring F–22 health and signature status of each aircraft. SAS is the application and functionality that evaluates the signature impact of damages and repairs to the OML on the aircraft. An inspector enters data into the program; the system calculates and determines whether the aircraft is within its allowable maintenance margin and provides an estimation of points gained from possible repairs for a prioritization of repairs.
F–35	Low observable health assessment system (LOHAS)	Used to determine F–35 signature health and prioritize maintenance. The sole purpose is to determine whether the aircraft is fully mission capable (FMC) or nonmission capable (NMC). If the weapon system is NMC, LOHAS provides tasks to the maintainer that need to be repaired to make it FMC.

LO inspection tiers

There are multiple methods used for material defect inspection of LO aircraft. Each method is classified by *tiers*, which are numbered 0 to V (fig 2–9). The most common method of LO inspection is the visual inspection. How often inspections are conducted depends on the aircraft-specific TMs. The inspection system of each aircraft is a unique evaluation system and includes documenting any new discrepancies noted during inspection and annotating them in the aircraft forms and/or entering them into an assessment system. The discrepancies are commonly marked on the aircraft, though methods differ among weapon systems.

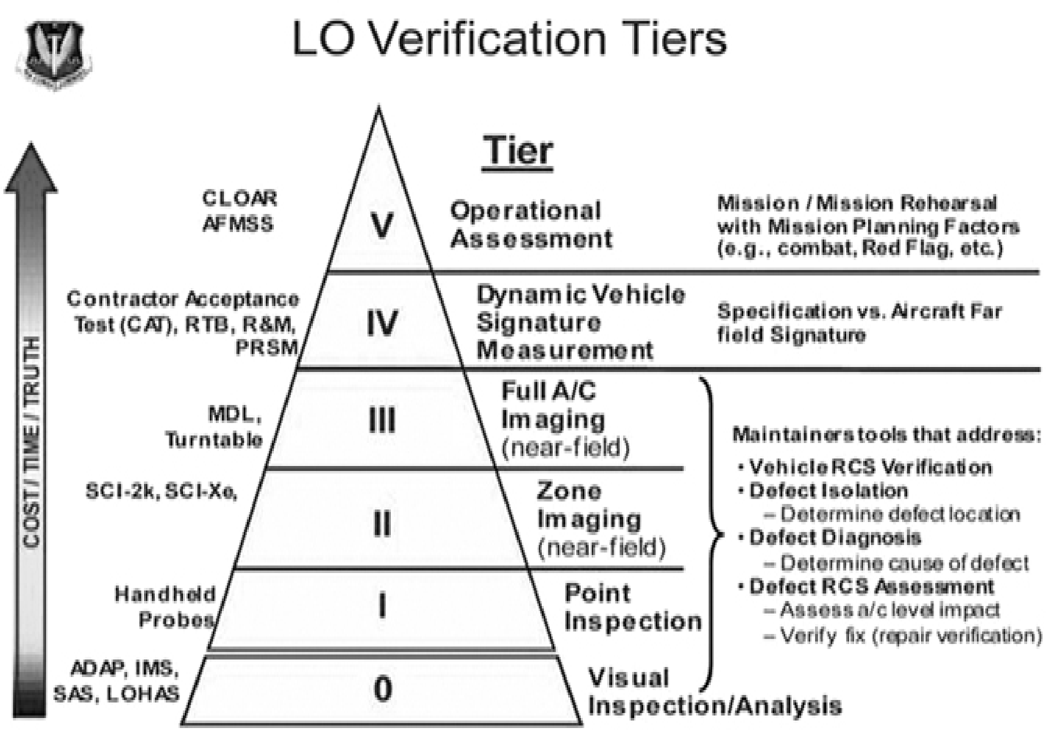

Figure 2–9. LO inspection tiers.

Tier 0

This consists of a visual inspection of the aircraft's LO coatings by a trained and qualified technician IAW its weapon-specific TO. Depending on the airframe, defects may be marked on the aircraft, recorded on aircraft forms, entered into an assessment system to determine the overall LO health of the aircraft, or all of the above.

Tier I

Tier I uses handheld point inspection tools (fig 2–10) to verify the integrity of the individual layers of LO materials. When used, these tools can identify proper placement of certain materials, as well as show degradation on some components, such as canopies and light lenses. The frequency of these inspections varies from airframe to airframe, as well as local operating procedures. Always use equipment only prescribed in the weapon system-specific TM.

MCP-T350 PAINT PROBE REFLECTOMETERS

Figure 2–10. Tier I inspection tools.

Tier II

Tier II inspections refer to zonal imaging. These inspections are performed with larger, more complex measurement equipment called a Repair Verification Radar (RVR). During a Tier II inspection, radar images are collected of small portions or zones of the aircraft. These radar measurements are also helpful in determining the integrity of a fresh coating repair and can reveal defects not visible to the human eye.

Tier III

This is a whole-body near-field aircraft measurement (fig. 2–11). Tier III imaging can be collected while the aircraft is in a static or dynamic state. If the collection is completed while the aircraft is static, shrouds are used to cover any part of the aircraft which cannot be placed in a flight representative condition (e.g., landing gear, hoist points, and fixtures) to prevent image contamination. Some airframes may require other support equipment to zero out flight controls.

Figure 2–11. Tier III inspection

Certain limiting factors apply to Tier III measurements, which typically include weather conditions, wind speed and direction, and site condition. A large area known as the radar site is required for whole-body radar imaging; it facilitates room for the radar equipment to move around the aircraft. In some instances, the radar is stationary and the aircraft is parked on a rotating surface, or turntable. These measurements provide a much broader picture of the aircraft and are very helpful in discovering problem areas and their causes.

Tier IV

Tier IV is a dynamic far-field whole-body RCS measurement often referred to as “flying the range.” This inspection provides real world data, a true RCS measurement of the aircraft. During a tier IV inspection, while in flight, inspectors are using radar to determine the actual aircraft RCS.

Tier V

Tier V is an operational assessment of aircraft and their respective signatures for mission-planning purposes. While this data is collected in a tier IV inspection, it is used in tier V to arrange aircraft by “ranking” them in order of which LO signatures provide the best aircraft for the mission requirements.

The bottom line regarding LO aircraft inspections is that if the aircraft are not inspected and maintained properly, they will lose their stealth capabilities. Even the smallest break in the chain of processes can allow the aircraft to be “seen,” which would put the mission and flight crew in jeopardy.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

411. Aircraft signature sources

1. What is a signature source?

2. Match the signature in column B with its source in column A. Items in column B may only be used once.

Column A	*Column B*
____ (1) Noise from the engines.	a. Visual.
____ (2) Energy escapes avionics bays and communication systems.	b. IR.
____ (3) Skin heating and exhaust.	c. Acoustic.
____ (4) Contrails, glints, engine smoke and paint scheme.	d. Radio emissions.

412. Signature reduction techniques

1. When designing LO aircraft, what are the seven main areas that must be considered?

2. What is a key determinant on whether an aircraft is LO?

3. What is the RCS of an object a critical factor in determining?

4. Match the type of wave interaction in column B with when it occurs in column A. Items in column B may only be used once.

Column A	*Column B*
____ (1) EM energy creeping across the surface of an object until it dissipates into free space.	a. Reflection.
____ (2) Energy is absorbed by an object and converted to heat.	b. Transmission.
____ (3) Direction of the energy wave is changed or bent by going from one media to another.	c. Traveling.
____ (4) Energy bounces off of an object.	d. Refraction.
____ (5) A wave that passes through a body.	e. Diffraction.
____ (6) A change in direction and intensity of a group of waves after they pass by an obstacle or through an aperture.	f. Absorption.

5. What is the most important factor for RCS reduction?

6. Which kind of reduction strategy is an aircraft's painting that corresponds with its primary mission?

7. What is it called when light reflects off the surface of the aircraft?

8. What is the primary source of an aircraft's IR signature?

9. How may an aircraft's IR signature possibly be reduced?

10. In addition to shielding onboard electronics and using fiber optics instead of copper wire, how can the RF emissions signature be reduced?

11. What is the goal of acoustic reduction?

413. Inspection principles

1. What is the basic purpose behind inspecting an LO process?

2. Why are aircraft inspections conducted?

3. In addition to looking for new damage during an inspection, what else will you be looking for?

4. During an inspection, what six things will you record when looking for damage?

5. What is the most common type of LO inspection?

6. What inspection tier collects radar images of small portions or zones of the aircraft?

Answers to Self-Test Questions

408

1. A series of processes that give an object the ability to defeat radar, thermal, acoustical, and visual detection.
2. The ability to defeat various detection methods.
3. The use of advanced composite materials on the B–1 bomber.

409

1. Radio Detection And Ranging.
2. A system made up of a transmitter and receiver designed to detect and locate a target.
3. The detection and location of objects.
4. Microwaves or radio waves.
5. What type and how much information is collected and processed.
6. RCS, speed, location, and direction.

410

1. The EM energy returned to the radar antenna.
2. The cross-sectional area of a conductive sphere that would reflect as much energy as the object in question; essentially, the size of the object as measured by radar.
3. Azimuth, elevation, frequency, and polarization.
4. Square meters and converted to dBsm.
5. A mathematical transformation of numbers into quantities that can be easily understood.

411

1. A characteristic of an object that can be detected by visual or mechanical means.
2. (1) c.
   (2) d.
   (3) b.
   (4) a.

412

1. Shaping, use of RAM, RAS, visual, IR, electronic emission, and acoustic reduction.
2. The size of its RCS.
3. How close you can be to a radar system before the system can detect you.
4. (1) c.

(2) f.

(3) d.

(4) a.

(5) b.

(6) e.

5. The shape of the object.
6. Visual reduction.
7. Glint.
8. The engines.
9. Through the use of shielding, active or passive cooling, and special materials and coatings to absorb or reflect and dissipate emissions.
10. By using RAM in avionics bays.
11. Reducing aircraft inlet and exhaust noise.

413

1. To ensure all LO coating systems are working as intended.
2. To identify any defects that may affect RCS, as well as defects in structural areas, including corrosion.
3. Further deterioration or continued expansion of existing damaged areas.
4. Location, length, width, depth/height, orientation, and classification of damage.
5. Visual.
6. Tier II.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

27. (408) Low observable (LO) technology gives an aircraft the ability to defeat radar, thermal, acoustical,
    a. and x-ray detection.
    b. and visual detection.
    c. x-ray and visual detection.
    d. and magnetic particle detection.

28. (408) The main purpose of making an aircraft low observable (LO) is to increase the aircraft's
    a. performance.
    b. survivability.
    c. range.
    d. speed.

29. (409) The acronym RADAR stands for
    a. response determinate aircraft rejuvenation.
    b. reactionary algorithm data response.
    c. random determinant analog review.
    d. radio detection and ranging.

30. (410) What is radar cross section (RCS)?
    a. How an object sounds on radar.
    b. One half of an objects signature on radar.
    c. The inside signature of an object on radar.
    d. The size of an object as measured by radar.

31. (410) Radar cross section (RCS) is typically measured in square
    a. meters.
    b. inches.
    c. yards.
    d. feet.

32. (411) Condensation trails, glints, and paint schemes are sources of which radar signature?
    a. Visual.
    b. Infrared.
    c. Acoustic.
    d. Electrical.

33. (411) What type of aircraft signature source is generated by energy backscatter?
    a. Numeric continuity.
    b. Radar cross section.
    c. Sound dispersal.
    d. Sonic vibration.

34. (412) What is the *most* important factor for radar cross section (RCS) reduction of an object?
    a. Speed.
    b. Agility.
    c. Shape.
    d. Color.

35. (412) Which reduction strategy uses painting an aircraft to match its primary mission?
    a. Visual.
    b. Infrared.
    c. Shaping.
    d. Acoustic.

36. (413) When you locate damage during an inspection, you will record length, width, depth/height, classification, and
    a. grouping.
    b. expansion.
    c. orientation.
    d. progression.

37. (413) What low observable (LO) verification tier is a whole body near field measurement?
    a. 0.
    b. I.
    c. II.
    d. III.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Low Observable Layout and Material

3–1. Low Observable Material Layout **3–1**
414. Layout techniques 3–1
415. Planform alignment 3–2
3–2. Low Observable Material Identification **3–7**
416. Radar-absorbent structure 3–7
417. Conductive and nonconductive materials 3–8
418. Radar-absorbent material 3–9
419. Resistive sheet 3–10
420. Sealants and fairing and filler materials 3–10

ONE OF THE MOST important steps in any process you do is the prep work. The ability to choose the correct materials for the job you are doing and knowing how to develop the layout for the new pieces you are making is vital in any project. In this unit, we are going to dive into the fundamentals of layout and the differences in the LO materials and coating you will be using.

We will begin this unit by showing you several layout techniques and discussing the principals of planform alignment. We will then discuss the various LO materials and how to identify them. Lastly, you will learn about the characteristics of radar-absorbing structures and material, conductive and nonconductive materials, resistive sheets, sealants, and fairing and filler material.

3–1. Low Observable Material Layout

The first step in the LO material application process is a well-thought-out and well-planned design. Whether you are performing a sheet metal, composite, corrosion, or LO materials repair, a good, solid layout is the foundation for any sound repair. Along with an effective layout, a planform alignment is required on all repairs and modifications; it is essential to reduce the frontal radar return.

414. Layout techniques

Many of the repairs you will be making to LO materials will have complex shapes that you must layout. Most of the time when you are developing these repairs, you will have to use a template to get the correct shape. Using material that is being removed is the simplest way to make a template. If that is not possible, another method is to place a clear template material, such as Mylar, over the repair area and trace the required shapes, and mark the cutting lines with an appropriate marking pen.

One of the most utilized methods to make a template is to use masking or Mylar tape. The process is fairly simple; you cover the repair area with tape, using the edges of the tape as your straight lines. Once the area is completely covered, you then remove the tape from the aircraft. After placing the tape on your repair material, you will use your tape as a guide to cut out the repair material in the precise shape.

It is vital to ensure angles are correct when creating templates; as a result, the use of a protractor to verify correct angles is often necessary as repair planform alignment is essential (fig. 3–1).

Simply stated, the purpose of a protractor is to measure or create an angle. A variation of this is the bevel protractor that has a pivoted arm and is used for marking and measuring angles. Keep in mind that the templates you create may contain angles that coincide with the classified aircraft angles. In this event, you must safeguard the templates and dispose of them IAW the proper classification guidance.

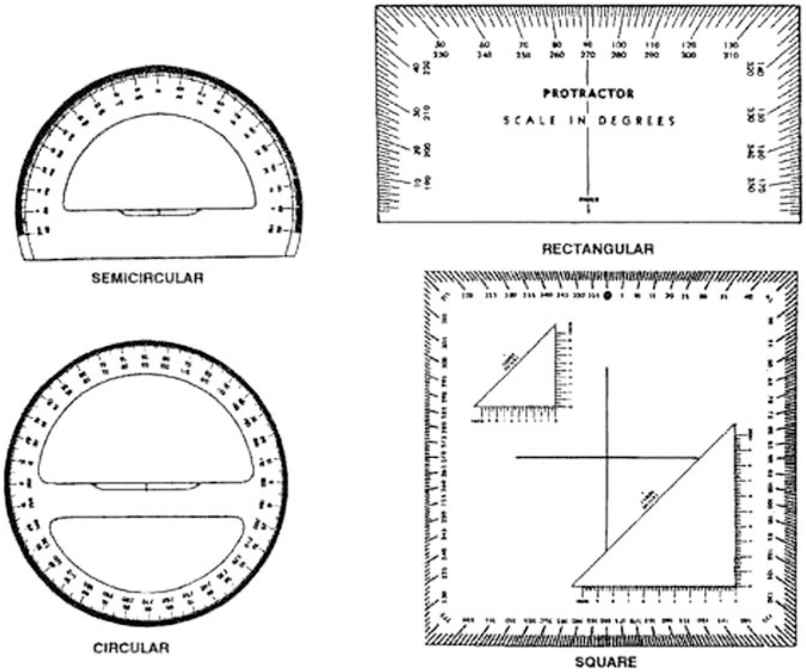

Figure 3–1. Protractors.

Straight lines are also important when creating both templates and cutting RAM, as well as other coatings. The best way to get a straight line is to use a straight edge. Almost anything can be used to draw or cut a straight line as long as it has a true straight edge. However, when selecting a material to use as a straight edge, ensure you choose a material that has an edge that cannot easily be deformed or cut. When cutting RAM, it is typically best to use a steel rule as it cannot be cut by the blades used to cut LO tape or boot layers.

415. Planform alignment

Keeping energy concentrated in well-defined spatial aspects is a key consideration during the design of stealth aircraft. Planform alignment (fig. 3–2) is one method used to concentrate energy and is incorporated into the early stages of the development. *Planform alignment* is defined as aligning all vehicle details (fig. 3–3) with the OML angles of the aircraft. It is a design strategy that is intended to reduce the frontal radar return through careful management of radar deflection angles. By using consistent geometry, engineers are able to deflect radar energy into tight, focused, and predictable directions away from the radar source. The planform alignment of the structure is vital and needs to be carried through on all repairs and modifications.

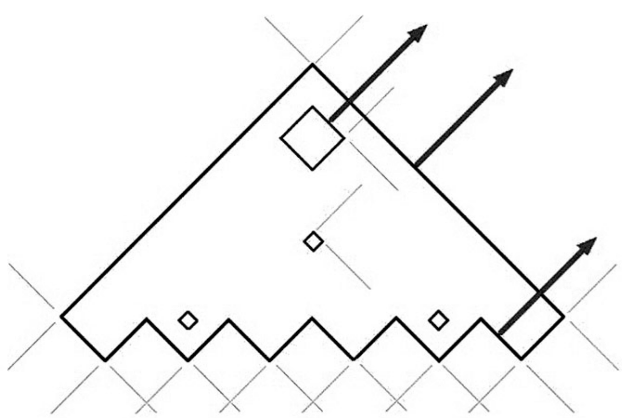

Figure 3–2. Planform alignment.

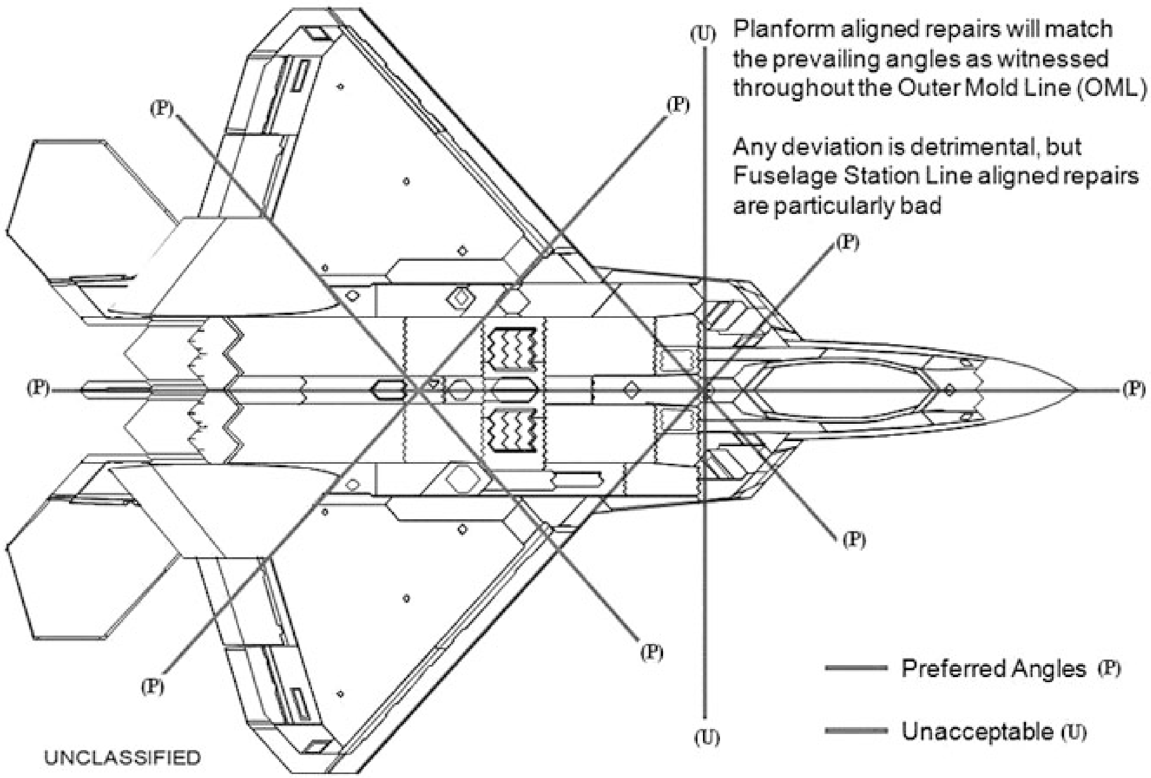

Figure 3–3. Aligning vehicle details with OML.

Although planform alignment angles vary from platform to platform, all LO platforms use it to prevent the radar energy bouncing back to a receiver. In fact, planform alignment is the most distinguishing visual characteristic of LO aircraft. Strong angularity and sharp creases throughout the design of the aircraft, as well as saw-tooth and arrowhead panel/door edges, are all characteristics of an LO aircraft. Panels, wings, tail sections, and other structures on a LO platform all use planform alignment to lower the RCS impact. Most planform alignment angles are going to be determined by the design of the aircraft and will be classified.

Individual LO material repairs, when performed correctly, generate a minimal RCS impact. However, the cumulative effect of incorrectly performed repairs can have a negative effect on the overall “LO health” of the aircraft. Most electrically conductive coatings require planform-aligned edges; as an LO maintainer, it will be your responsibility to ensure that repair edges are consistent with planform alignment angles to minimize the impact of the LO repair.

As with all repairs, the first step in an LO repair is to research the damaged area; afterwards, you can lay out the repair. There are many different shapes that can be used to configure a planform-aligned repair. Parallelogram (fig. 3–4), trapezoid (fig. 3–5), single-fastener diamond, and saw-tooth shapes (fig. 3–6) are commonly used to match aircraft angles. Saw-tooth shapes are widely used because they allow for smaller repair areas. When developing repairs in planform alignment, it is important to pay particular attention to the butt line and station lines of the aircraft. Aligning the repair with the aircraft butt line allows for a good planform alignment; however, any alignment with a station line is particularly bad and should always be avoided. Figure 3–7 shows some of the alignment options that are available during repair, whereas figure 3–8 shows some instances of improper alignment.

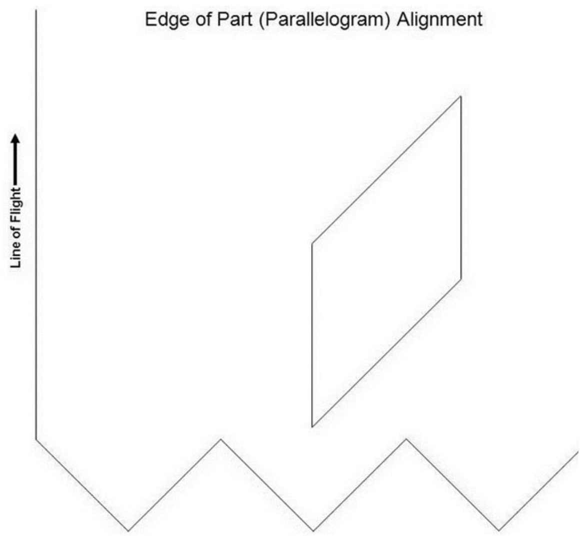

Figure 3–4. Parallelogram alignment.

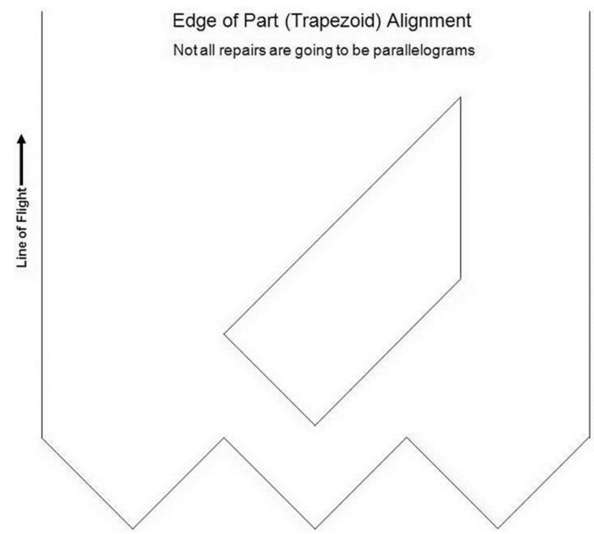

Figure 3–5. Trapezoid alignment.

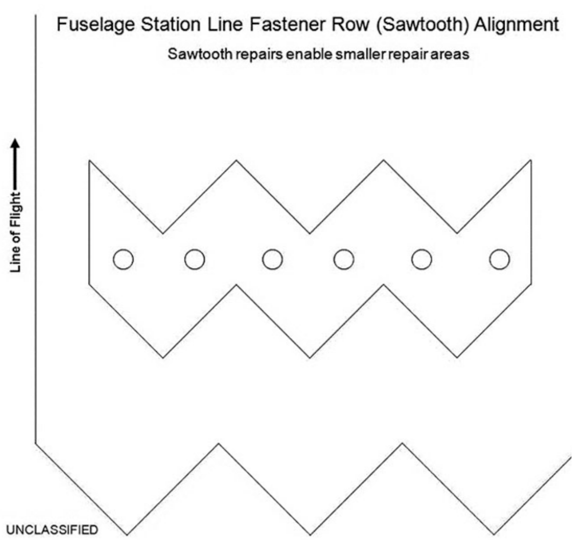

Figure 3–6. Saw-tooth shape alignment.

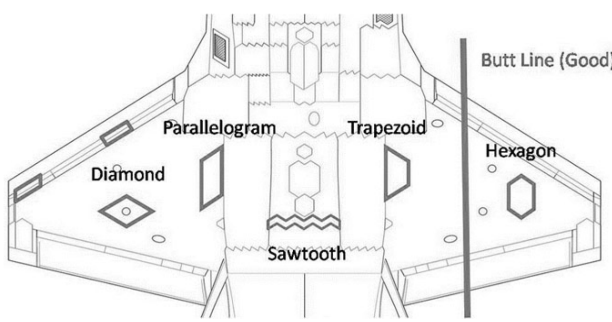

Figure 3–7. Alignment options.

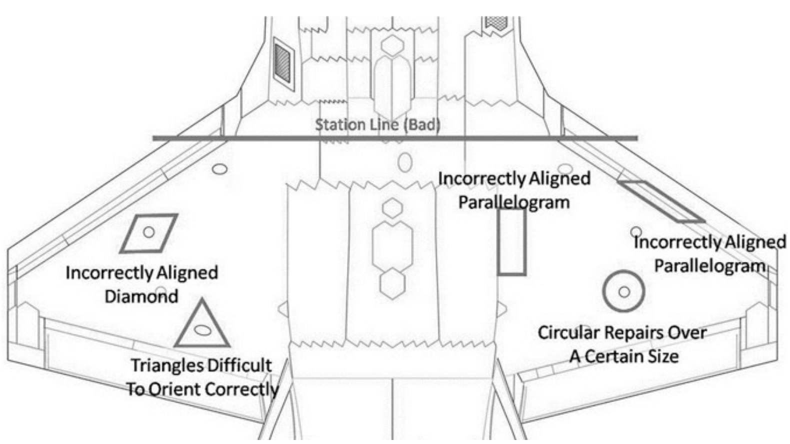

Figure 3–8. Improper alignment.

Opposite-wing alignment and edge of part are two common planform methods you may use to obtain the shapes just referred to.

- Opposite-wing alignment refers to using the leading edge angle of the nearest wing and the opposite wing as reference for alignment.
- Edge of part refers to using the edge of the part that you are repairing as a guide for alignment.

To use the edge-of-part method, simply measure equal distances from the panel edges to the edge of the damaged coating, ensuring all sides are straight and all angles correctly mirror the components. You can use a protractor at this point to ensure your angles are precise. If you are unable to use the panel lines to obtain your planform alignment, you may have to use the opposite-wing–alignment (fig. 3–9) method, which uses major component angles, such as the leading edges. It is important to remember that the entire aircraft must be in planform alignment, and all angles must match to maintain continuity.

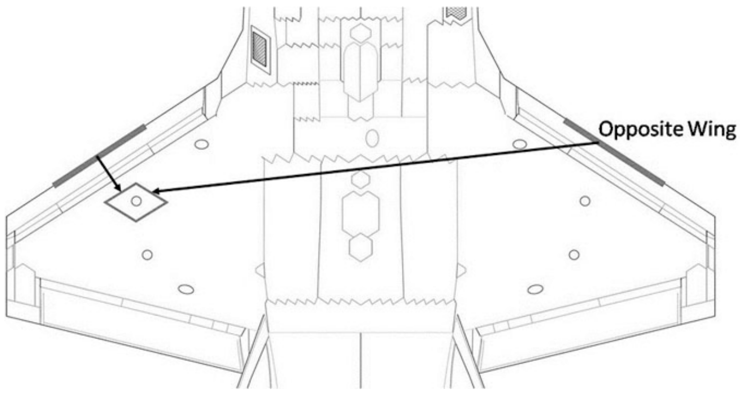

Figure 3–9. Opposite-wing alignment.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

414. Layout techniques

1. When developing a repair, how can you ensure that you get the correct layout shape?

2. Describe how to use clear template material.

3. What is the purpose of a protractor?

4. Why might you have to safeguard the templates that you make?

5. Why is a steel rule good to use as a straight edge?

415. Planform alignment

1. What is a key consideration during the design of stealth aircraft?

2. How is planform alignment defined?

3. Why do LO platforms use planform alignment?

4. What determines planform alignment angles?

5. What are four shapes that are commonly used to match aircraft angles?

6. Explain opposite-wing alignment.

7. Explain edge-of-part alignment.

8. Describe how to perform a planform alignment using the edge-of-part method.

3–2. Low Observable Material Identification

Invisible to the enemy! While there are a lot of factors that go into creating a stealth aircraft, aircraft structure and advanced materials are key components of LO technology. Within this section, we will discuss both structure as well as materials. In addition, we will describe sealants and filler materials that are used on the structure and materials to help ensure continued LO.

On stealth aircraft, LO materials must be treated and maintained as a system. The combination of inspections, evaluation, repair, and verification of each material ensures the integrity of the LO system and survivability of the aircraft. As an LO maintainer, you will need to be able to identify these materials.

416. Radar-absorbent structure

There are multiple ways to reduce the RCS of an aircraft. As we discussed earlier, both RAM and RAS are used to minimize the overall RCS of an aircraft. In this unit, we will discuss RAS, which is an important part of the RCS reduction equation.

RAS location

The RAS where radar energy will typically be concentrated is around the perimeter of the aircraft. RAS incorporates RAMs into the aircraft structure. This is an advantage over RAM because RAS also provides structural strength as well as RCS reduction; RAM on the other hand provides no structural benefits and adds weight to an aircraft. The areas that contain RAS include wing-leading edges, trailing edges, flight-control surfaces, and horizontal stabilizers.

RAS purpose

RAS is the bulk absorber of radar energy. These structures are made from composite materials with electrically resistive cores and densities.

The following three components make up an RAS (fig. 3–10):

- Radar-transparent skin.
- Loaded core.
- A reflector assembly.

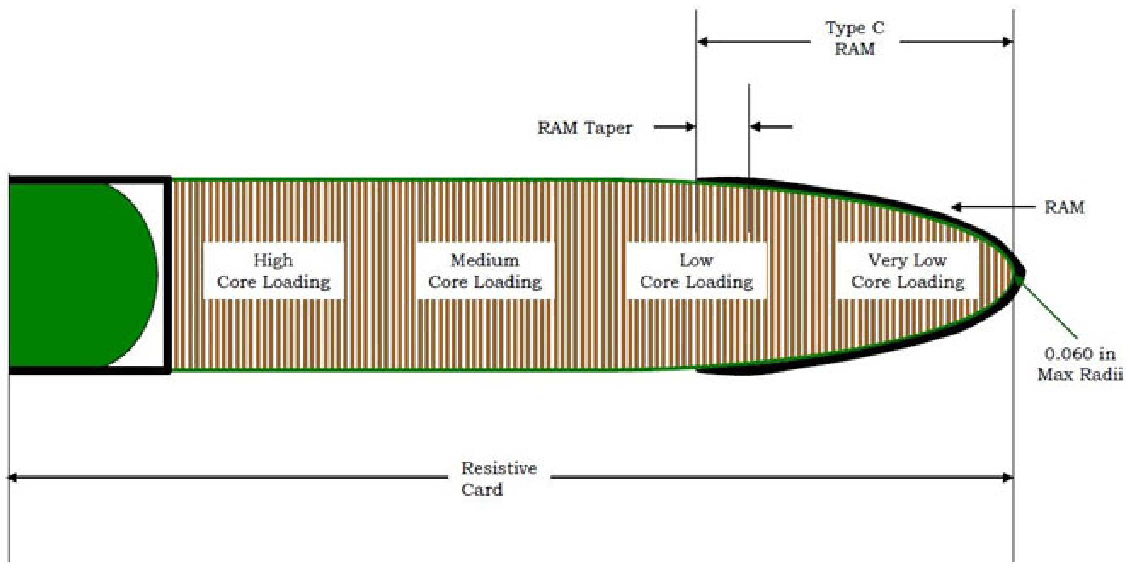

Figure 3–10. RAS components.

EM energy hits the radar-transparent skin and enters the loaded core, which has resistive properties that weaken the current entering through the skin. As the current travels through the core, it will hit a reflector assembly; the weakened current is then redirected back to the core and dissipates (fig. 3–11). The core is what provides compressive strength to the aircraft skin. Not all of the current passes through the skin; whatever current that does not enter the core is carried over the skin via the resistive card (R-Card).

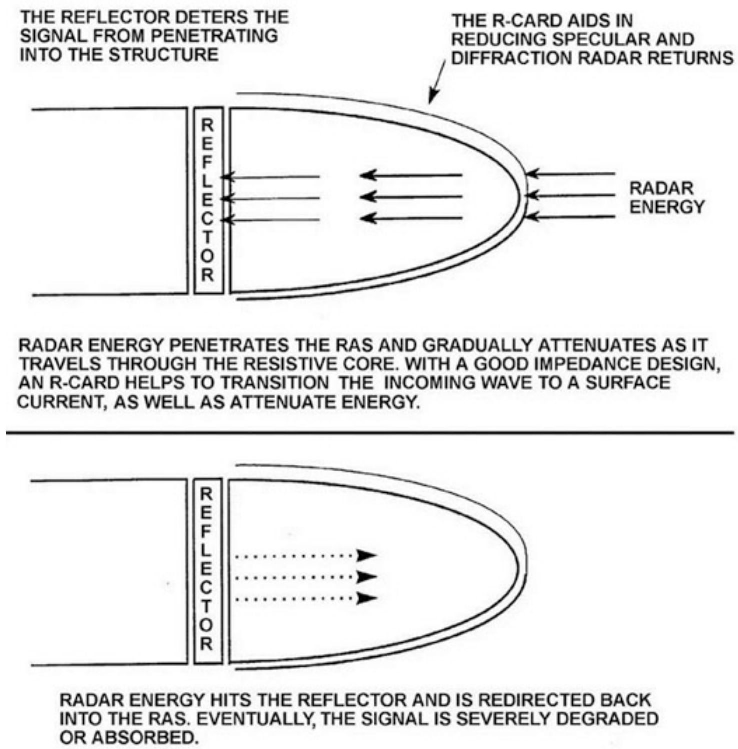

Figure 3–11. How RAS works.

417. Conductive and nonconductive materials

Within this lesson, we will discuss conductive and nonconductive materials that cover an LO aircraft. While we cannot discuss each one, LO aircraft utilize a variety of conductive and nonconductive materials. The metallic particles in the conductive layer are used to dissipate an energy current over the whole surface of the aircraft. Conductive materials also help to hide cavities, open spaces, anomalies, and gaps so that radar waves are not transmitted back to the receiver. These coatings usually contain high levels of very conductive material and can be applied to the surface or intertwined into the top layer of the composite panel. If the panel does not have this layer built into its matrix, it must be applied to the surface. The preferable method of conductive coating application is spray painting, but it can also be rolled or brushed on. Doors, access panels, canopies, fastener heads, inlets, and exhausts can create significant scattering sources if conductive coatings are not applied.

Stealth aircraft also employ several nonconductive materials. For the conductive materials to work properly, nonconductive materials must be correctly mixed, applied, and tied into the adjacent area to maintain continuity across the aircraft's surface. In addition to maintaining continuity, nonconductive materials are also used for corrosion protection. Due to the dissimilar metal potential with LO coatings, the use of a corrosion-inhibiting primer is employed to provide a barrier between conductive LO coatings and the metallic structure.

Composites and ceramics

Due to their light weight and strength, composite structures are becoming more and more prevalent in the aerospace industry. Although some composite materials can be conductive, LO platforms use composites because many are nonconductive and do not reflect radar energy, thus reducing the signature. However, underlying metallic assemblies can reflect radar energy; for this reason, most composite structures need an electrically conductive coating. As an alternative, composite manufacturers can embed electrically conductive material and design different geometries into the structure, lowering the signature of the airframe. Before starting any maintenance or repair process, it is important to consult technical drawings, weapon system-specific TMs, or engineering guidance to prevent unnecessary damage to an assembly.

Ceramics are used as heat shields for fire protection and to provide thermal insulation on aircraft. Ceramics are heat resistive, lightweight, and do not corrode; however, they are very brittle and have a tendency to crack and break. Other significant characteristics of ceramics include high-melting temperatures, tensile strength, and chemical inertness. Refer to technical drawings, weapon system-specific TM, or engineering guidance before starting any process to remove and repair ceramic material. Each weapon system has different tolerances and specifications that must be met.

ITO

ITO is one of the many conductive materials you will use. ITO is a transparent, conductive film that is applied to transparencies, such as windows, windscreens, navigational lenses, and marker lenses. This conductive film completes the conductive link from the OML across the transparency, while maintaining the highest levels of optical quality.

IR materials

IR materials, which may be conductive or nonconductive, are applied to an aircraft to reduce the overall thermal signature. Types of IR materials used in an LO shop are IR topcoat and primer. These topcoats are specially designed and mixed to control the IR signature of the aircraft.

418. Radar-absorbent material

RAM is a class of material used in stealth technology to disguise a structure from radar detection. Although no one RAM can perfectly absorb radar at all frequencies, some compositions have greater absorbency at some frequencies than at others. A material’s absorbency at a given frequency of radar wave depends on its composition and thickness.

Dielectric RAM

Dielectric RAM is designed to allow energy to pass through material. While doing so, the energy is absorbed and reduced, thus lowering the overall signature of the structure. This type of RAM can be made of carbon/graphite, silicon carbide micro balloons, carbon powder, or chopped fiber and other resistive materials. Its performance is based on the thickness, electrical loading, and type of dielectric material. It is lighter and less effective than magnetic RAM. Dielectric RAM is available in sheets, liquids (for spraying, brushing, and rolling applications), foams, and paste.

Magnetic RAM

Magnetic RAM, known as MAGRAM, boot, or iron-filled elastomer (IFE) is a special coating that uses iron fillers set in a binder material. It is designed to absorb, reduce, or direct the signature of the structure. It is made of carbonyl iron, powder ferrites, and other magnetic materials. MAGRAM converts radar energy into heat, which can be dissipated over the surface of the structure. MAGRAM is very heavy, and its performance is based on the thickness and the products from which it was made. It is available in sheets, liquids (for spraying, brushing, and rolling applications), foams, and pastes.

NOTE: The aircraft-specific TO will tell you which RAM to use; however, dielectric RAM and MAGRAM are *not* interchangeable.

419. Resistive sheet

The R-Card is typically placed on the leading and trailing edges of the perimeter of the aircraft. It transitions EM energy smoothly from a resistive body to a conductive body (fig. 3–12). R-Cards add resistance to the surface, usually by a thin sheet of resistance film or cloth. If cloth is used, it is impregnated with carbon or some other resistive material, also referred to as KAPTON.

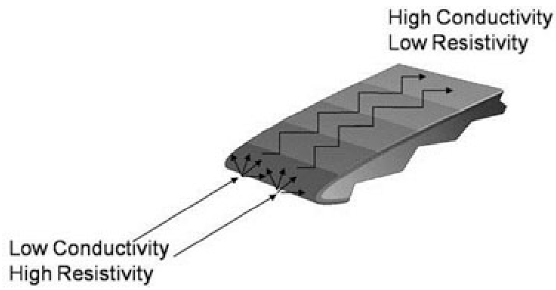

Figure 3–12. R-Card transition.

The R-Card typically has several resistive bands or is tapered from low resistance, nearly matching the conductive surface, to high resistance at the edge of the aircraft. Resistive materials are bonded to the OML surface of the RAS or are embedded between layers of radar-transparent composite materials, such as fiberglass skins.

420. Sealants and fairing and filler materials

Most LO designs are based on either a conductive or absorbing surface, where smoothness is critical and must be maintained. Conductive and absorptive sealants and fairing and filler materials are used to maintain these surfaces. For instance, the OML on the F–22 is conductive; as a result, all of the gaps must be filled with a conductive filler or caulk. The B–2 has conductive and resistive surfaces; therefore, the fillers and caulks will vary in electrical properties. These materials are installed in panel seams, fastener heads, void, and transition areas.

Sealants

We have already discussed the use of sealant in structural sealing. Sealants have a variety of uses on LO aircraft. As an LO maintainer, you will be required to use sealants to bond sheet RAM and tapes, install fasteners, seal nut plates, and use as a weather strip. Sealants may be conductive or nonconductive.

Most of the sealants used in LO are grey in color. This is a result of mixing a white base and a black accelerator. If too much accelerator is used, the end color will be black. This is referred to as mixing “hot.” This type of mix will result in premature bond failure. Too little of the accelerator will result in a light grey color and an uncured sealant.

Fairing and filler materials

Aircraft design is the basis for all LO aircraft; they are all designed to have smooth transitions to ensure proper aerodynamic flow. In addition to aerodynamics, the way radar waves hit a stealth aircraft is very important; if the entire surface is not smooth, a chance exists for detection. Fairing materials are used to provide a smooth transition between two surfaces that have a mismatched height, also known as a step condition. They are also used to fill gaps and voids in the OML. Filling these voids, and fairing a transition area, ensures radar waves can travel smoothly across the surface without providing any unnecessary EM return. Fairing materials may be conductive or nonconductive.

Some sealants provide a conductive path between conductive structural surfaces and panels for both gap and filler seal applications. When sealants are used in this manner, they are known as fillers, which work the same way as fairing materials when used to fill gaps.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

416. Radar-absorbent structure

1. Where is the RAS where radar energy will typically be concentrated around an aircraft?

2. What three components make up an RAS?

3. In an RAS, what gives compressive strength to the aircraft skin?

417. Conductive and nonconductive materials

1. What is the conductive layer applied to the surface of an aircraft used for?

2. What must happen to the underlying nonconductive materials for the conductive layer to work properly?

3. What is used as a barrier between LO coatings and metal structure?

4. What does a composite structure need to prevent underlying metallic assemblies from reflecting radar energy?

5. What are ceramics used for on aircraft?

6. What are three advantages of using ceramics on aircraft?

7. Why is ITO applied to transparencies?

8. What is applied to the surface of the aircraft to reduce the overall thermal signature?

418. Radar-absorbent material

1. What is RAM used for in stealth technologies?

2. What is dielectric RAM performance based upon?

3. In what forms is dielectric RAM available?

4. What is MAGRAM?

419. Resistive sheet

1. Where on an aircraft are resistive sheets typically placed?

2. What does the resistive sheet do?

420. Sealants and fairing and filler materials

1. As an LO maintainer, what will you be required to use sealants for?

2. What will be the result of a "hot" sealant mixture?

3. What is the purpose of fairing materials?

Answers to Self-Test Questions

414

1. By using a template.
2. Place it over the repair area, trace the required shapes, and mark the cutting lines with an appropriate marking pen.
3. To measure or create an angle.
4. They may contain angles that coincide with classified aircraft angles.
5. It cannot be cut by the blades used to cut LO tape or boot layers.

415

1. Keeping energy concentrated in well-defined spatial aspects.
2. Aligning all vehicle details with the OML angles of the aircraft.
3. To prevent radar energy bouncing back to a receiver.
4. The design of the aircraft.
5. Parallelogram, trapezoid, single-fastener diamond, and saw tooth.
6. Refers to using the leading edge angle of the nearest wing and the opposite wing as reference for alignment.
7. Refers to using the edge of the part that you are repairing as a guide for alignment.
8. Measure equal distances from the panel edges to the edge of the damaged coating, ensuring all sides are straight and all angles mirror the components.

416

1. Around the perimeter of the aircraft.
2. Radar-transparent skin, loaded core, and reflector assembly.
3. The core.

417

1. To dissipate the current over the whole surface of the aircraft.
2. They must be correctly mixed, applied, and tied into the adjacent area to maintain continuity across the aircraft's surface.
3. A corrosion-inhibiting primer.
4. An electrically conductive coating.
5. As heat shields for fire protection and to provide thermal insulation.
6. They are heat resistive, lightweight, and do not corrode.
7. It completes the conductive link from OML across the transparency, while maintaining the highest levels of optical quality.
8. IR materials.

418

1. To disguise a structure from radar detection.
2. The thickness, electrical loading, and type of dielectric material.
3. Sheets, liquids, foams, and pastes.
4. Magnetic RAM and is a special coating that uses iron fillers set in a binder material.

419

1. The leading and trailing edges of the perimeter of the aircraft.
2. It transitions EM energy from a resistive body to a conductive body.

420

1. To bond sheet RAM and tapes, install fasteners, seal nut plates, and use as a weather strip.
2. A premature bond failure.
3. To provide a smooth transition between two surfaces that have a mismatched height, also known as a step condition.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

38. (414) During a repair layout, what tool would you use to create or measure an angle?
    a. Clinometer compass.
    b. Inclinometer.
    c. Protractor.
    d. Square.

39. (414) The *best way* to create a straight line when cutting radar absorbant material (RAM) is to use a
    a. square.
    b. steel rule.
    c. beveled edge.
    d. rectangular straight edge.

40. (415) Arranging all aircraft details so that they coincide with the outer mold line (OML) angles of the aircraft is called
    a. freeform construction.
    b. contour development.
    c. planned engineering.
    d. planform alignment.

41. (415) What alignment shape is widely used because it allows for smaller repair areas?
    a. Rectangle.
    b. Saw-tooth.
    c. Trapezoid.
    d. Parallelogram.

42. (415) When developing a repair in good planform alignment, you would align your repair with the aircraft
    a. empennage line.
    b. fuselage line.
    c. station line.
    d. butt line.

43. (416) What do the resistive properties of the loaded core of a radar-absorbing structure (RAS) do to the electromagnetic (EM) energy entering it?
    a. Strengthens it.
    b. Replicates it.
    c. Weakens it.
    d. repulses it.

44. (417) Dissipating an energy current over the whole surface of the aircraft is purpose of the
    a. reactive layer.
    b. recitation layer.
    c. condenser layer.
    d. conductive layer.

45. (417) A corrosion-inhibiting primer is recommended to be used as a barrier between low observable (LO) coatings and metal structure because of
    a. asymmetric metal potential.
    b. dissimilar metal potential.
    c. similar metal potential.
    d. concurrent layer.

46. (417) Low observable (LO) platforms use composite materials because they *do not* reflect radar and are
    a. reactive.
    b. conductive.
    c. suppressive.
    d. nonconductive.

47. (417) Ceramics are used as insulation on aircraft because they *do not* corrode, are heat resistant, and
    a. immalleable.
    b. inexpensive.
    c. lightweight.
    d. conductive.

48. (418) A radar-absorbing materials' (RAM) absorbency at a given frequency depends on its thickness and
    a. complicity.
    b. composition.
    c. compunction.
    d. compurgation.

49. (418) A dielectric radar-absorbing materials' (RAM) performance is based on the type of dielectric material, electrical loading, and
    a. thickness.
    b. weight.
    c. width.
    d. color.

50. (419) What type of sheet is an R-Card?
    a. Attractive.
    b. Assistive.
    c. Resistive.
    d. Reactive.

51. (419) The R-Card is typically bonded to the radar-absorbing structure (RAS) or embedded between composite materials that are
    a. heat sensitive.
    b. radar transparent.
    c. moisture absorbing.
    d. electrically conductive.

52. (420) What is the result a hot sealant mixture?
    a. Decreased thermal protection.
    b. Enhanced thermal protection.
    c. Increased bond potential.
    d. Premature bond failure.

53. (420) What type of materials are used to provide a smooth transition between two surfaces that have a mismatched height?
   a. Fading.
   b. Fairing.
   c. Floating.
   d. Feigning.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Low Observable Coating Removal and Application

4–1. Radar Absorbing Material Removal 4–1
421. Identifying low observable defects 4–1
422. Removing basic low observable coatings 4–6
423. Racetracking 4–11
4–2. Application of Material 4–16
424. Preparing the surface 4–16
425. Using low observable primers and paints 4–19
426. Applying radar absorbing material 4–21
427. Applying filler and fairing material 4–24
428. Curing materials 4–27
429. Verifying the process 4–31

LIKE CONVENTIONAL aircraft, stealth aircraft have coating systems that consist of more than just one type of coating. LO systems may have primers, conductive coatings, RAM, and topcoats applied all over the aircraft. Proper coating removal and replacement is an integral part of any LO system. While techniques used during the removal process are similar to standard removal tasks, the introduction of conductive coatings requires additional steps to ensure LO integrity is maintained. Before removing any coatings, it is very important to formulate a plan to prevent removing too much material and creating new damage that could lengthen the downtime of the weapon system.

Within this unit, we will discuss identifying LO defects, removing the surface where the defects are located, and in such a way that ensures a smooth transition from layer to layer. We will also consider the preparation of the LO surface to effectively apply both primer and paint, as well as the RAM. Along with filler and fairing materials, we'll also discuss curing materials. Finally, we will consider the entire process of maintaining and verifying the aircraft's LO integrity.

4–1. Radar Absorbing Material Removal

Removing RAM can be difficult to accomplish if not done correctly. The first objective is to properly identify actual LO defects. Afterwards, proper removal of both the basic LO coatings as well as layer from layer to provide a smooth transition are essential. During this process, using proper tools and techniques is critical. Not doing so may cause serious damage to the aircraft structure. By being able to identify the various tools available to you and the techniques involved in using them, you will soon become highly skilled in removing RAM and other LO coatings.

421. Identifying low observable defects

As a LOASM specialist, part of your responsibilities lie in the identification and repair of damage to your aircraft. There are multiple types of inspections, but the one you will probably use most is the visual inspection.

Visual inspection

A visual inspection is both a time-consuming and critical process in maintaining the LO system. A visual inspection is performed on the OML or the exterior surface of the aircraft without the aid of diagnostic equipment. The purpose of the visual inspection is to identify, mark, evaluate, and document any notable defects. The survivability of the pilot and aircraft in combat operations relies solely on aircraft signature and the integrity of the visual inspection and data input conducted by the maintainer.

Assessment

An assessment includes accurately identifying the location, width, depth/height, length, orientation, and classification of damage. The correct identification of damage type(s), dimensional data, and repair data is integral to RCS reporting margins, which are used to determine if the LO system is mission capable.

Documentation

Accurate signature data entry and documentation is vital to LO signature management. All efforts must be made to ensure accurate entries are made in both the evaluation and repair entries. Whether a mismeasurement, damage classification, location, and depth, inputting the wrong data can skew signature information and cause a miscalculation of mission-capable status. This data is entered into the IMS, SAS, or the LOHAS.

Types of defects

The types of defects commonly found vary, depending on the materials and the weapon system. Always refer to your weapon system-specific TO for precise defect information. The defects described in the following table are typical to what a technician will encounter on an LO platform.

Type of Defect	Description
Bubbles	Bubbles are more commonly found in tapes and sheet RAM materials as opposed to spray RAM. With the sheet material, you have the possibility of liquid or other contaminates getting under the material, causing it to bubble. Another cause of bubbles can be extreme heat, which expands the material and breaks down the adhesive bond. Depending on the area and airframe, small bubbles are regarded as negligible, and no repair will be required until it grows beyond the set limit. Weapon system-specific TMs provide guidance on what is negligible and what constitutes a repair.
Disbonds	Disbonds are very similar to bubbles in material, and sometimes disbonds are called bubbles and vice versa. Disbonds refer to the material not adhering or bonding to the surface. The main difference between disbonds and bubbles is that disbonds are typically larger in area and do not have liquid or other contamination between the materials and surface. It is simply the breakdown and failure of the adhesion. Given the larger area of disbonds, they typically require repair or some maintenance action taken.
Uplifted edge	As the name implies, an uplifted edge occurs at the edge of the LO materials. It is important to perform preventative maintenance because lack of attention can lead to damage propagation of the LO material being further uplifted or completely torn off while in flight.
Gapping/porting	Gapping/porting is defined as any portion of the blade seal not making contact with the mating surface. Porting conditions are typically measured with feeler gauge in thousandths of an inch. Refer to the applicable weapon system-specific manual for damage/repair limitations.
Cracks	Cracks are common on sprayed coatings, cover strips, sheet RAM material, fairing materials, and gap fillers. These are typically caused by airframe stresses and temperature. Sprayed coatings are much more prone to cracking than sheet RAM materials. Cracks can open and close, depending on the surface temperature of the airframe.
Gouge	Gouge is defined as material that has been removed on a part, not to exceed material thickness. It is commonly mistaken for missing material.
Missing material	Missing material is just as it sounds. The difference between missing material and a gouge is that the material is completely removed by some form of damage to the substrate.

Type of Defect	Description
Out-of-contour/step condition	Out-of-contour (or step condition) defects describe raised or low areas and are sometimes associated with other defect types. These are typically caused by improper surface blending/contouring prior to applying sheet material. Other causes include swollen or low gap-filler material; heat and cold affects the swelling and contracting of the material used. Out-of-contour defects can be found on both sprayed coatings and sheet material areas.

Corrosion

Another type of damage that you will have to keep an eye out for is corrosion; it is costly and can be difficult to control because of the dissimilar metals on LO airframes. All aircraft contain some metal structures, and when metal structures are covered by LO material, the metal is more susceptible to corrosion. Corrosion is a serious problem on stealth platforms due to multiple LO material stack-up (or layers of coatings) that hides the initial stages of corrosion. Metal particulates in the caulks and gap fillers are highly prone to corrosion. When corrosion becomes visibly evident by disbonds and bubbles in the LO material, extensive repair is usually required.

While you are removing coatings/materials, ensure that you perform a thorough corrosion inspection, paying particular attention to areas around gaps, seams, crevices, drain holes, fastener heads, and internal structures. Corrosion can grow quickly; therefore, even a small area of corrosion is detrimental to the airframe and needs to be repaired promptly. During the inspection, visually look for nicks, scratches, and gouges. Also, to identify corrosion not seen on the surface, look for the areas appearing to be disbonds or bubbles but are solid to the touch. This could be corrosion building up underneath the LO coating.

If you locate corrosion damage, you will need to remove it; afterwards, you will need to apply conversion coatings and protective primers to all exposed bare-metal surfaces IAW weapon system technical guidance. During the removal of metallic panels, exercise extreme care not to damage the outer-sheet material or coatings. Never use screwdrivers or other metallic tools to pry off a panel, and always inspect substructure for damages before panel reinstallation.

Barely visible inspected damage

When you have to remove LO coatings from composite structures or panels, ensure that you take extra care not to damage the composite around panel edges and/or fasteners holes. During the removal process from a composite structure, you will need to do a thorough damage inspection. Barely visible inspected damage (BVID) is quite common on composite aircraft. A composite structure can be easily damaged and show no defect on the outer surface; however, the back side of the assembly can sustain substantial damages—for this reason, further inspection methods are warranted (e.g., visual, tap hammer, ultrasound). You will have to consult additional technical directives for further guidance.

Specific areas of inspection

Since there are many different types of coatings you will be inspecting, you need to be familiar with some of the specific areas and items you will be looking for.

R-card

The most important point to check when inspecting an R-Card is to ensure the correct one is installed. This inspection may require you to perform a point inspection, or zonal imaging. Other defects to look for in R-Cards include disbonds, chips, and proper alignment.

Conductive coatings

Conductive materials can come in many forms, such as tapes, sheets, coatings, and pastes. For each one of these applications, the most important inspection is the Ohm's test, which will verify if the conductive material has a resistive current going across it.

Conductive spray on coating material must be inspected during the application process. If the vehicle and the metal additives separate during the application process, the appearance of the coating will look “cloudy” and/or it will not have a uniform appearance. Pastes are generally used to fill gaps, panel seams, and to correct differences between skin heights. If voids are present in the paste applications, the voids could degrade or eliminate the resistance reading (during the Ohm’s test) that is required across the gap or seam. A very important inspection item for conductive sheet and tape material repairs will be maintaining proper gap tolerances between the existing material and the repair/replacement material.

IR

IR materials are applied to an aircraft to reduce the amount of heat radiated from the skin of the aircraft. The most common type of IR material used in an LO shop is IR primer and topcoat. This topcoat is a special coating that contains specific mixtures of metals that are designed to control the IR signature. The maintainer needs to pay close attention to the mixture when applying the IR coatings to ensure that the metals do not separate in the coating system. This type of defect on gray IR coatings is often referred to as “blued” or “bluing” (fig. 4–1). If the metal content has separated, the paint becomes blue and will become visible on the surface. This defect can only be corrected by removing the defective coating and reapplying. When applying the coating with a roller or brush, ensure that you mix the material often during application. Be sure to use the minimum amount of roller pressure to transfer the material from the roller to the surface; the most common discrepancies on cured IR materials are nicks and scratches.

Figure 4–1. Blue topcoat.

Edge molding

Edge molding is RAM that has been formed to wrap around aircraft panels. Extreme caution is required when handling this type of RAM and the panels with edge molding installed; this type of RAM has a tendency to break very easily. When inspecting molded RAM, pay close attention to the areas that have been formed. Aircraft-specific TOs will dictate what type of discrepancy to annotate.

Topcoat

Because a lot of conductive coatings, RAM, and RAS materials have a metal additive, they are environmentally sensitive and must be protected by a good topcoat system.

Look for the following when inspecting the topcoat:

1. Gouges.
2. Scratches.
3. Abrasions.
4. Missing material.

5. Peeling paint.
6. Cracks.

Ensure that the coating is cured; a very important part of the topcoat inspection is to ensure that the conductive coat is not visible.

Marking and measuring damage

The correct marking of aircraft surface defects is an important function of the OML inspection process. Markings visually depict the extent of the damages and allow future inspectors to easily identify damage and check for any growth in the previously documented damage. Typically, an ultra-fine–tip black marker is the only authorized marking utensil permitted. Keep in mind that not all LO aircraft use the same marking system; however, they do share some similarities. Always check weapon system-specific marking guides before using any of these damage identification markings.

Defect	Marking Process
Cracks and scratches	It is important to mark cracks and scratches, so they can be identified later for growth. Mark with small parentheses at the termination points of the crack or scratch. The parentheses show which direction the crack was originally measured. To mark and identify the *additional* cracking, place parentheses on both sides of the new growth. Measurement for straight and curved cracks or scratches is done from point to point.
Out-of-contour/step condition	Mark out-of-contour (step condition) damage with a dashed line closely around the perimeter of the damage.
Gouges, disbonds, and missing material	Gouges, disbonds, and missing material are marked minimally with dotted lines at the boundary of the damage. It is critical to mark the damage close to the boundary for accurate tracking of the damage growth and measurements. Damages outside the boundaries of regular shapes may need some averaging to accurately depict their size. Damage is measured in length and width, length always being the longest dimension.
Combination of defects	Different types of defects exist side by side. Treat each of these defects as its own defect; mark and document accordingly. Begin by first marking cracks and then mark other defects. The last step is to measure the dimensions of each separate defect and evaluate those damages using the aircraft-specific evaluation task.
Fastener coated	Some weapon systems have coated fastener heads on panels which allow quick access to subsystems without removing LO material. These coatings typically consist of sheet material cut out in a washer-type shape and then bonded to the fastener head. During inspections, the technician needs to carefully verify that all fastener heads are coated as these materials can separate during panel installation or during flight and create a radar scatter or hot spot. Any missing material needs to be annotated and marked according to the weapon system-specific manual.
Fastener filled	Some fasteners are filled with a fairing or gap-filling material. Filler cracks of fasteners occur when the material in the countersink recess disbonds from the countersink wall. This will present itself as a crack around the circumference of the fastener head. Filler failure is when the filler is completely missing from the countersink recess. Fastener-filler cracks can be marked with an X on the head of the fastener. Filler failures can be marked by a dot in the fastener head.

422. Removing basic low observable coatings

The LO platform that you will be working on will determine specific task steps for the LO coating removal process. The information in this lesson is designed to give you a basic overview of the removal processes.

Removal tools

Mechanical removal tools include a variety of hand tools, pneumatic sanders, pneumatic scrapers, media blasting, and lasers. Some of the mechanical removal methods can be aggressive and can create damage in a short amount of time if not monitored or used properly. Each method may or may not be approved for use on a certain platform; therefore, it is important to check the appropriate weapon system-specific TM prior to using any mechanical tools. Unauthorized tools may cause damage of coatings and aircraft structures.

Hand tools

The use of hand tools is the least aggressive method, as well as the most widely used removal technique for LO coatings.

Hand tools include nonmetallic, phenolic or nylon scrapers, and sanding blocks. Care must be given in all situations to prevent enlarging the damaged area and to prevent damage to substrate.

Nonmetallic scrapers

Nonmetallic scrapers (fig. 4–2) are made of either phenolic-laminated fiberglass or a hard-nylon material. They come in a wide variety of shapes, sizes, material composition, and hardness. You may have to locally manufacture scrapers from phenolic as needed, or your shop will purchase ready-made scrapers from a commercial vendor; either way, it is important that your scrapers are kept sharp. Sometimes you may be authorized to use a mallet in conjunction with the scrapers to remove coatings, gap fillers, or fastener-head fill. If you are authorized, exercise extreme caution as this method can cause delaminations to the composite structure or panel if they are used carelessly.

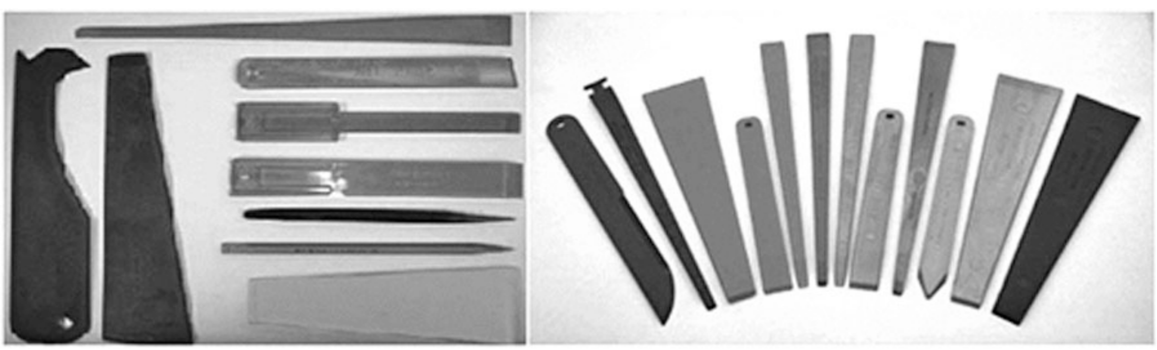

Figure 4–2. Nonmetallic scrapers.

Metallic scraping tools

Due to the sensitive nature of LO systems, metallic scraping tools are not authorized to remove LO coatings and seam fillers. Metal scrapers have a tendency to be too aggressive in the removal process, therefore, causing damage and/or enlarging the repair area. Always check the weapon system-specific TM for authorized tools and equipment used for coating removal.

Sanding block

Using a sanding block (fig. 4–3) is the best method for detail sanding. A sanding block affords you the best control and helps to prevent damage to outer areas. Blocks come in different sizes and shapes; choose an appropriate one for the size of the area. Sanding blocks may be commercially procured, or they can be something as simple as a block of wood with sandpaper wrapped around it. The key is to use the block that will give you the best result.

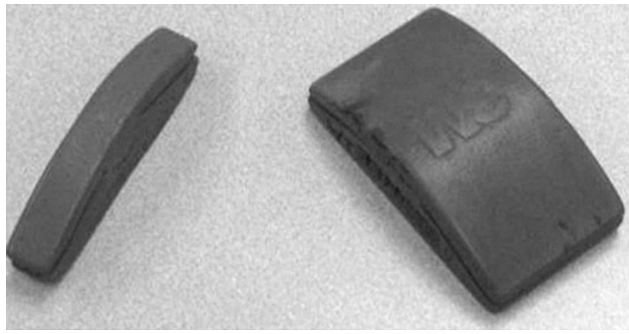

Figure 4–3. Sanding blocks.

Pneumatic removal

In some instances, you will use a pneumatic sander in lieu of hand sanding. Pneumatic sanders and scrapers are widely used because they are a faster method of coating removal; however, ensure that you consult applicable tech data for authorized tool use.

Pneumatic sander

Pneumatic sanders (fig. 4–4) are used extensively to remove LO coatings. Using a pneumatic sander gives you good control but can create further damage if you are not properly trained on how to use the tool. While using a pneumatic sander, care must be given to make sure that each coating layer is removed individually. The key is to prevent further damage to the surrounding areas.

Figure 4–4. Pneumatic sander.

Pneumatic scraper

There are going to be times that you will be authorized to remove coatings using the pneumatic scraper (fig. 4–5). This tool may be used to remove LO coatings, such as gap filler, RAM, and other coatings. It can substantially cut your time and effort, if used properly. It is an adjustable-speed vibration gun designed so that a nonmetallic scraper insert (fig. 4–6) can be installed. When you press the trigger, the tool actuates and repeatedly strikes the scraper. This simulates striking the scraper with a mallet at a very high rate of speed. These tools have a tendency to dull very quickly so a pneumatic blade sharpener is included in the kit. It rapidly puts an edge on all blades up to one inch width.

Figure 4–5. Pneumatic scraper.

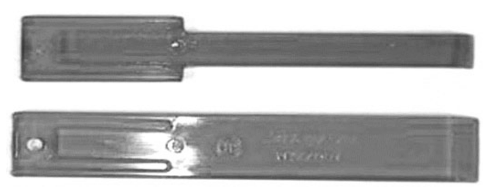

Figure 4–6. Pneumatic nonmetallic scraper inserts.

The pneumatic scraper tool can be used on virtually every area of an aircraft without damage to the substrate. However, you must use extreme caution while using it because this tool has a tendency to be very aggressive with little effort from the operator. When you use a coating removal tool, always use a low trajectory to prevent delamination in the composite structure and the adjoining panels. To prevent edge damage, never position the pneumatic scraper on the edge of a panel. Instead, start from an interior point and work out towards the edges. Extra care should be taken around fastener holes to prevent delaminations. As with pneumatic sanders, pneumatic scrapers should only be used by trained technicians when authorized.

Media blasting and laser removal systems

There may be times when media blasting is authorized for coating removal. If media blast is used, care must be exercised to control the many variables that affect the blast machine's performance. Failure to control these variables can result in damage to the surface and substrate. This method requires a skilled hand and an operator that is highly qualified.

A technology that is currently under development is the Laser Coating Removal System. The basic concept is that high-powered lasers are used to remove coatings from the surface of the aircraft. As you can imagine, this is a complicated process and is still in the developmental stage.

Removal processes

The type of aircraft you are working on and the material that you are removing will determine the process needed.

Sheet RAM

When beginning the sheet RAM removal process, you must first determine the repair size and shape. Once you have your size and shape laid out, use a straight edge placed along the outline of the repair, and lightly score the RAM using an approved cutting tool. Several passes may be required to complete this part for the task. Remember, it is important not to cut into the underlying surface, as this will cause additional damage to the substrate. When this process is complete, carefully remove the RAM with nonmetallic scrapers. After the RAM is removed, there will be residual adhesive left behind. Remove this adhesive using an approved cleaner or solvent and an abrasive pad.

Spray-coat RAM removal

A pneumatic sander is used to remove spray-coat RAM. To prevent removing good material and damaging adjacent surface areas, mask the area around the damage to be removed. Sand the area in the same manner as sanding to remove paint. Be careful—personal protection equipment (PPE) must be used because the residual dust that is created can irritate the lungs, eyes, and skin.

LO tape

To remove LO tape, you will first apply masking around the tape or fairing material to be removed. Next, you will use an approved scraper and/or cutting tool to remove enough fairing material to access the tape edges; lift and pull the tape back. Keep the tape as parallel to the aircraft surface as possible until the tape is completely removed. Finally, remove any tape residue with a scraper and clean with an approved solvent.

Fastener-coating removal

On LO weapon systems, most fasteners are hidden and covered with LO coatings, preventing a return on the signature of each fastener. Before you can remove fasteners, you must first locate them by visual methods or with blueprints and weapon system-specific TMs. Sometimes, thermal cameras may also be used to locate hidden/filled fasteners under LO coatings when visual means do not allow detection. Once you find the outline of the fastener, use a nonmetallic scraper to remove the LO material.

Gap-filler and fairing compounds

All aircraft platforms (including LO platforms) have seams and gaps where panels meet or come together (fig. 4–7); however, the difference is that on an LO platform they need to be filled in, hiding the gaps from radar signals. When it becomes necessary to remove the filler material in the seams and gaps, you will use nonmetallic tools, such as picks or probes, to prevent damaging the substructure. You will use the same processes, materials, and techniques to remove fairing material as you do with filler material.

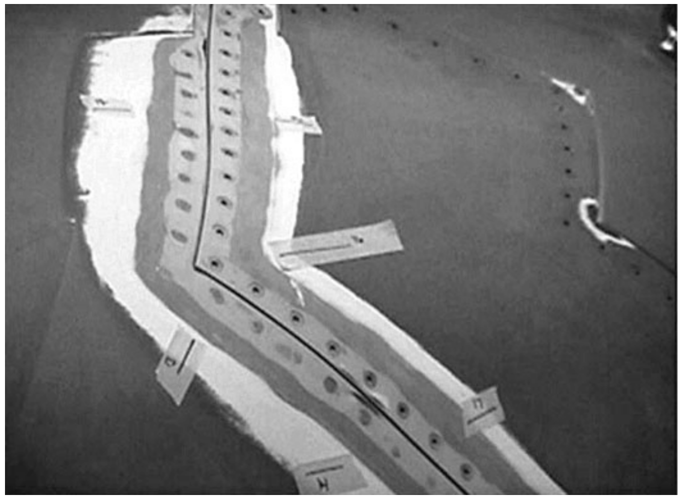

Figure 4–7. Panel seam.

There are some areas of the aircraft that may have what are known as unsupported seams or gaps, areas that do not have a substructure underneath. The panels are typically held in place with a wire mesh on the underside of the panel and filled in with a sealant to allow for a smooth surface. Unsupported gaps/seams are commonly found on removable panels where it was not feasible during the build of the aircraft to install a substrate. Extreme caution should be exercised when removing the filler material from these gaps and seams because damage to the wire mesh can create unnecessary work, causing delay and additional aircraft downtime. Refer to the applicable weapons system-specific manual for locations and approved repair processes.

Zip cord

Some panels on the F–22 have zip cords to aid in the identification of panel perimeter and removal of gap fillers. A zip cord (fig. 4–8) is braided nylon string that is placed in the seam or gap and has filler material placed over it. If you have to remove the panel, you would first locate the seam using a nonmetallic probe or scraper. Locate the end of the installed zip cord and uncover about three inches of it. Pull the cord outward (fig. 4–9) and toward the seam; the gap filler will come out with the cord. Although the zip cord removes much of the filler, excess material will have to be cleaned up after the cord has been removed.

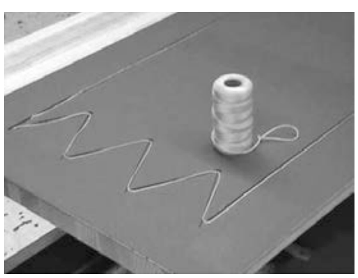

Figure 4–8. Zip cord.

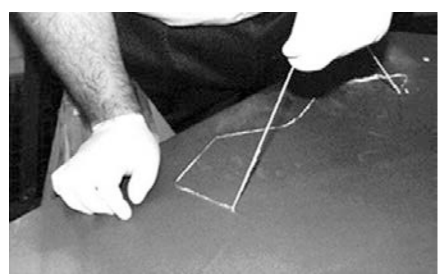

Figure 4–9. Zip cord removal.

Disposal of coating materials

During your career, you will encounter many hazardous and/or sensitive materials. The coating materials that you will be working with may be hazardous to humans as well as the environment. In addition, some of the materials may be considered sensitive or even classified; LO coatings may contain classified shapes, angles, or tapers. Coatings can also contain hazardous metals, such as mercury, lead, iron, silver, and chromates. If you were to dispose of these materials improperly, you could damage the environment as well as compromise national security. Therefore, you must take great care and consideration when determining how to dispose of coating materials. Depending on the weapons system, some materials require specific disposal procedures.

When discarding excess or removed LO coating material, disposal equipment, such as industrial shredders (fig. 4–10), incinerators, and handheld cutting devices are used to safeguard the sensitivity of the materials and keep it out of the hands of our adversaries.

Figure 4–10. Industrial shredder.

Shredders

Shredders are primarily used at facilities where the maintainers produce a lot of excess during the removal and installation process. They are designed to shred coating material at a rapid pace, cutting to dimensions as small as one-fourth inch. This ensures that no classified angles or tapers can be taken from scrap materials.

Incinerator and "two-person rule"

Other methods of disposal are through the use of an incinerator and/or the use of the "two-person rule." An incinerator will melt or burn the materials into an unusable state. The two-person–rule concept is that while one person is disposing of the material, the second person acts as a witness to ensure proper disposal procedures are adhered to. The two-person concept may be used with any disposal method.

As an LO maintainer, you will be creating and disposing of both solid waste and liquid waste on a daily basis. Because precious metals are incorporated into stealth aircraft and are embedded in panels, paints, and other LO coatings, it is essential that all of the coating materials you dispose of are entered into the correct waste-collection points or waste streams. If you do not dispose of them into the correct waste stream, you run the risk of cross-contaminating waste streams. This can lead to very expensive disposal fees for your work center or even an Environmental Protection Agency fine for you.

Solid waste materials are consolidated accordingly and put into specific, approved waste containers. Liquid waste is another item that you will be concerned with due to the types and amounts required to repair stealth aircraft. Because of the large volume of solid and liquid wastes that you will generate, hazardous waste containers will be located at satellite accumulation points near where you will be working. You will want to ensure that each container is clearly labeled for the type of waste that the container can hold. For example, you may need separate containers for solid waste, liquid waste, metal, rags, and masking material. The containers will need to be emptied as they near capacity IAW state, local, and installation disposal policies.

423. Racetracking

LO coatings often contain multiple layers in an area that operate as a system. To repair an area, you must know what coatings are in the area you are working. Once determined, you can begin to remove these coatings by racetracking the repair area. This section will provide you with the definition and purpose of racetracking.

Racetracking basics

To understand racetracking, you must first know how racetracking is defined and the different elements that are involved. First of all, racetracking (fig. 4–11) is the systematic removal of a coatings stack up in a way that ensures a smooth transition from layer to layer. A stack up is the number and combination of coating materials applied to the surface (fig. 4–12) as dictated by the weapon-specific TO. The smooth transition during racetracking is accomplished through proper tie-in and the removal of hard edges or transitions. Tie-in is a transition between an original coating and a new coating by overlapping, alternating paints.

Figure 4–11. Racetracking.

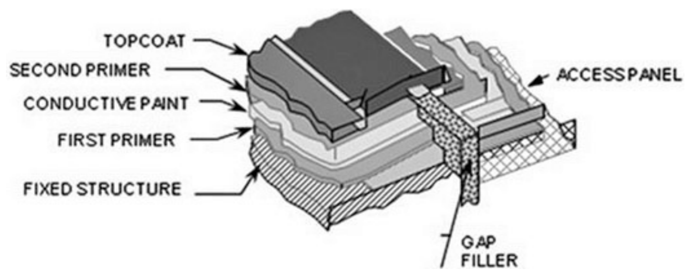

Figure 4–12. Basic stack up.

Racetracking is accomplished because each coating layer applied to the aircraft has a specific purpose. The goal is to maintain continuity within each layer from the repaired area to the nonrepaired area. It is important to remove the coatings layer by layer; this method allows you to create a tie-in that will be used for the stack up of the new materials. A tie-in ensures that the proper amounts of existing coatings are covered by repair coatings. The most important tie-in is the conductive layer because it allows EM energy to travel across the aircraft. If the conductive coating is not properly tied in, an unfavorable radar return could result. A minimum tie-in must be maintained at all times and can be determined by consulting the weapons system-specific technical data.

Beware, some coating stack ups have materials that are similar in color or have terminating rather than overlapping edges; extreme care should be taken to identify all the layers. Also, not all LO aircraft will have conductive coatings applied. Advancements in LO technology and lessons learned from previous and existing LO platforms have led to manufacturers removing the conductive coating in the paint stack up and embedding it in the advanced composite panels. The F–35 does not use a conductive coating in its stack up because it has been embedded in the aircraft structure and RAM; on the other hand, the F–22 and B–2 have conductive coatings applied in their stack ups.

The process of racetracking

The first thing that you will need to do after identifying the damage is research the damaged area. You will need to determine the stack up and the minimum tie-in dimension and lay out the repair. The layout should incorporate larger-than-minimum tie-in dimensions to allow for sanding imperfections. Configure the repair in planform alignment angles by measuring equal distance from the panel edges to the edge of the damaged coating. Figures 4–13 and 4–14 show how to configure a planform aligned repair by measuring. Always mask the surrounding area to prevent excessive material removal.

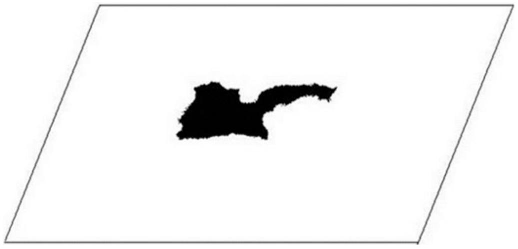

Figure 4–13. Damaged area.

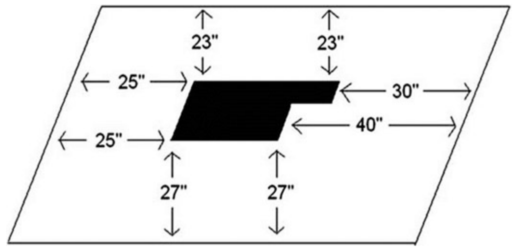

Figure 4–14. Damaged area configured using planform alignment.

After laying out the repair on the aircraft, remove the topcoat in the repair area. Once the topcoat is removed, protect a specific width of primer around the border of the repair site. Extreme caution is required to ensure that the layer is not sanded through, exposing the layer below. This type of defect is known as a *burn through* (fig. 4–15). Next, you will sand the primer off, exposing the layer beneath. Keep in mind that each underlying layer may be a conductive coating and that minimum tie-in measurements must be maintained per weapon system-specific technical data. Once again, mask the border of the conductive coating to a specific width to protect it. Continue this process until all of the required coatings are removed. Be sure not to sand through the bottom layer of primer as it protects the composite material. Finally, remove the tape and the repair area will look like a racetrack.

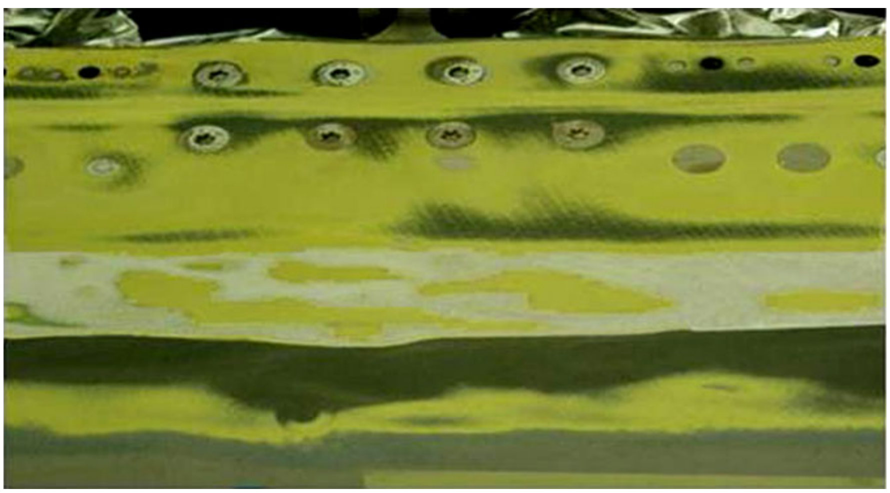

Figure 4–15. Burn through.

Exercise caution when removing conductive coatings; they contain metals as their conductive elements, and oxidation or corrosion of the coatings will occur if left unprotected from the elements. High temperature, humidity, and salt environment will speed this process exponentially. If an aircraft assembly requires repair and must sit for an extended period of time, do not expose electrically conductive layers until absolutely necessary. If not feasible to repair within a reasonable time frame, cover with appropriate material to provide a protective layer to slow the corrosion process. Simply sanding the corroded surface will not remove the damage because the resistivity values of the paint have been completely changed. The entire repair will have to be stepped back to clean the area.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

421. Identifying low observable defects

1. What can happen if the signature data you input is not accurate?

2. Why is it important to perform preventative maintenance on uplifted edge damage?

3. Why is corrosion a serious problem on LO aircraft?

4. How can you tell that there is corrosion under an LO coating?

5. Where do you need to pay particular attention when performing a corrosion inspection on LO aircraft?

6. Why might you have to perform an ultrasound inspection on a composite panel?

7. How do you verify if the conductive material has a resistive current going across it?

8. How can you tell if the vehicle and metal additives have separated during the application process?

9. How is IR topcoat “bluing” corrected?

10. Where should you pay close attention when inspecting edge molding?

11. How do you mark cracks and scratches?

12. How are gouges, disbonds, and missing material marked?

422. Removing basic low observable coatings

1. What is the least aggressive removal technique for LO coatings?

2. Describe nonmetallic scrapers.

3. What happens if you use a mallet and scraper combination carelessly?

4. Why are metallic scraping tools *not authorized* for use on LO aircraft?

5. Why is the sanding block the best tool for detail sanding?

6. What may happen if you are not properly trained on how to use a pneumatic sander to remove LO coatings?

7. How can you prevent delamination of the composite panel when using a pneumatic scraper?

8. When removing sheet RAM, what do you do after you have the size and shape of the repair area laid out?

9. How do you remove the material in seams and gaps?

10. What do LO coatings contain that make it necessary to dispose of them properly?

11. Where might you find an industrial shredder for disposing of RAM?

423. Racetracking

1. How would you systematically remove the coatings of a stack up in a way that ensures a smooth transition from layer to layer?

2. How is the smooth transition during racetracking accomplished?

3. What is the goal of racetracking?

4. What does removing coatings layer by layer allow you to accomplish?

5. Why is the conductive tie-in layer the most important tie-in layer?

6. What is the first thing that you must do after identifying damaged material?

7. Why should you incorporate larger-than-minimum tie-in dimensions into your layout?

8. How do you configure a repair for planform alignment?

9. Describe a “burn through.”

10. Why is it important *not* to sand through the bottom layer of primer?

11. Why must you exercise extreme care when removing conductive coatings?

12. How do you fix a conductive coating area that has corroded?

4–2. Application of Material

Applying LO material is process dependent, requiring technicians to follow strict and required process controls set forth in the weapon system-specific TM. Many factors play a role when it comes to applying LO materials. It is your responsibility as an LO technician to ensure a multitude of factors are in an acceptable range before starting any application process. For example, the work area must be clean; the shelf-life expiration dates, batch numbers, and mix ratios on all materials must be checked; and the ambient temperature and humidity must be controlled. Being out of the acceptable range on any of these factors could potentially cause material degradation, faulty curing, or jeopardize material performance altogether. If all of your factors are within acceptable ranges per specific technical data and manufacturer's instructions, you may start the application process.

424. Preparing the surface

When it comes to any coating application, surface preparation is the most important process; it lays the foundation for all the work that is subsequently accomplished on a repair area. How you perform surface preparation can make a very effective LO system or an inoperable one that will have multiple problems and defects as time goes by.

Preparation considerations

To produce an effective coating system, there are certain things that need to be taken into consideration. Personnel safety, aircraft surface temperature, and surface cleanliness all play major roles in the overall outcome of your coating system.

Safety

Mixing chemicals, sanding, and painting are all hazardous operations that require only personnel performing the operation to be in the immediate area. As a technician, you must follow all guidance given by the local safety office, bio-environmental engineers, applicable TM guidance, and manufacturers' instructions when performing hazardous operations. It is also your responsibility to ensure that all personnel in the area are observing all required safety precautions.

Some of the hazards that you need to protect yourself and your coworkers from are issues regarding toxicity, personnel health, flammability of materials, ventilation, handling of equipment, electrical grounding, storage of coating materials, area preparation, use of vapor-proof lights, and so on. You can refer to your section's current bio-environmental survey for the minimum recommended PPE and proper procedures to prevent waste from contaminating air, water, or soil. Also, make sure you contact the base bio-environmental office to discuss any new procedures that may begin with a new workload. Remember, to be effective, you must operate safely!

Aircraft surface temperature

The aircraft surface temperature must be maintained at the required temperature for the material being applied. Each material that you apply will have specific guidelines from the manufacturer that must be followed. If materials are applied to surfaces that are too hot or too cold, the probability of material failure is great. When aircraft are exposed to extreme environments, time should be allocated to allow aircraft surface temperatures to adjust to material-specific guidelines. These times will vary, depending on how long aircraft have been exposed to extreme temperatures, and are dependent of the number of degrees it takes to get within range.

Depending on the conditions of the environment, ideal surface temperatures can be achieved by using a variety of methods. Repairs should only be attempted if surface temperatures are between 60° and 95° F. Sometimes, environmental conditions can be controlled by simply utilizing the support of aerospace ground equipment (AGE), such as an aircraft air conditioner, heater, or environmental control unit. If you need to use one of these units, you would position the air duct in the vicinity of the repair area. You can adjust the temperature by using a combination of the unit's control panel and positioning of the air ducts.

NOTE: Do not apply coatings when temperature and humidity are not within guidelines.

When environmental conditions cannot be controlled by positioning a duct adjacent to the repair area, consider using a maintainer-fabricated enclosure to localize the repair area to better control and maintain proper temperature and humidity. Figure 4–16 shows an example of an F–35 aircraft with a maintainer-fabricated enclosure attached. Finally, if conditions prevent the use of support equipment or a maintainer-fabricated enclosure, use the specific weapon system's small or large enclosure, deployable shelter, or wait until an environmentally controlled facility is available.

Figure 4–16. Maintainer-fabricated enclosure.

Surface cleaning requirements

A common and recurring theme whenever dealing with LO coatings is cleanliness. Prior to performing a coating repair, the surface must be cleaned and dried. Properly cleaning the surface prevents contamination of the repair material. A contaminate-free surface is key to ensuring good adhesion. Always refer to the specific weapon system TM for any particular cleaning procedures and authorized materials.

Approved solvents are used to clean an area of contaminates, such as dirt, dust, grease, aircraft fluids, and adhesive residue prior to bonding or coating. While using these solvents, care must be taken to prevent the solvents from being contaminated and, therefore, contaminating the surface you are trying to clean. While using solvents, there are precautions that must be taken to ensure your personal safety as well as the safety of the equipment you are working on. Listed are some of these precautions and considerations:

- Solvents must be used only when wearing approved PPE.
- Most solvents are flammable and have low flash points.
- Do *not* use flammable solvents near open flames.
- Inhaling solvent vapors and mists may cause respiratory irritation.
- In extreme cases, exposure can cause fluid accumulation in the lungs and central nervous system depression.
- Always use solvents in a well-ventilated area.
- Do *not* leave solvent-soaked rags on the aircraft surface.
- All surfaces must be wiped dry prior to evaporation to prevent redepositing contaminates onto the surface.

Several applications of the cleaning solvent should be used and applied each time with a clean, dry, lint-free cloth. Do not dip the cloth or the part into the solvent container or place the contaminated rags against the solvent container opening. Use a squeeze bottle or pour the solvent onto the rag and not onto the surface. You will want to clean an area at least twice the size of the repair using one of the following dual-wipe methods.

Method 1

Start from the center of the repair area and wipe towards the outside. After one pass has been made, fold or flip the rag so a clean area of the rag will be used. Dry wipe before the solvent evaporates. Switch to clean cloths frequently. Repeat the entire wiping process until the rags show no signs of contamination. A water-break test may be required. Allow the surface to dry completely before applying adhesives or coatings.

Method 2

Start from one side of the repair area and wipe straight across to the other side. After one pass has been made, fold or flip the rag so a clean area of the rag will be used. Dry wipe before the solvent evaporates. Switch to clean cloths frequently. Repeat until the entire area is wiped. Repeat the entire wiping process; however, wipe a slightly smaller area, being careful not to pull contaminates from areas that were not wiped. Repeat until the rags show no signs of contamination. At this point a water-break test may be required. Allow the surface to dry completely before applying adhesives or coatings.

Metallic and nonmetallic surface preparation

When you are preparing to apply coatings, particular attention should be given to the integrity of any subcoating in the repair area that is not being replaced. If a subcoating is damaged, it must be repaired prior to applying any type of LO coating.

After ensuring the repair area can accept a coating and the surface is clean, both metallic and nonmetallic surfaces must be masked. The purpose of masking is to prevent additional damage to surrounding surfaces and coatings. When masking, you will need to cover all antennae, vents, or air data sensors with approved masking paper and tape that is listed in the weapon system-specific TM. All masking material that is applied to the aircraft must be properly annotated IAW technical data and local policies.

Metallic surfaces

Whether you are bonding coating materials or repair materials, metal treatment for bonding is critical and care must be taken to create an active surface for bonding in addition to removing contaminates. To improve adhesion and decrease corrosion potential, it is important to prepare bare metal surfaces prior to applying LO materials. Refer to TOs 1–1A–1, *Engineering Handbook Series for Aircraft Repair General Manual for Structural Repair;* 1–1–8, *Application and Removal of Organic Coatings, Aerospace and Non-Aerospace Equipment*; 1–1–690, *General Advanced Composite Repair Manual;* 1–1–694 *Application and Removal of Low Observable coatings on Aerospace,* and most importantly, the weapon system-specific TM for further guidance.

Nonmetallic surfaces

Proper preparation of the repair area before any bonding or coating application process is critical to ensure a quality repair is achieved. Strength and durability of the materials will be adversely affected if the repair area is not properly prepared. In some cases, weapon system-specific technical data may omit the solvent-wipe step; this step should only be omitted when authorized. All composite surfaces should be prepared for LO coatings by cleaning IAW weapon system-specific technical data, as well as TO 1–1–690 and TO 1–1–694.

Composites are not the only nonmetallic surface you will be required to prepare. LO coatings are also considered a nonmetallic surface, and special care should be taken to properly prepare the surface prior to adding additional coatings to it. Prior to applying any coating to a RAM surface, you must first repair any defects in the surface.. Once you have fixed any defects, you are ready to move on.

The next step in preparing the nonmetallic surface is to mask the area to be primed, and then scuff sand the area with a medium-to-fine–grade sandpaper. This will ensure that the primer will adhere to the surface. After scuff sanding and before any coatings can be applied, the surface is required to be clean and dry. Clean the area with an approved solvent and clean cloth, using one of the cleaning methods listed above.

425. Using low observable primers and paints

The LO system is comprised of many different types of specialized coatings. Many of these coatings have different methods of application, and it is important to precisely follow the manufacturing guidelines and/or weapon system-specific manual.

LO material-coating stack ups can vary, depending on the surface location and the material configuration. Prior to applying LO coating material, you will need to research the proper application sequence for the repair area and determine application method. For specific LO coating stack ups, it will be necessary to refer to the weapon system-specific TM.

Primers

Primers used on LO platforms vary widely and will naturally have different mixing and application requirements. Always refer to the manufacturer's instructions for proper mixing ratios and dwell times. Primers are used for their adhesion-improving and corrosion-inhibiting properties between the structure and subsequent materials. Depending on your application requirement and TO instruction, you will be using either a chromate-free waterborne primer or a chromate (solvent-borne) primer. Both can be used on composite structures and provide a barrier between conductive LO coatings and metallic structure.

Conductive coatings

You may be required to apply conductive coatings. The tie-in of conductive paints is the most important aspect of the LO coating system. Preparation and application of these paints require constant agitation to ensure the metallic solids in the coating do not settle to the bottom of the mixing tray or the spray equipment. Agitation during mixing is achieved with either a paint shaker or paint mixer; during application you will likely be required to use an agitating paint gun or pressure pot to ensure equal distribution of metal particles. Immediately wipe and clean any stray splatters and drips adjacent to the conductive layer of the aircraft. Failure to remove stray splatters and drips will result in a detrimental RCS impact. For more information on conductive coating application, refer to the weapon system-specific TM.

Topcoats

The exterior finish of an aircraft serves several purposes. First is to protect the airframe from deterioration. On metal structures, the primers and paint protect against corrosion. For composite structures, they minimize moisture intrusion and provide UV protection for the resins and materials. Paint also protects surfaces from chemical attack by the atmosphere or chemicals used during maintenance and operation. Additionally, paint provides a smooth surface to the aircraft that reduces drag, glint, and glare and provides an appropriate color to increase aircraft survivability. All composite surface panels and parts should, at a minimum, be primed prior to aircraft flight because unprotected composite panels begin to deteriorate when exposed to moisture and sunlight.

There are several types of exterior finishes or topcoats that can be applied to stealth aircraft. The wrong type applied to an area could have adverse effects on the overall signature of the aircraft. Some of the different types of topcoat that you may deal with include IR, high-temp, Teflon-filled, and rain-erosion coatings.

Methods

The three different methods used to apply primers and paints include brush, roll, and spray. Individual circumstances and aircraft-specific technical data will determine which coating method to use. Paint brushes and rollers can be used effectively for touch-up and maintenance painting. Listed are some advantages of brush and roller touch-up over spray applications:

- Little to no masking is required.
- More economical for small-area and low-volume painting because much less paint is required.
- Requirement for solvent thinners is very limited.
- More efficient for application of stencil-type markings.
- Coating transfer efficiency is almost 100 percent with no over spray.
- Very little air pollution generated because of the small amount of solvent evaporation.
- Hazardous and nonhazardous waste is minimized and limited to used brushes or roller covers and small amounts of excess primer or paint.

Brush method

It is very difficult to get a smooth, professional appearance with the brush touch-up method on aircraft surfaces. Using a brush leaves stroke marks in the coating. Therefore, brush touch-up should be limited. Be sure to check the weapon system-specific TO for limitations. Check your aircraft-specific TO for types and styles of brushes allowed to apply coatings on your aircraft. Figure 4–17 is an example of a few commonly used brushes.

Roll method

Although not as good as the spray method for aircraft surfaces, rollers (fig. 4–18) do provide a smoother and more professional appearance than brushes, and may be used in repair areas. The aircraft specific TO and type of material that you are applying is going to determine the type of roller to use. The most effective roller covers for application of coatings are manufactured from an ultrahigh-density foam. The core roller center should be resistant to water and solvent.

Figure 4–17. Artist brushes.

Figure 4–18. Paint rollers.

NOTE: To minimize spillage when using manual rollers, move the roller across a container grid to eliminate excess coating material.

Polyurethanes and epoxy coatings require a little more paint than normal on the roller during application to achieve a smooth surface; a second cross-coat may be required.

The application procedure is described in the following table:

Step	Description
1	Scuff sand and solvent wipe the touch-up area.
2	Mix and thin the primer or paint for roller application per the manufacturer’s instructions. Mix the least amount possible for the job at hand.
3	Pour the primer or paint into approved paint tray.

Step	Description
4	Dip the roller fully into the primer or paint. Withdraw the roller, and move the roller across the vertical metal grid to distribute the liquid throughout the roller pile and eliminate any excess.
5	Always start application in a corner of the area being touched up. Place the free end of the roller about three feet away from where the roller stroke will end so that it covers a small portion of the left or right “feathered” edge of the area being touched up completely and with the roller at an angle to this edge. For horizontal surfaces, always make the first stroke away from you. Without lifting the roller from the surface, make alternate strokes toward and away from you to form a “W” pattern. For vertical surfaces, always make the first stroke upward. Without lifting the roller from the surface, make alternate up and down strokes to form an “M” pattern. Fill in the gaps in the “W” or “M” patterns with crisscrossing strokes of the roller moving back across the “W” or “M” pattern and still not lifting the roller from the surface.
6	Make sure that the entire section is completely covered, including its “feathered” edges, before moving to an adjacent section or finishing the touch up of an area. Always use even pressure on the roller to prevent bubbles and blotches in the primer or paint.
7	If the touch-up area is not entirely covered, touch up a section adjacent to the first section, making sure it overlaps the first section about two inches. Application is by the same techniques as in step 5.
8	If primer was applied, allow the proper cure time and then apply the topcoat using the same roller techniques as in step 1–7.

Spray method

It is important to read the manufacturer’s instructions before mixing primers and paints. Spray applications on LO aircraft are different from legacy aircraft paint systems and must be agitated for the material to flow consistently. Some of the coatings used on LO aircraft contain heavy metals to reduce aircraft RCS. If these materials are allowed to sit in a container without agitation, the metal content will separate from the liquid. Consequently, not continually agitating your material could result in a loss of RCS properties. Agitation can be accomplished using either mechanical or pneumatic agitators incorporated into the spray equipment.

The thickness of the coatings can be better controlled using spray guns. Spraying is the preferred method for LO coating application because it provides a more uniform coating. For this type of application, a standard high-volume, low-pressure (HVLP) spray gun can be used. Spray operations require strict environmental conditions controlled with paint booths. When it is not practical to spray, you may be required to use a roller or brush to apply primer or other coatings.

426. Applying radar absorbing material

RAM plays a very important role in reducing an aircraft’s signature. To be effective, great care needs to be taken during the installation or replacement of RAM. You must follow the weapon system-specific technical data for information on material type, required angles, placement of repair pieces, and adhesive application. These coatings are applied using two methods:

- The most common method employs bonding adhesives to attach the RAM to the surface.
- The other method is to spray the RAM onto the surface. Because of the exact mixing procedures, the spray method is normally reserved for use at the factory and is done on an exceptional basis in the field.

Failure to follow instructions could damage the aircraft and put lives in danger. Remember, the LO system is only as good as the LO maintenance performed.

Bonding sheet RAM

Sheet coat RAM is manufactured specifically for predetermined areas of the aircraft. Solid stock or sheet RAM comes in several forms. Sheet RAM can be used for cover strips; covering large, flat surfaces; and repairing spray RAM when authorized by aircraft-specific technical data. Sheet RAM can be applied to an aircraft in several ways; when doing so, consider surface area, shape, contours, and available equipment.

Tapering

Other considerations during the application process are electrical discontinuities and aerodynamic smoothness of the repair area. To minimize electrical discontinuities and maintain aerodynamic smoothness, you may be required to taper sheet RAM. Tapering is done by sanding and is similar to chamfering metal patches. This process should be done off the aircraft to protect against sanding into undamaged coatings.

Bonding

Typically, the preferred method to apply RAM to a structure is by bonding, which uses paste or liquid adhesive to bond the RAM to the surface. Silicon and epoxy adhesives are most commonly used. Make sure to scuff sand the RAM prior to applying the adhesive. Scuff sanding provides a stronger bond line between the aircraft surface and the RAM. Apply the adhesive to the underside of the RAM, and lay the RAM into place. Once the new piece is installed, roll it down with a rubber-wheeled roller to remove any air bubbles. Some manufacturers recommend the use of a heat blanket under a vacuum bag during the curing process. If setting up a vacuum bag is impractical or impossible, a positive-pressure setup may be required.

After the replacement piece is in place, its perimeter must have a specific gap IAW the applicable TOs. After the proper gap is obtained, fill it with a paste, caulk, or gap filler (depending on applicable tech data) to ensure the smoothness of the surface coating and transition between pieces of RAM. This decreases the chance that radar will detect the gap. After the coating has been replaced and is cured, apply protective coating IAW the aircraft-specific technical data.

Edge molding

Edge molding is RAM that is formed to a specific three dimensional shape for the edge of panels. It is specifically designed to help the transition of EM energy across the aircraft’s OML. Edge molding comes in a 90° edge or a “J” shape edge. Technical data will dictate which type is to be used and where. Extreme caution is required when handling this type of RAM, and the panels with edge molding installed as this type of RAM has a tendency to break very easily.

The steps in the following table are general guidelines on how to apply edge molding after the damaged edge molding is removed using planform alignment techniques.

Step	Description
1	Clean and prepare surface of the structure IAW TO directions.
2	Cut edge molding to fit using planform alignment techniques.
3	Apply an approved sealant/adhesive to the edge molding.
4	Slide edge molding into place, making sure the edge of the panel is completely covered with no air gap between the two. Pressure-sensitive tape may be used to help maintain position of the molding.
5	Apply even positive pressure to the molding and panel. Using a vacuum bag is the preferred method; however, placing tape over the molding and onto the structure may be permissible.
6	Cure repair IAW technical data.
7	Remove vacuum bag/tape and inspect for defects.

Keep in mind that if you have to use aluminum tape instead of vacuum pressure, you must ensure that it does not contact any LO coating. The adhesive on the aluminum tape is very strong and will pull up undamaged coatings when removed. Use pressure-sensitive tape as a barrier between the coatings and the aluminum tape.

Adhesives

There are several ways to adhere RAM to an aircraft. Depending on the airframe, the TO may require you to use a sealant, room temperature vulcanizing (RTV), or a RAM with pressure-sensitive adhesive (PSA).

Sealants

The use of a sealant is a common adhesive for bonding RAM. It is very important to obtain the correct thickness when applying sealant to RAM. Applying sealant too thick allows the RAM to flex, causing cracks and other RCS concerns. Applying sealant too thin causes a weak bond line, which could allow for RAM departure. There are several tools available to ensure proper sealant thickness is achieved.

Wet-film gauge is one tool that can be used after application. To achieve a proper mil thickness, scrim cloth is common practice on some aircraft; a silk screen can also be used during application.

Silk screening is a process in which sealant is forced through a mesh-screen material with a squeegee. The screen is prepared with open areas to allow the sealant to pass through, as well as closed areas that block the sealant. The open and closed areas are designed to provide a very uniform sealing area by controlling the size, shape, and thickness of the sealant layer.

Remember, mixing sealants must be accomplished IAW manufacturer's instructions. Improper mixing will result in poor adhesion and/or improper curing.

Pressure-sensitive adhesives

Another way to bond RAM to an aircraft is through the use of PSA, as it has the adhesive preapplied by the manufacturer and comes protected by a removable liner. PSA RAM can easily be cut into various shapes and allows for simple and quick applications; this permits minimal repair downtime.

Applying PSA RAM is referred to as a peel-and-stick application process. All you have to do is cut the RAM to the shape of the repair or panel, peel the separator sheet that covers the adhesive, and stick it into place. Once the new piece is installed, roll it down with a rubber-wheeled roller to remove any air bubbles. You can also use a vacuum bag setup to remove the air bubbles.

Even though applying PSA RAM is relatively simple, certain precautions must still be taken to ensure an acceptable bond. Always wear gloves and keep your work area clean when working with this material. Ensure the adhesive does not become contaminated with oils from your skin or other chemicals that can degrade the adhesive strength and cause premature failure. Remember, do not deviate from technical data and always use the correct adhesive for the job!

Fasteners

Different sections of the aircraft will have different types of fasteners. Some of the fasteners will be exposed, while others will not. Regardless, both exposed and unexposed fasteners may need to be covered with RAM. Prior to covering them, you must ensure that the fasteners have been installed correctly (fig. 4–19).

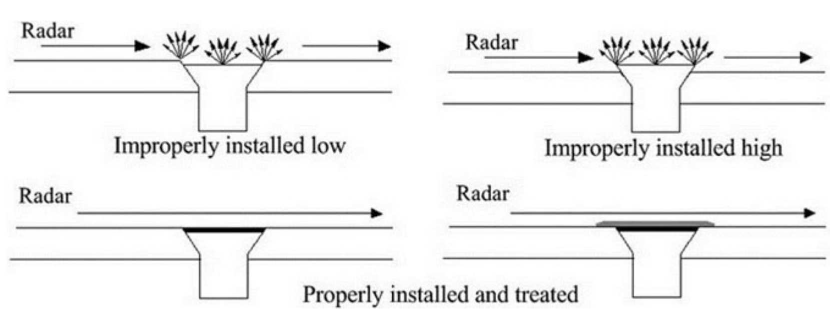

Figure 4–19. Fastener heads.

- The surface of fastener heads must be clean of any debris.
- Pay particular attention to high-seated fasteners.
- Proper and required torque values must be applied to the fasteners.

Failure to properly install and inspect fasteners prior to applying LO materials will create extensive LO coating rework. If left uncoated or incorrectly installed, the fasteners could impact the signature of the weapon system.

Various panels on certain aircraft require RAM-coated washers to be applied to the fasteners. For example, frequently accessed panels have covered fasteners. Prior to RAM application, you would first need to remove any deteriorated or damaged RAM material from screw-fastener heads, and then clean the surface. Next, you can use a RAM washer-cutter kit to stamp out fastener washers. A washer-cutter kit typically consists of a rawhide mallet, a plastic cutting board, and various size washer-cutting dies. The dies are marked with a letter that corresponds to the appropriate-sized fasteners. The cutter is used to cut out the various sizes of washer requirements. To install the RAM, wipe the fastener heads with an approved solvent, apply the applicable adhesive, and bond the RAM washer to the top of the fastener head. For more specific processes, it will be necessary to consult the weapon system-specific TM.

427. Applying filler and fairing material

Fillers, also known as gap fillers, paste, slurry, or caulk on some airframes, come in two basic types: conductive and nonconductive. Both are typically installed with sealant guns. Many of the filler materials require cold storage to maintain shelf life. When repair materials are removed from cold storage, they must remain sealed in manufactures' containers and allowed to acclimate in the work area before using them to perform any repair procedures. If the repair materials are now allowed to acclimate properly, condensation and moisture can degrade the overall performance, shelf life, and work life of the material.

Gap filler

When we refer to gaps, we are talking about the distance between mating panels. Gaps on LO aircraft must be filled with a filler to ensure the smoothness of the aircraft structure (fig. 4–20). By filling the gaps, you allow surface waves to travel along without a discontinuity, which will minimize the RCS impact.

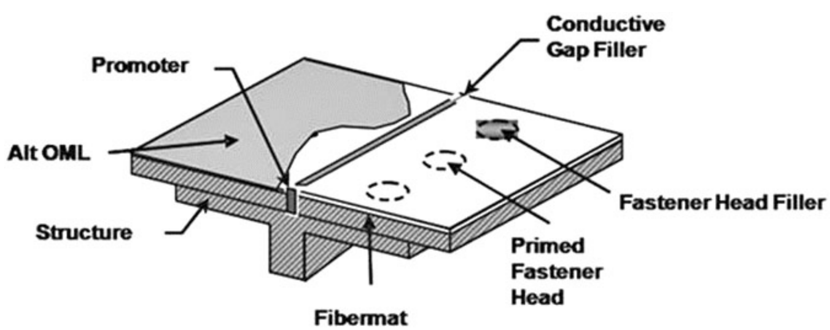

Figure 4–20. Gap filler.

Use of zip cords

For some aircraft, zip cords are installed prior to gap-filler application. The purpose of a zip cord is to aid in the removal of the gap filler during future maintenance actions. Install zip cords IAW applicable aircraft technical data. If working on an overhead panel, the cord may not stay in without you using some form of aid to hold it in until the gap filler is applied.

Protecting the substructure

Before any filler can be applied to a panel seam, you must ensure that the substructure is protected. Conductive fillers contain heavy metals and can be very corrosive to the airframe and metal panels. As a corrosion-control maintainer, you have learned that before you apply organic coatings to any surface, it must be clean and dry. The same applies to preparing gaps for filler applications; panel seams must be cleaned and primed. Use only authorized chemicals when cleaning; isopropyl alcohol (IPA) is a common cleaning chemical used on LO platforms. Ensure that you read and follow all safety instructions and warnings. After cleaning operations are complete on a repair, wait 10 minutes to allow any trapped cleaning chemicals to dry before applying primer.

Applying the primer

It is important that you ensure 100 percent coverage in the panel gap and fastener heads; depending on the type of aircraft you are working, there may be several ways to apply primer to panel gaps and fasteners. For priming seams and fasteners, the spray-and-roll method is not practical. The most effective way to apply coatings to panel seams, fasteners, and small touch-up repairs is to use a fantail artist brush. After allowing the primer to cure IAW the aircraft-specific TM, ensure that you inspect for unprimed areas and reapply as necessary.

Once the primer is cured, the filler (caulk) can be applied to the gaps and fastener heads. Consider all available tools and the size of the job when applying gap filler. It is important to apply the filler in a manner that you do not leave air bubbles in the gap; it can be applied with a squeegee (fig. 4–21), tongue depressor, scraper, caulking gun, and so forth.

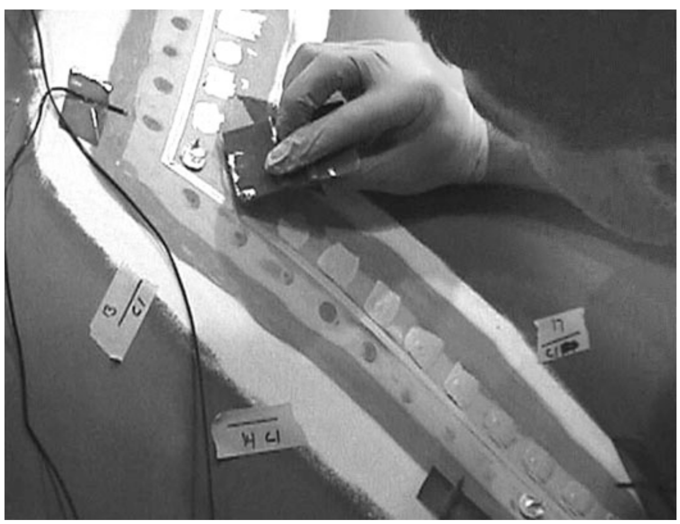

Figure 4–21. Gap-filler application.

Skiving

Skiving is an LO maintenance technique used to cut away thin layers of excess gap filler to maintain aerodynamic smoothness requirements. Depending on the specific weapons system, gap filler is applied in gaps to ensure the smooth surface over the void. The most important preparation step when using the skiving technique is to temporarily place metal shims on each side of the gap to protect the surrounding area. Apply the metal shims to both sides of the gap to prevent the skiving (cutting) tool from coming into contact with or damaging the surface of the panel or aircraft. Once the gap filler is cut away, sand the remaining filler flush with the surface.

Fairing materials

Signature reduction relies on a smooth, continuous conductive layer; therefore, surface smoothness is critical and must be maintained. At times, adjoining panel surfaces are mismatched in height; this can cause a step-height condition (fig. 4–22), which will cause a return on the signature of the structure. LO weapon systems use fairing materials to alleviate step conditions between OML skins, panels, doors, or aerodynamic fairings.

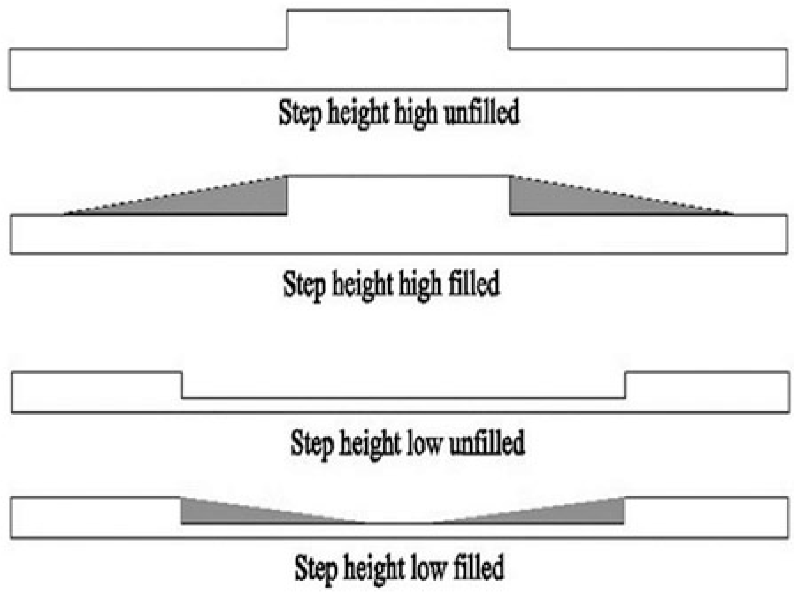

Figure 4–22. Step-height conditions.

Just as with fillers, the two types of fairing materials are conductive and nonconductive. The type of fairing material will be determined by the weapon system-specific TO data. You will use the same processes, materials, and techniques to apply fairing material as you do with filler material. The main difference between filler and fairing material is that with fairing material you must incorporate a fairing ratio.

A properly applied fairing will allow radar energy to flow smoothly across the mismatched panels. The ratio of the fairing repair will be determined by the TO (e.g., a panel that has a 0.130-inch step condition and the technical data requires a 100:1 fairing ratio [fig. 4–23]). To calculate your transition, simply multiply the first part of the ratio by your step condition; for example, 100 × 0.130 inch = 13 inches. You would have to create a 13-inch transition area to overcome the 0.130-inch step condition. If the TM required a 75:1 ratio for the same 0.130-inch step condition, your transition would be 9¾ inches (75 × 0.130 inch = 9.75 inches).

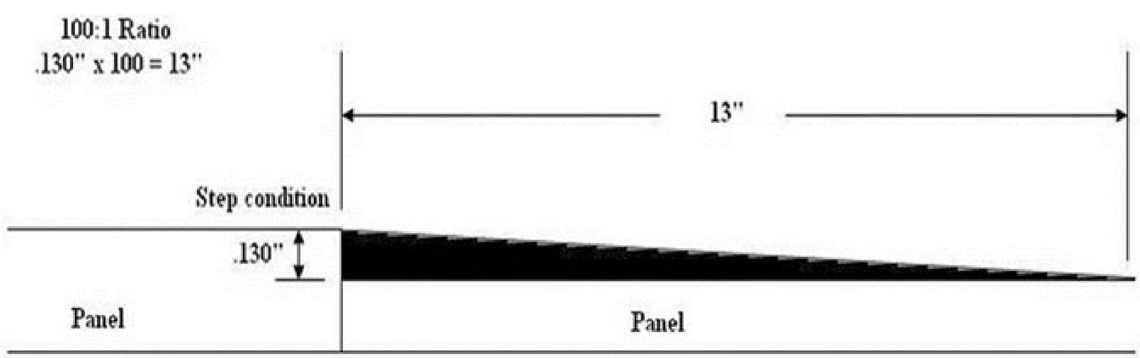

Figure 4–23. Fairing ratio—100:1.

428. Curing materials

The curing process is a vital step in the coating application process. There are several different configurations that can be used and many variables that will affect the curing process. Such things as ambient air temperature, aircraft surface temperature, and relative humidity of areas being repaired/restored should be considered in any coating application decision. Ensure weapon system-specific manual guidance and manufacture guidelines are closely followed.

Factors that affect the cure process

Issues of primary concern that may adversely affect cure times are described in the following table:

Factor	Result
Low humidity	Retards the cure of moisture-cured coatings.
High humidity	Can reduce the work life of vulcanizing materials, ultimately causing the materials to cure too fast.
Low temperatures	Causes slow drying, or cure, longer tack-free time.
High temperatures	Causes a rapid evaporation of solvent that leads to premature skimming, pinholes, cracked finish, or excessive dryness.
Condensation on the aircraft surface or in the applied coating	Causes a coating failure and/or degradation of the LO properties.
Incomplete curing	May cause weak bond line between layers.

Ambient and forced cures

Ambient cures are material cures that occur at room temperature without heat or other devices to help speed up the cure time. Ambient cures usually require the material to be in a controlled environment for temperature and humidity. Some LO materials are sensitive to UV rays, and repairs should be accomplished in a shaded environment. Careful consideration of the repair size, conditions in a repair facility, outdoor environment, and length of cure is necessary when choosing an ambient cure. If time permits, ambient cures are preferred. However, operations tempo may dictate that the material be force cured.

Forced cures allow for shorter repair times and are material cures aided by heat or other devices to speed up the curing process. The ability to rapidly cure LO coatings will decrease the repair time and may significantly increase the aircraft availability. Care should be taken when using a force cure to not damage surrounding LO materials or structure by exceeding temperature range. Force-cure procedures and limitations can be found in the weapon system-specific TM.

Contact cures

A contact cure is when you are required to conduct a cure under direct pressure. A contact vacuum-bag system (fig. 4–24) is used when uniform pressure is required across the bonded surface. This system is the same as the one you use when repairing composite components. However, it is important to gather all materials and equipment ahead of time and to rehearse the repair procedures to discover any trouble spots before starting the vacuum-bag system. Pre-bagging is especially important if a cure cycle is to be accelerated with a heat or humidity source. Refer to weapon system-specific TM and TO 1–1–690 for step-by-step setup of vacuum bags.

Noncontact cures

If you are required to accelerate the cure and you cannot have anything touching the surface, you can set up a noncontact cure. For a noncontact cure, you will need to build a heat bag or tent that encompasses the entire repair site. This bag needs to be large enough to allow a heat gun to circulate air in the bag. Place a minimum of three TCs ½ inch away from the repair area. Two noncontact systems that can be used are the heated noncontact vacuum-bag system and the heated noncontact bagging system.

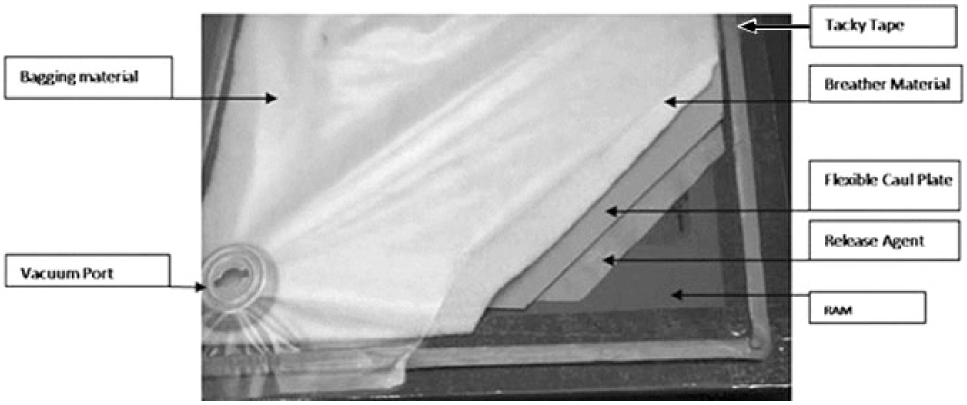

Figure 4–24. Contact vacuum-bag system.

Heated noncontact vacuum-bag system

A noncontact vacuum bag system (fig. 4–25) is used when the area to be bonded cannot withstand surface pressure. A scenario most likely to fall into this category would be exposed core that could crush under constant vacuum pressure. Protect and cover the repair area using a tool, such as a heat tunnel, that will withstand and diffuse the vacuum pressure.

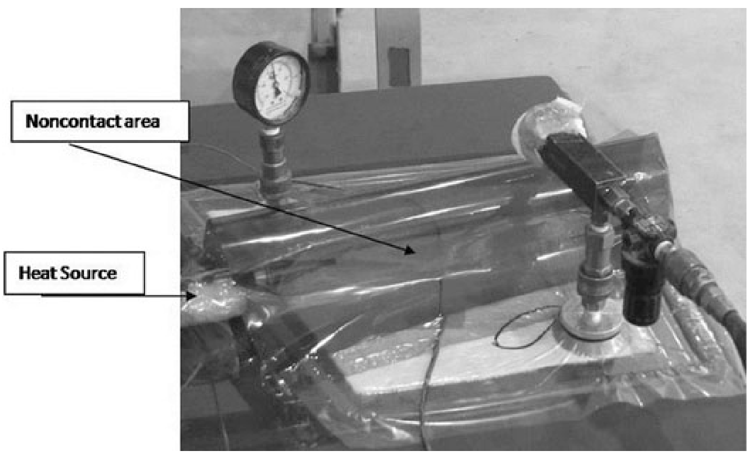

Figure 4–25. Noncontact vacuum-bag system.

Heated noncontact bagging system

A noncontact bagging system or curing oven is used when heat, not pressure, is required for the repair. In most cases, bagging material is constructed around the repair (fig. 4–26), held up with make-shift frames to prevent the bagging from collapsing and contacting the repair area. A heat source, primarily a heat gun or hot-air gun, is used to accelerate the cure. Always use TCs to monitor the temperature.

Types of curing equipment

There are several pieces of equipment that you may use to cure the wide variety of LO materials. Any time that you are using equipment to elevate the temperature of a material, extreme caution should be exercised. Never leave heating equipment unattended.

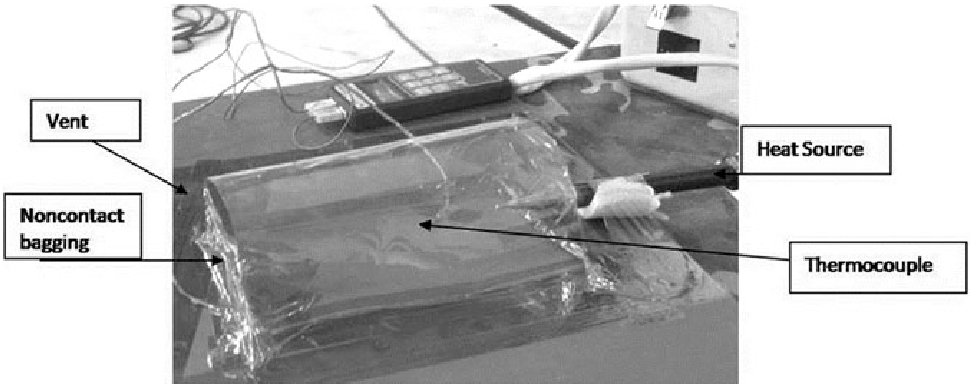

Figure 4–26. Heated noncontact curing oven.

Vacuum kit

Vacuum kits (fig. 4–27) typically consist of a vacuum gauge, quick-disconnect fitting, vacuum port, and vacuum base. These kits are commonly used to apply external pressure to materials during the curing process. Vacuum kits can be operated with regular wall air or a vacuum system.

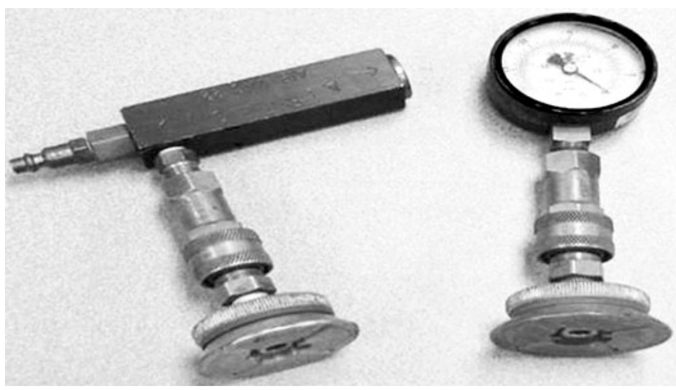

Figure 4–27. Vacuum kit.

Hot-melt iron

A hot-melt iron (fig. 4–28) is a tool used for applying LO thermoplastic materials on the F–35 aircraft. Similar to a soldering iron, the hot-melt iron heats up a thermoplastic material, which, in turn, melts to fill in the repair site (fig. 4–29). Some examples of hot-melt material can be fastener dots for fastener filler and hot-melt sticks for gouge repairs.

Figure 4–28. Hot-melt iron.

Figure 4–29. Hot-melt application to fastener heads.

Heat tunnels

Heat tunnels (fig. 4–30) are locally manufactured and designed for OML areas that require forced (accelerated) cures. They are reusable assemblies that assist in eliminating waste and save man-hours. The dimension and shape of the tunnel will be determined by the size and shape of the repair area. The top of the assemblies should be manufactured with adjustable port openings to increase or decrease temperature range. Heat tunnels are used in conjunction with heat and nitrogen guns and are monitored with TCs.

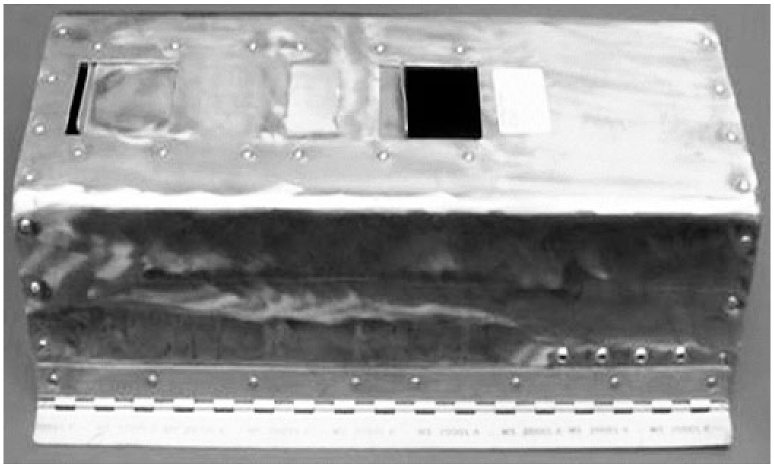

Figure 4–30. Heat tunnel.

Heat guns

Heat guns are used on certain weapons systems to force cure coating repairs. Different configurations have been used in the field to facilitate maintenance. Some models of heat guns can reach extremely high temperatures and can cause serious injury and/or extensive damage to equipment if not used and monitored correctly. TCs shall be used at all times to monitor the surface temperature. Refer to specific weapon system-specific repair manual and TO 1–1–690.

Nitrogen heat gun

The compressed air/nitrogen heating gun is designed as a portable source of heat and is safe for use around fueled aircraft because an open heating element is not required. The compressed air/nitrogen heating tool can be used to provide heat for noncontact curing processes.

Always refer to the operator’s manual for safe operating procedures for the compressed air/nitrogen heating tool. Use extreme caution if you are using nitrogen; in a poorly ventilated area, nitrogen can cause suffocation. The following steps provide a brief summary of the procedures for use:

1. Push down and fully turn the air regulator knob counterclockwise. This is to ensure that the air regulator is off.
2. Remove the dust cap from the air inlet nipple where you would connect the air or nitrogen source line to.
3. Attach the air/nitrogen hose to the inlet nipple, making sure there is a firm connection. Do not exceed 200 pound-forces per square inch gauge (psig).
4. Once the air/nitrogen source is properly attached, push down and turn the air regulator knob clockwise until the pressure on the air pressure gauge indicates between 5 to 7 psig.
5. Plug in the power cord to an appropriate grounded power supply.
6. Set the power switch to the ON position. The power lamp and heated-air–on lamp will both illuminate. (If the lights do not illuminate, check the switch located on the gun handle. The switch must be positioned toward the front of the handle.)

7. There is a one-minute warm-up time. During this warm-up period, ensure that the indicated air pressure increases to between 10 and 15 psig on the air-pressure gauge.
8. You can now adjust the temperature control knob to the desired temperature setting.
9. You can turn the air/nitrogen pressure off and on to the gun without powering down the module by using the switch mounted on the gun handle.

After you complete your task with the compressed air/nitrogen heating tool, use the following shutdown procedures:

1. Push down and fully turn the air regulator knob counterclockwise. Observe that the air pressure gauge indication drops to 0 psig and the heated air lamp extinguishes.
2. Position the switch on the heating gun toward the rear of the handle.
3. Place the power switch to the OFF position, and observe that the power lamp goes out.
4. Allow the air/nitrogen to flow for a minimum of one minute to cool the heating gun. (This procedure is done to extend the life of the heating element.)
5. Disconnect the power connecter from the power source.
6. Disconnect the compressed air/nitrogen hose from the air inlet nipple, and install the dust cap on the air inlet nipple.

Portable compressed hot air system

Typically used on the B–2 aircraft, the portable compressed hot-air system (PCHAS) is a portable compressed-air heating system for delivering a flow of heated air that can be directed at the surface of the aircraft. The system includes a heater module for receiving and heating a continuous volume of air. Also included is a hot-air distribution system that allows for placement of multiple hot-air tubes on different areas of the aircraft. A PCHAS can reach temperatures of over 600°F for high-temperature cures.

429. Verifying the process

Maintaining LO combat aircraft in a mission-ready state is of paramount importance, and our aircraft must be ready to be sent into combat at a moment’s notice. Furthermore, the aircrew of our stealth aircraft must have full confidence that the stealth characteristics of their jet are in place and working as intended. The success of the mission and the lives of the aircrew depend upon the quality of your maintenance. To ensure the integrity of the weapons platform, a comprehensive inspection and verification system has been established. Process verification is extremely important during all phases of application and repair because stealth characteristics are dependent upon the processes involved in applying LO materials. Two of the most common types of process verification that you will be performing are visual and aerodynamic smoothness verification. Other methods include point inspections (using Loresta Meters), zonal radar imaging (such as RVRs), and full-body imaging (flying the “Range”).

Visual verification

You will perform a visual process verification every time that you work on an LO aircraft or component. Visual process verification is simply a visual inspection, which is performed without the aid of diagnostic equipment, of the processes being performed. Whether you are removing damage, preparing an area for repair, stacking repair materials, or applying coatings, it will be necessary to verify that all required steps were performed. To visually verify any process, you will need to have the applicable TO readily available to reference specific requirements. The list of items that you will need to inspect or verify is long; however, the following list provides some of the things that you may be looking for:

- Shelf life of materials is current.
- Repair site is clean.

- Correct materials are being used.
- Correct tie-in measurements are used.
- Repair meets planform alignment requirements.
- Materials are mixed IAW manufacturer's instructions.
- Materials are stacked in proper sequence.

It is important to continually verify your processes so that if problems do arise, they can be fixed early. If you do not identify problems early, they may not be detected until later when costly rework will be necessary.

Aerodynamic smoothness

Additional attention should be given to maintain aerodynamic smoothness prior to and during application of LO coatings. Coatings that are not aerodynamically smooth can cause an RCS impact. Smoothness criteria to be concerned with include gaps, step conditions, fastener flushness, and alignment issues. Mechanical verification is accomplished to assess compliance with designed tolerances. All these parameters can be verified using mechanical means, such as feeler gauges (fig. 4–31), pit-depth gauges, or optical tools (fig. 4–32). Specific requirements and repairs for aerodynamic smoothness can be found in your weapon system-specific TM.

Figure 4–31. Feeler gauges.

Figure 4–32. Optical comparator.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

424. Preparing the surface

1. What three things play major roles in the overall outcome of your coating system?

2. As a maintainer, what guidance must you follow when performing hazardous operations?

3. Where can you find a list of *minimum* recommended PPE to help protect yourself during hazardous operations?

4. What should you do if a new workload is introduced into your work center?

5. What is the temperature range for attempting repairs?

6. What is the key to ensuring good adhesion of a repair material?

7. When preparing surfaces, what is the purpose of masking?

8. Why is it important to prepare bare-metal surfaces prior to applying LO materials?

9. What will happen if a composite repair area is not properly prepared?

10. What must you do prior to applying any coating to a RAM surface?

11. What do you do to help ensure that the flex primer adheres to the RAM?

12. What do you clean the repair area with prior to applying any coatings?

425. Using low observable primers and paints

1. In order to vary, what can LO coating material stack ups depend upon?

2. Why are primers used?

3. What is the most important aspect of the LO coating system?

4. When applying conductive coatings, what is the purpose of constant agitation of the material?

5. What will happen if splatters and drips are allowed to remain on the surface of the aircraft?

6. What are the three methods for applying primers and paints?

7. What determines which coating application method to use for primers and paints?

8. What type of brush should be used to apply primers and paints?

9. Describe the most effective roller cover for applying topcoat materials.

10. Why is spraying the preferred method for applying primer?

426. Applying radar absorbing material

1. During the RAM application process, what information will the weapon system-specific technical data provide you?

2. How can sheet RAM be used?

3. What must you consider when applying sheet RAM?

4. Why would you have to taper sheet RAM?

5. What must you do after the RAM replacement piece is in place and the proper gap is obtained?

6. What can you do to maintain the position of edge molding during application?

7. What is the result of applying too thick of a layer of sealant to RAM?

8. What two methods can be used to obtain the correct mil thickness for sealant?

9. Describe the peel-and-stick application process.

10. What must you do prior to applying RAM to fasteners?

11. What is the result of applying RAM over improperly installed fasteners?

12. What does a RAM washer-cutter kit typically consists of?

427. Applying filler and fairing material

1. What are fillers also known as?

2. What are the two basic types of fillers?

3. When repair materials are removed from cold storage, how must they be cared for?

4. Why must gaps be filled on LO aircraft?

5. What is the purpose of a zip cord?

6. What is the most effective way to apply primer to seams and fasteners?

7. What is the most important preparation step when skiving?

8. What does a step-height condition cause?

9. What determines the type of fairing material you will use?

10. If your technical data calls for a 100:1 fairing ratio for a .150-inch step condition, how long would your transition area be?

428. Curing materials

1. What is an ambient cure?

2. What is a forced cure?

3. What can happen if temperature ranges specified in the TM are exceeded?

4. When is a contact vacuum-bag system used?

5. What can you do to discover any trouble spots prior to starting a vacuum bag?

6. When would you use a noncontact cure?

7. Describe how to set up a noncontact cure.

8. When would you use a noncontact vacuum-bag system?

9. What is a vacuum kit typically used for?

10. How does a hot-melt iron work?

11. What determines the size and shape of a heat tunnel?

12. Why are heat guns used on certain weapons systems?

13. What are used to monitor surface temperatures when using a heat gun?

429. Verifying the process

1. When will you perform visual process verification?

2. What is visual process verification?

3. What do you need to visually verify any process?

4. Why is it important to continually verify your processes?

5. What can happen when coatings are not aerodynamically smooth?

6. What is the purpose of mechanical verification?

7. How can you verify required parameters have been met?

Answers to Self-Test Questions

421

1. It can skew signature information and cause a miscalculation of mission-capable status.
2. Because lack of attention can lead to damage propagation of the LO material being further uplifted or completely torn off while in flight.
3. Due to multiple LO material stack-up that hides the initial stages of corrosion.
4. It becomes visibly evident by disbonds and bubbles.
5. Areas around gaps, seams, crevices, drain holes, fastener heads, and internal structures.
6. A composite structure can easily be damaged and show no defect on the outer surface; however, the backside may have sustained substantial damage.
7. Conduct an Ohm's test.
8. The appearance of the coating will look "cloudy" and/or it will not have a uniform appearance.
9. By removing the defective coating and reapplying.
10. To the areas that have been formed.
11. With small parentheses at the termination points of the crack or scratch.
12. Minimally with dotted lines at the boundary of the damage.

422

1. The use of hand tools.
2. They are made of either phenolic-laminated fiberglass or a hard-nylon material. They come in a wide variety of shapes, sizes, material compositions, and hardness.

3. You can cause delaminations to composite panels or structure.
4. They have a tendency to be too aggressive in the removal process and can cause damage or the enlargement of the repair area.
5. It affords you the best control and helps to prevent damage to outer areas.
6. You may create further damage.
7. By always using a low trajectory.
8. Use a straight edge placed along the outline of the repair, and lightly score the RAM using an approved cutting tool.
9. By using nonmetallic picks or probes.
10. Classified shapes, angles, or tapers and hazardous metals, such as mercury, lead, iron, silver, and chromates.
11. At facilities where a lot of excess RAM is produced during the removal and installation process.

423

1. By racetracking.
2. Through proper tie-in.
3. To maintain continuity within each layer from the repaired area to the nonrepaired area.
4. To create a tie-in that will be used for the stack up of new materials.
5. It allows the EM energy to travel across the aircraft.
6. Research the damaged area.
7. To allow for sanding imperfections.
8. By measuring equal distance from the panel edges to the edge of the damaged coating.
9. When you sand through a coating layer and expose the coating layer below.
10. The bottom primer protects the composite material.
11. They contain metals as their conductive elements, and oxidation or corrosion of the coatings will occur if left unprotected from the elements.
12. The entire repair area will have to be stepped back to clean the area.

424

1. Personnel safety, aircraft surface temperature, and surface cleanliness.
2. All guidance given by the local safety office, bio-environmental engineers, applicable TM guidance, and manufacturer’s instructions.
3. Your section’s current bio-environmental survey.
4. Contact the base environmental office to discuss any new procedures.
5. Between 60° and 95°F.
6. A contaminate-free surface.
7. To prevent additional damage to surrounding surfaces and coatings.
8. To create an active bonding surface, remove contaminates, improve adhesion, and decrease corrosion potential.
9. Strength and durability of the materials will be adversely affected.
10. You must first repair any defects in the surface of the material.
11. Scuff sand the area with a medium-to-fine–grade sandpaper.
12. With an approved solvent and clean cloth.

425

1. Surface location and material configuration.
2. For their adhesion-improving and corrosion-inhibiting properties between the structure and subsequent materials.
3. The tie-in of conductive paints.

4. To ensure the metallic solids in the coating do not settle to the bottom of the mixing tray or spray equipment.
5. It will result in a detrimental RCS impact.
6. Brush, roll, and spray.
7. Individual circumstances and aircraft-specific technical data.
8. Those described in your aircraft-specific TO for types and styles of brushes allowed to apply coatings on your aircraft.
9. Those manufactured from ultra-high–density foam.
10. It provides a more uniform coating.

426

1. Information on material type, required angles, placement of repair pieces, and adhesive application.
2. For cover strips; covering large, flat surfaces; and repairing spray RAM when authorized by aircraft-specific technical data.
3. Surface area, shape, contours, and available equipment.
4. To minimize electrical discontinuities and maintain aerodynamic smoothness.
5. Fill it with a paste, caulk, or gap filler (depending on applicable tech data) to ensure the smoothness of the surface coating and transition between pieces of RAM.
6. Use pressure-sensitive tape to hold it in place.
7. The RAM can flex, causing cracks and other concerns.
8. Use scrim cloth or silk screen.
9. Cut the RAM to the shape of the repair or panel, peel the separator sheet that covers the adhesive, and stick it into place. After the new piece is installed, roll it down with a rubber-wheeled roller to remove any air bubbles.
10. Ensure that the fasteners have been installed correctly.
11. It will create extensive LO coating rework.
12. A rawhide mallet, a plastic cutting board, and various size washer-cutting dies.

427

1. Gap fillers, paste, slurry, or caulk.
2. Conductive and nonconductive.
3. They must remain in manufacturer's containers and be allowed to acclimate in the work area prior to being used to perform any repair procedures.
4. To ensure the smoothness of the aircraft structure.
5. To aid in the removal of gap filler during maintenance actions.
6. Use a fantail artist brush.
7. Temporarily place metal shims on each side of the gap to protect the surrounding area.
8. It will cause a return on the signature of the structure.
9. The weapon system-specific TO data.
10. 15 inches.

428

1. A material cure that occurs at room temperature without heat or other devices to help speed up the cure time.
2. A material cure aided by heat or other devices to speed up the curing process.
3. Damage surrounding LO materials or structure can occur.
4. When uniform pressure is required across the bonded surface.
5. Gather all materials and equipment ahead of time, and rehearse the repair procedures.
6. When you are required to accelerate the cure but cannot have anything touching the surface.

7. Build a heat bag or tent that encompasses the entire repair site. The bag needs to be large enough to allow a heat gun to circulate air in the bag. Place a minimum of three TCs ½ inch away from the repair area.
8. When the area to be bonded cannot withstand surface pressure.
9. To apply external pressure to materials during the curing process.
10. It heats up a thermoplastic material that, in turn, melts to fill in the repair site.
11. The size and shape of the repair area.
12. To force cure repairs.
13. TCs.

429

1. Every time you work on an LO aircraft or component.
2. A visual inspection that is performed without the aid of diagnostic equipment of the processes being performed.
3. The applicable TO to reference specific requirements.
4. So that if problems do arise, they can be fixed early.
5. They can cause an RCS impact.
6. To assess compliance with designed tolerances.
7. By using feeler gauges, pit-depth gauges, or optical tools.

Complete the unit review exercises.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

54. (421) When assessing low observable (LO) material defects, you must accurately identify width, depth/height, length, orientation, classification of damage, and
    a. disbursement.
    b. magnitude.
    c. relevance.
    d. location.

55. (421) Extreme heat expands the radar absorbing material (RAM), breaks down the adhesive bond and causes
    a. cracks.
    b. bubbles.
    c. gapping.
    d. uplifted edge.

56. (421) Corrosion is a serious problem for stealth aircraft because low observable (LO) coatings
    a. can hide the initial stages.
    b. allow contamination of other aircraft areas.
    c. make it difficult to effectively measure the extent of damage.
    d. are made of permeable material that permits moisture build-up.

57. (421) Extensive repair is usually required on low observable (LO) materials when corrosion becomes visibly evident by showing
    a. discoloration.
    b. curling edges.
    c. nicks and gouges.
    d. bubbles and disbonds.

58. (422) While using a pneumatic scraper to remove low observable (LO) coatings, what type of trajectory must you use to prevent delaminations in the composite structure?
    a. Low.
    b. Medium.
    c. High.
    d. Very high.

59. (422) When using a pneumatic scraper to remove low observable (LO) coatings around the edge of a panel, the direction you should scrape is from an
    a. edge and work towards an interior point.
    b. edge and work across to the opposite edge.
    c. interior point and work out toward the edges.
    d. interior point and work further to a more inward point.

60. (422) What tool do you use to remove filler material from gaps and seams on low observable (LO) aircraft?
a. Metallic scribe.
b. Sanding block.
c. Nonmetallic pick.
d. Pneumatic scraper.

61. (422) In order to safeguard the sensitivity of the material when discarding excess radar-absorbing material (RAM), you may have to use disposal equipment such as industrial shredders, hand-held cutting devices, and
a. grinders.
b. scrapers.
c. band saws.
d. incinerators.

62. (423) The term that describes the systematic removal of low observable (LO) coatings in a way that ensures a smooth transition between layers is
a. racetracking.
b. gap picking.
c. stack up.
d. fairing.

63. (423) Transitioning between an original coating and a new coating by overlapping alternating paints is called
a. racetracking.
b. stack up.
c. fairing.
d. tie-in.

64. (423) You should incorporate larger than minimum dimensions during your removal layout to allow for
a. composite repairs.
b. planform alignment.
c. sanding imperfections.
d. excess material removal.

65. (423) Sand a coating layer until the layer below is visible is called a burn
a. in.
b. out.
c. strip.
d. through.

66. (423) What can occur if the conductive elements of a coating are left exposed and unprotected for an extended period of time in a hot and humid environment?
a. Cross contamination.
b. Delamination.
c. Oxidation.
d. Distortion.

67. (424) What determines the aircraft surface temperature that must be maintained for a specific material application?
a. Location of the coating.
b. Manufacturer’s instructions.
c. General coating system technical order.
d. Weapon system specific technical order.

68. (424) The solvent wipe cleaning step for composite materials be omitted
    a. after the defects on the radar absorbent material (RAM) have been repaired.
    b. when the primer has been mixed to the manufacturer's specifications.
    c. after scuff sanding and coatings have been properly applied.
    d. when authorized by aircraft technical data.

69. (424) To ensure that flex primer will adhere to the surface of radar-absorbing material (RAM), scuff sand the surface of the RAM with
    a. coarse-grade sandpaper.
    b. coarse-grade steel wool.
    c. medium-to-fine grade sandpaper.
    d. medium-to-fine grade steel wool.

70. (425) What material is used for its adhesion-improving and corrosion-inhibiting properties?
    a. Paint.
    b. Primer.
    c. Kapton.
    d. Indium Tin Oxide.

71. (425) The exterior finish of the aircraft minimizes the moisture intrusion and provides ultraviolet protection for
    a. mechanical systems.
    b. resins and materials.
    c. metallic structures.
    d. electrical systems.

72. (425) The most effective roller covers for the application of primer are made from
    a. lint free, extra density, high quality soft woven fabric.
    b. high quality, medium-density bleached cotton.
    c. super-dense natural sponge.
    d. ultrahigh-density foam.

73. (426) When applying sheet-type radar-absorbing material (RAM), you must consider surface area, shape, available equipment, and
    a. caster.
    b. camber.
    c. contour.
    d. composition.

74. (426) When applying radar-absorbing material (RAM) with pressure-sensitive adhesive (PSA), you roll it down with a rubber-wheeled roller to
    a. remove air bubbles.
    b. improve aerodynamics.
    c. reduce the material thickness.
    d. decrease electrical discontinuities.

75. (427) How can you prevent moisture and condensation from degrading the performance of filler material that has been removed from cold storage?
    a. Open the manufacturers' containers and mix the components immediately.
    b. Allow the material to acclimate in the sealed manufacturers' containers.
    c. Open the manufacturers' containers and use the material immediately.
    d. Allow the material to acclimate in work center mixing containers.

76. (427) Zip cords are installed around some panels to aid in gap filler
    a. removal.
    b. restoration.
    c. application.
    d. identification.

77. (427) The most effective way to apply primer to panel seams during small repairs is to use a/an
    a. roller.
    b. airbrush.
    c. fantail artist brush.
    d. high volume/low pressure (HVLP) spray unit.

78. (428) When a repair requires uniform pressure across the bonded surface, you will use a
    a. portable compressed hot air system.
    b. heated noncontact bagging system.
    c. noncontact vacuum bag system.
    d. contact vacuum bag system.

79. (429) An inspection without the aid of diagnostic equipment of the procedures being performed is a/an
    a. tactile process verification.
    b. visual process verification.
    c. conductivity process check.
    d. aerodynamic process check.

80. (429) Mechanical verification of aerodynamic smoothness can be accomplished through the use of feeler gauges, pit depth gauges, and
    a. multimeters.
    b. optical tools.
    c. glossimeters.
    d. sonic comparators.

Glossary

Abbreviations and Acronyms

Acronym	Definition
°	degree
AAA	anti-aircraft artillery
AGE	aircraft ground equipment
ASSIGN TC	assign thermocouple
BMI	bismaleimide
BVID	barely visible inspected damage
dB	decibels
dBsm	decibels relative to square meters
EM	electromagnetic
F	Fahrenheit
FMC	fully mission capable
g	grams
GHz	gigahertz
HF	high frequency
Hg	mercury
HVLP	high-volume, low-pressure
IAW	in accordance with
IFE	iron-filled elastomer
IMS	inspection management system
inHg	inches in mercury
IPA	isopropyl alcohol
IR	infrared
ISR	intelligence, surveillance, and reconnaissance
ITO	indium tin oxide
LO	low observable
LOASM	low observable aircraft structural maintenance
LOHAS	low observable health assessment system
MAGRAM	Magnetic RAM
MHz	megahertz
mm	millimeter
NDI	nondestructive inspection
NMC	nonmission capable
NP	nonperforated
OEM	original equipment manufacture
OML	outer mold line
PCHAS	portable compressed hot air system

Acronym	Definition
PPE	personal protective equipment
pre-preg	pre-impregnated
PSA	pressure-sensitive adhesive
psi	pounds per square inch
PSIG	per square inch gauge
PVA	polyvinyl acetate
PVC	polyvinyl chloride
PVF	polyvinyl fluoride
RADAR	Radio Detection And Ranging
RAM	radar-absorbent material
RAS	radar-absorbent structure
R-Card	resistive card
RCS	radar cross section
RF	radio frequency
RLM	Reichsluftfahrtministerium
RTV	room temperature vulcanizing
RVR	Repair Verification Radar
SAM	surface-to-air
SAS	signature assessment system
SILOC	standard industrial laminate orientation code
TCTO	time compliance technical order
TC	thermocouple
TEST TC	test thermocouple
TM	technical manual
TO	technical order
UD	unidirectional
UHF	ultra high frequency
UV	ultraviolet
VHF	very high frequency
WWII	World War II

Student Notes

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