SUBCOURSE AL0992 | EDITION A

BASIC AIRFRAME REPAIR

AIPD

READINESS/ PROFESSIONALISM THRU GROWTH

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

BASIC AIRFRAME REPAIR

Subcourse Number AL0992

EDITION A

US Army Aviation Logistics School
Fort Eustis, Virginia 23604-5439

4 Credit Hours

Edition Date: September 1994

SUBCOURSE OVERVIEW

This subcourse is designed to provide you with a general familiarization of the airframe of today's aircraft and repair procedures. You will study the design and construction of aircraft parts and assemblies, metals used in the construction, and the metal qualities and stresses involved. You will also study procedures involved in the repair of damages to the aircraft skin and structure and the type of hardware required.

Early aviation's aircraft made of wood and fabric, reinforced with metal, were strong enough to withstand the vibrations and torsion stresses met at slow speed. However, with the need for higher speeds, greater payloads, and more powerful engines, wood became unsatisfactory. Manufacturers and designers realized that structural parts made with metal must replace the wood and fabric. So they developed light, strong metal alloys. To these they applied structural forming and reinforcing methods to reduce weight and to gain the strength required for increased performance.

Making repairs involved selecting the right metal for structural strength and streamlining, choosing the type of rivet to use, and determining the type of patch that will meet structural requirements. Also important is determining how much weight can be added, within safe limits, and choosing the method of structural forming and reinforcement to use.

You will find this text divided into two chapters which discuss airframe parts, metals, processes, hardware and damage repair. However, the discussion here is not a substitute for the technical manual (TM) applicable to a specific aircraft or a particular repair technique. The information given here is designed to give you a general background in basic airframe repair.

This subcourse is to be completed on a self-study basis. You will grade your lessons as you complete them using the lesson answer keys which are enclosed. If you have answered any question incorrectly, study the question reference shown on the answer key and evaluate all possible solutions.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

TERMINAL LEARNING OBJECTIVE

ACTION: You will demonstrate a knowledge of the basic fundamentals of airframe repair including airframe parts, metals, metal processing, hardware, and required procedures.

CONDITIONS: You will use the material in this subcourse.

STANDARD: To demonstrate competency of this task, you must achieve a minimum of 70% on the subcourse examination.

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LESSON 1

AIRFRAME PARTS, METALS, PROCESSES, AND HARDWARE

STP Tasks: 551-753-1002
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OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn airframe parts, metal qualities and stresses, metal working processes, and selected items of aircraft hardware.

LEARNING OBJECTIVE:

ACTION: You will identify and describe airframe parts demonstrate your knowledge of aircraft metals and metal processing, and apply your knowledge of selected items of aircraft hardware.

CONDITIONS: You will study the material in this lesson in a classroom environment or at home.

STANDARDS: You will correctly answer all the questions in the practice exercise before you proceed to the next lesson.

REFERENCES: The material contained in this lesson was derived from the following publications: FM 1-563 (Fundamentals of Airframe Maintenance). TM 1-1500-204-23-10

INTRODUCTION

An aircraft is constructed of many parts, or structural members, that are either riveted, bolted, screwed, bonded, or welded together. These structural members form units or assemblies, and they are then designated principal airframe parts. Individual structural members may vary in size, shape, or composition; however, the principal airframe parts they form are readily identified on any conventional aircraft as illustrated in Figures 1-1 and 1-2.

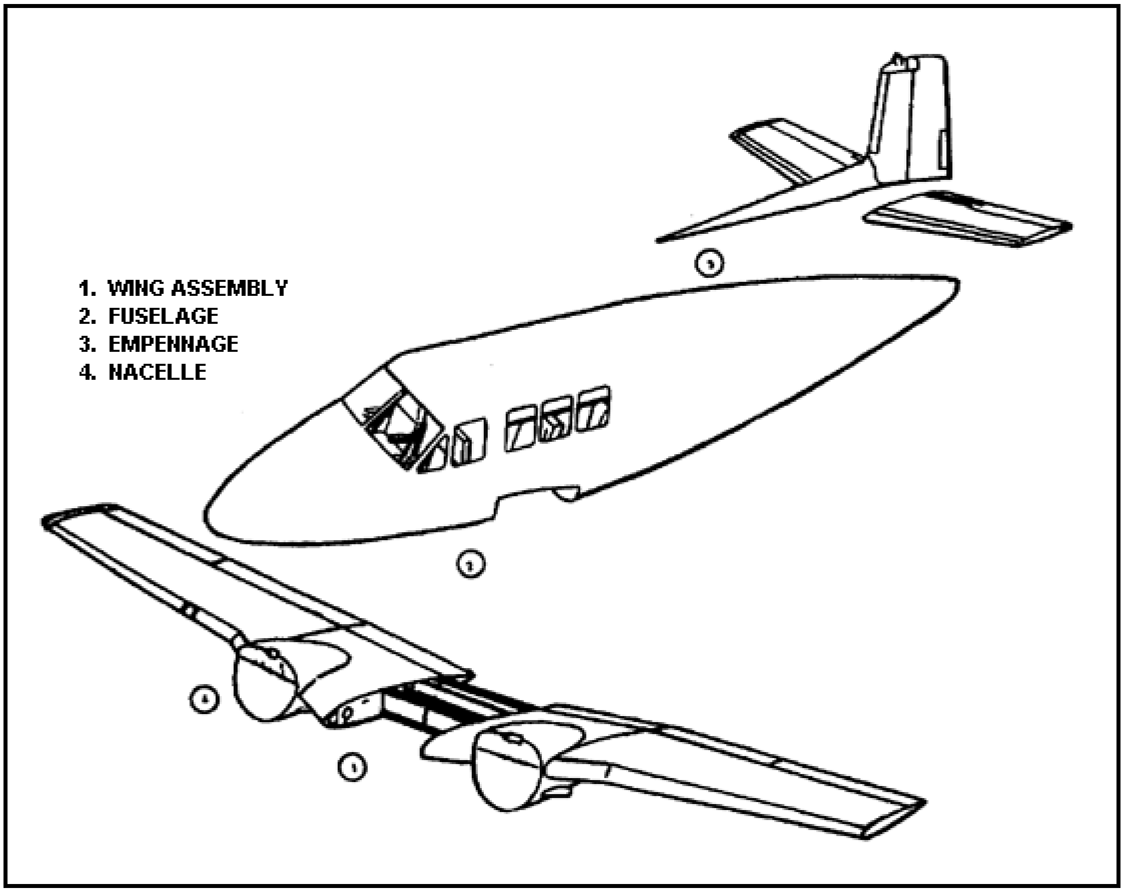

Figure 1-1. Principal Airframe Parts (Airplane).

Some aircraft manufacturers may use different names for the parts of an airplane or helicopter airframe, but the names shown in the figures are understood internationally. A working knowledge of the location, construction, and purpose of the various structural units of the aircraft is the basis for an intelligent approach to airframe repair.

This chapter, divided into four sections, describes airframe parts, metal qualities and stresses, metal-working processes, and aviation hardware.

PART A: AIRFRAME PARTS

GENERAL

The principal parts of an airframe are most commonly made of aluminum alloys in the form of shells. As a result, the main

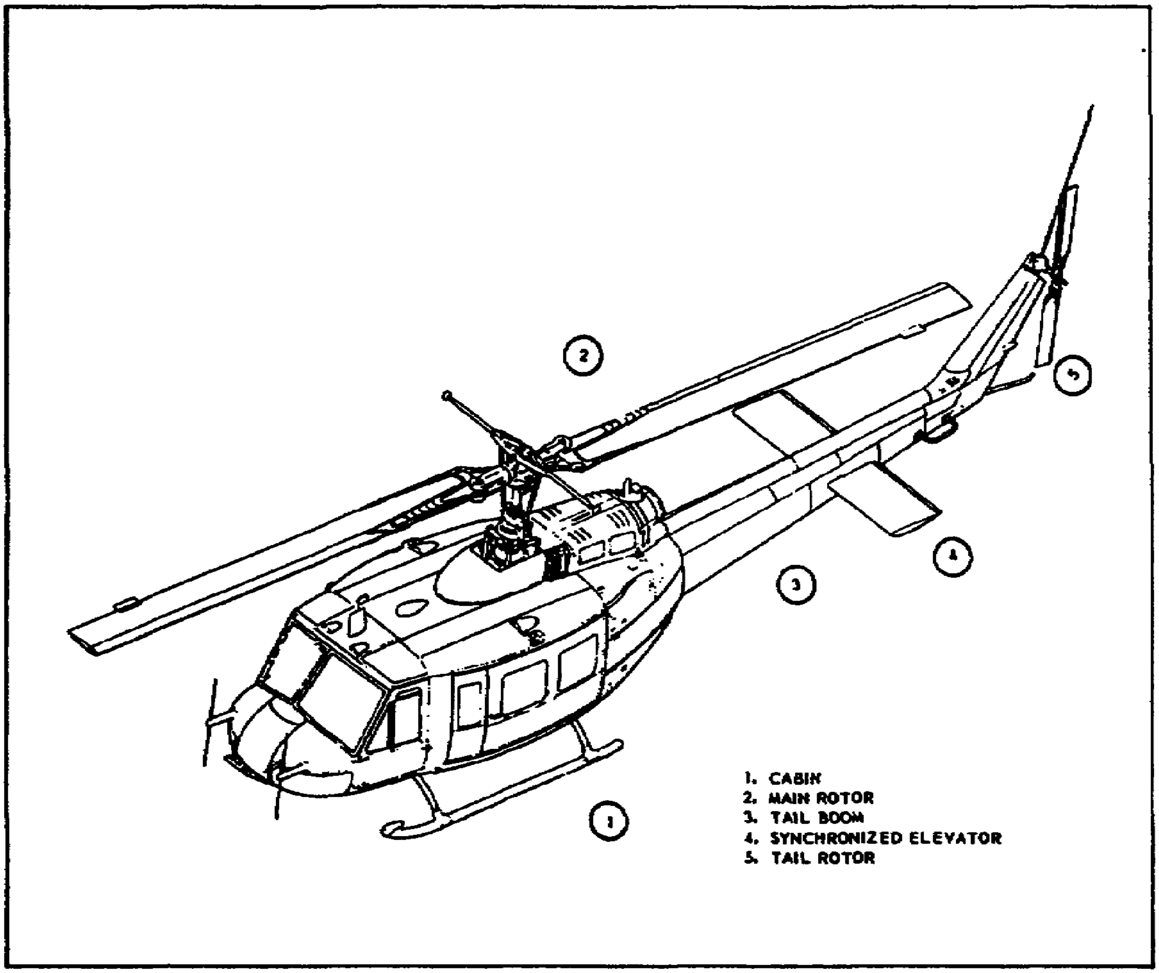

Figure 1-2. Principal Airframe Parts (Helicopter).

problem is to make the relatively thin shells strong enough to withstand compression and shear loads and to maintain a favorable weight-to-strength relation. In general, the discussion here explains how this is achieved for airplanes and helicopters.

This section describes the four principal parts of an airplane and the cabin and tailboom sections of a helicopter. The descriptions include details involving truss, monocoque, and semimonocoque constructions.

PRINCIPAL AIRFRAME PARTS (AIRPLANES)

An airplane's four principal parts are the fuselage, nacelle, wings and empennage. The descriptions in the following paragraphs cover the truss, monocoque, semimonocoque, and reinforced shell constructions for the fuselage; the structural members used; construction for the nacelle; monospar, multispar, and box-beam wing constructions; and empennage constructions.

Fuselage. The main structural unit of an airplane is the fuselage. Other structural units are directly or indirectly attached to it. In outline and general design, the fuselage of one airplane is much the same as any other. Designs vary principally in the size and arrangement of the different compartments. On military single-engine airplanes, the fuselage houses the powerplant, personnel, and cargo. The basic fuselage constructions are truss and monocoque. The truss construction, a rigid framework of beams, struts, and bars, shown in Figure 1-3, resists deformation by applied loads. Many smaller general aviation aircraft and a number of older military aircraft have used truss construction.

A monocoque fuselage, shown in Figure 1-3, is like a shell in that the skin bears the primary stresses in spite of the formers, frame assemblies, and bulkheads that give the fuselage its shape. The construction strength required depends upon the power used, speed, maneuverability, and design. The full monocoque construction is seldom used because the skin is the principal part of the airframe. The big problem in monocoque construction is maintaining strength and keeping weight down. To overcome this problem, the semimonocoque and reinforced shells were developed. These shells are used in the majority of present-day military aircraft.

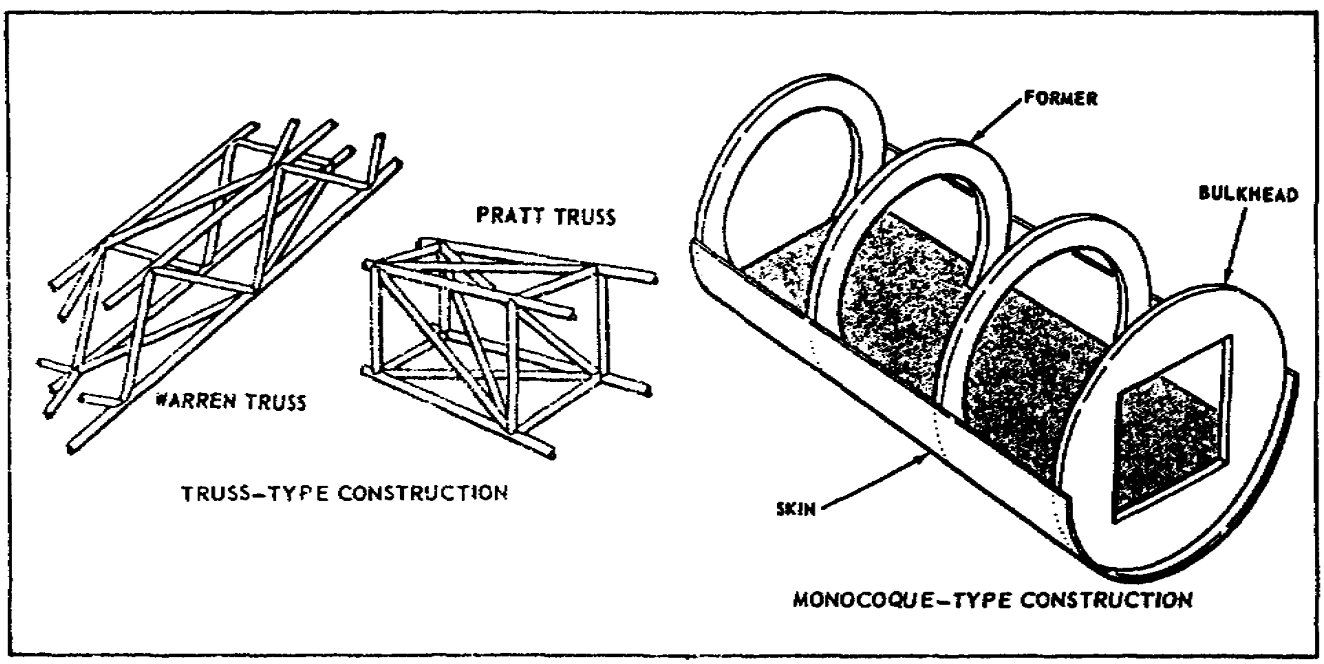

Figure 1-3. Fuselage Construction.

The semimonocoque fuselage, in addition to having vertical reinforcements (formers), has the skin reinforced by longitudinal members (stringers and longerons). The reinforced shell has the skin reinforced by a complete framework of structural members. Examples of semimonocoque and reinforced shell constructions are shown in Figures 1-4 and 1-5.

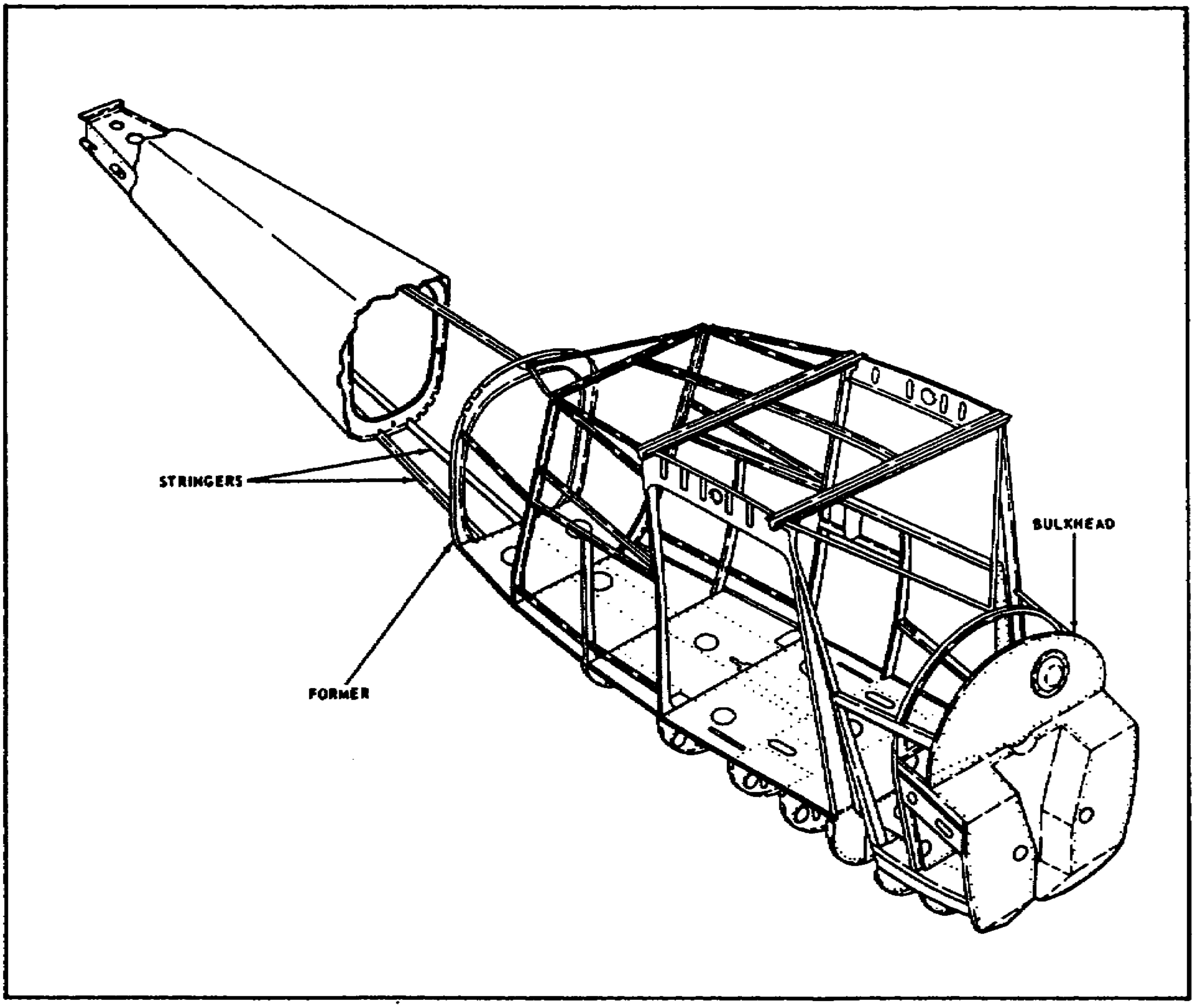

Figure 1-4. Semimonocoque Construction.

Structural Members. Formers, frame assemblies, and bulkheads give cross-sectional shape, rigidity, and strength to the fuselage. The shapes and sizes of these members vary considerably, depending on their function and position in the fuselage. Formers are the lightest, and they are used primarily for fillings or skin attachments between the larger members. Frame assemblies are the most numerous and outstanding members in the fuselage in appearance and as strengthening devices. Whenever frame assemblies are used to separate one area from another, they are circular or disc-shaped, reinforced, and equipped with doors or other means of access, and are then called bulkheads.

Channel members, hat-shaped sections, and built-up assemblies are inserted to give additional strength. Station webs are built-up assemblies located at various points to attach fittings or external parts, such as empennage surface fittings, engine mounts, wing attachments, and landing gear.

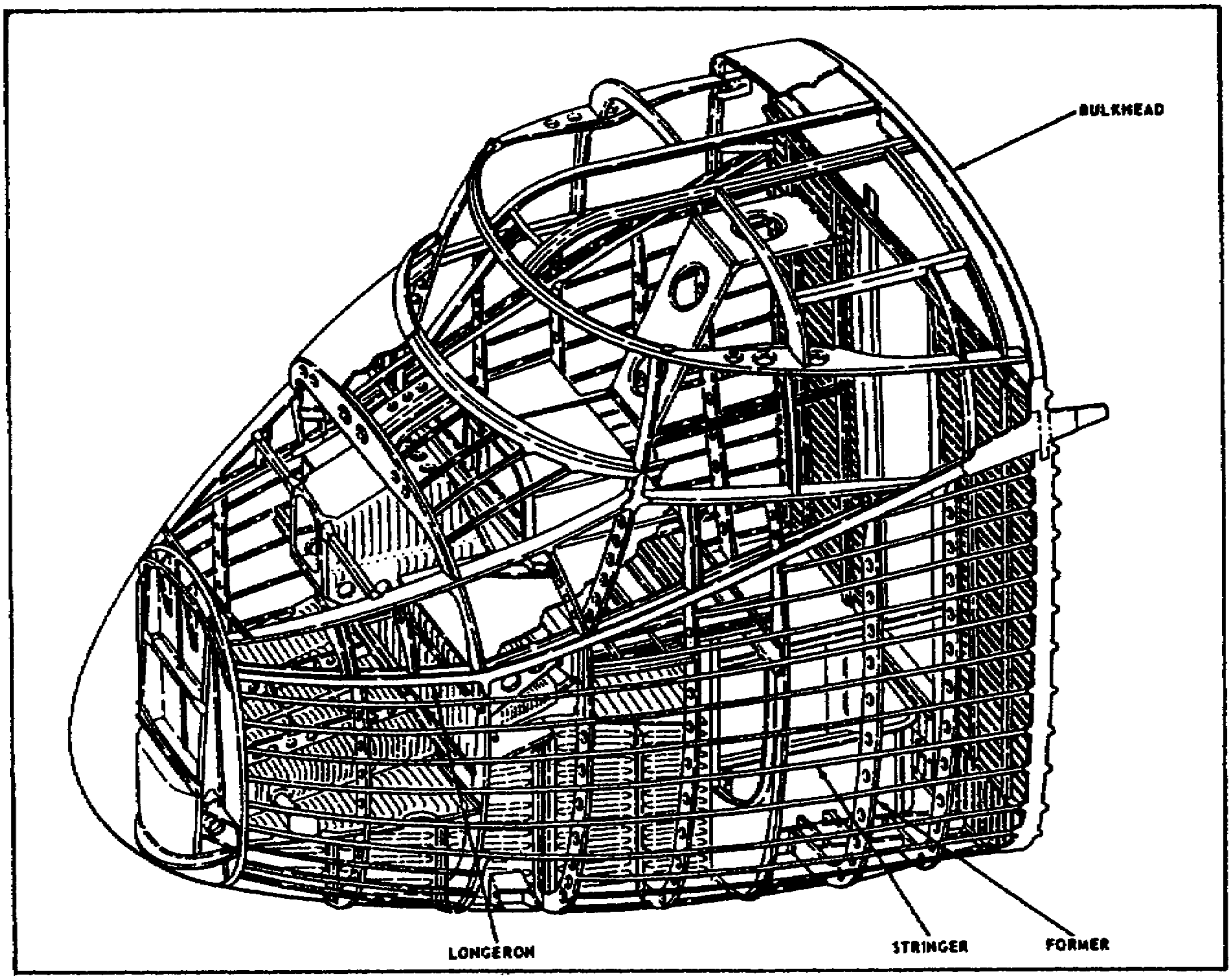

Figure 1-5. Reinforced Shell Construction.

Stringers and longerons are the main lengthwise members in fuselage structures. Notice in Figure 1-5 that the longeron is a fairly heavy member. Usually, several of these run the whole length of the fuselage. The stringers are smaller and lighter, and are used primarily for giving shape to the attached skin.

Longerons are stronger and heavier than stringers, and hold the bulkheads and formers, which, in turn hold the stringers. All these joined together make a rigid fuselage framework.

<u>Nacelle</u>. The streamlined structures (nacelles) on multiengine aircraft are used primarily to house engines. Figure 1-6 shows the construction of a nacelle in general use. Here also, designs vary depending upon the manufacturer and the use to be made of the nacelle. On twin-engine airplanes, nacelles also house the main landing gear and related equipment. Whether the nacelle houses a reciprocating piston or jet engine,

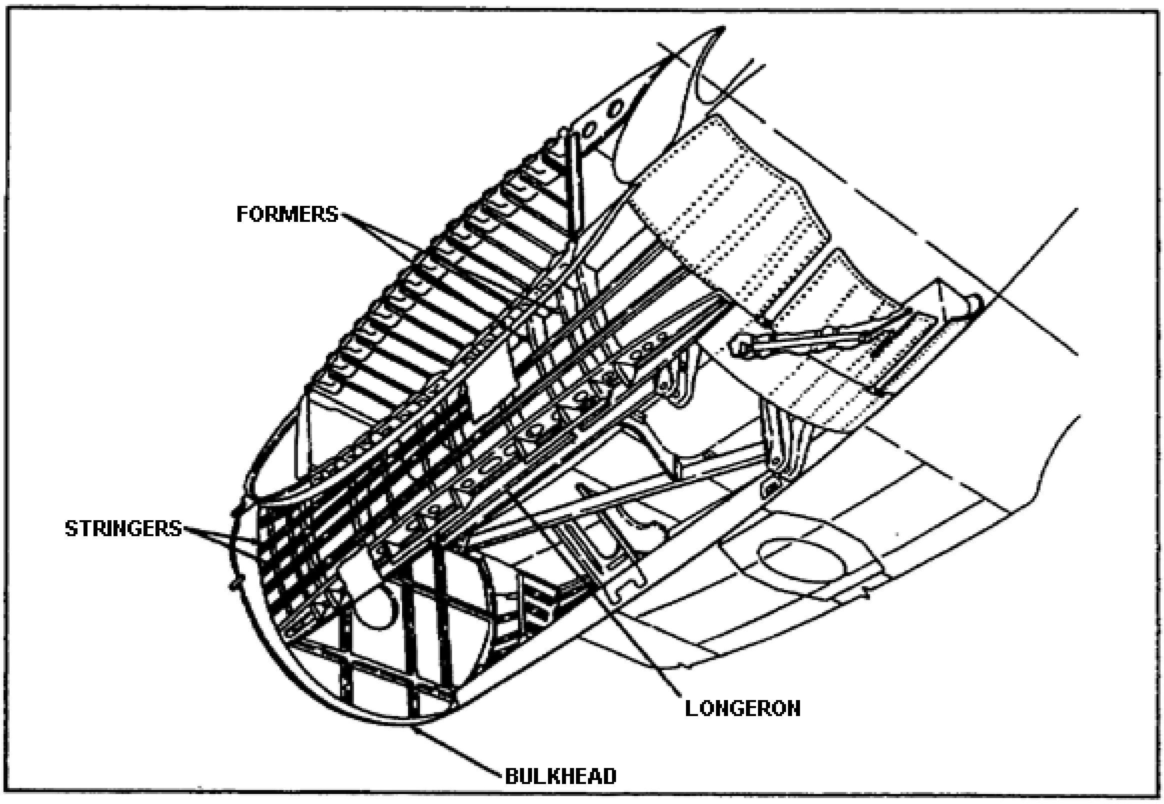

Figure 1-6. Nacelle Construction.

landing gear, or cargo, repair fundamentals are essentially the same as for a fuselage. The nacelle must have sufficient strength to withstand the compression and shear loads it will be subjected to; its weight must be kept within allowable limits; and the exterior must be aerodynamically suited for the nacelle's location on the aircraft.

Wings. Airplane surfaces designed to give lifting force when moved forward rapidly through the air are wings. Wing design for any given airplane depends upon size, weight, and use of the airplane; desired speed in flight and at landing; and the desired rate of climb. Wings are designated as left and right, corresponding to the left and right hands of the pilot seated in the cockpit. Variations in design give a wing its particular features. The wing tip may be square, rounded, or tapered. Both the leading edge and the trailing edge of the wing may be straight or curved. Many types of modern airplanes have swept-back wings. Wings on military airplanes are generally of cantilever design; that is, no external bracing is needed. Wings of this design are usually of the stressed-skin type. This means that the skin is part of the wing structure and carries part of the wing stresses.

Spar and Box-Beam Wings. In general, monospar, multispar, and box-beam are the three basic wing-construction designs. Modifications of these designs may be used by various manufacturers. A separate description of each basic design is given in the paragraphs that follow.

The monospar wing has only one main longitudinal member in its construction. Ribs or bulkheads supply the necessary contour or shape to the airfoil. The strict monospar wing is not in common use. However, this design is modified by adding fake spars or light shear webs along the trailing edge to support the control surfaces.

The multispar wing has more than one main longitudinal member in its construction. To give the wing contour and relieve stress on the wing's skin, ribs or bulkheads are often included. This construction, or some modification of it, is used in lighter airplanes.

The box-beam wing uses two main longitudinal members with connecting bulkheads to give additional strength and contour to the wing. A corrugated sheet of aluminum alloy may be placed between the bulkheads and the smooth outer skin so that the wing can better carry tension and compression loads. Sometimes, heavy longitudinal stiffeners are substituted for the corrugated sheets. A combination of corrugated sheets on the upper surface of the wing and stiffeners on the lower surface is sometimes used.

Wing Spars. Figure 1-7 shows spars, ribs, bulkheads, stringers, and stiffeners. These, the wing's main structural components, are riveted or welded together.

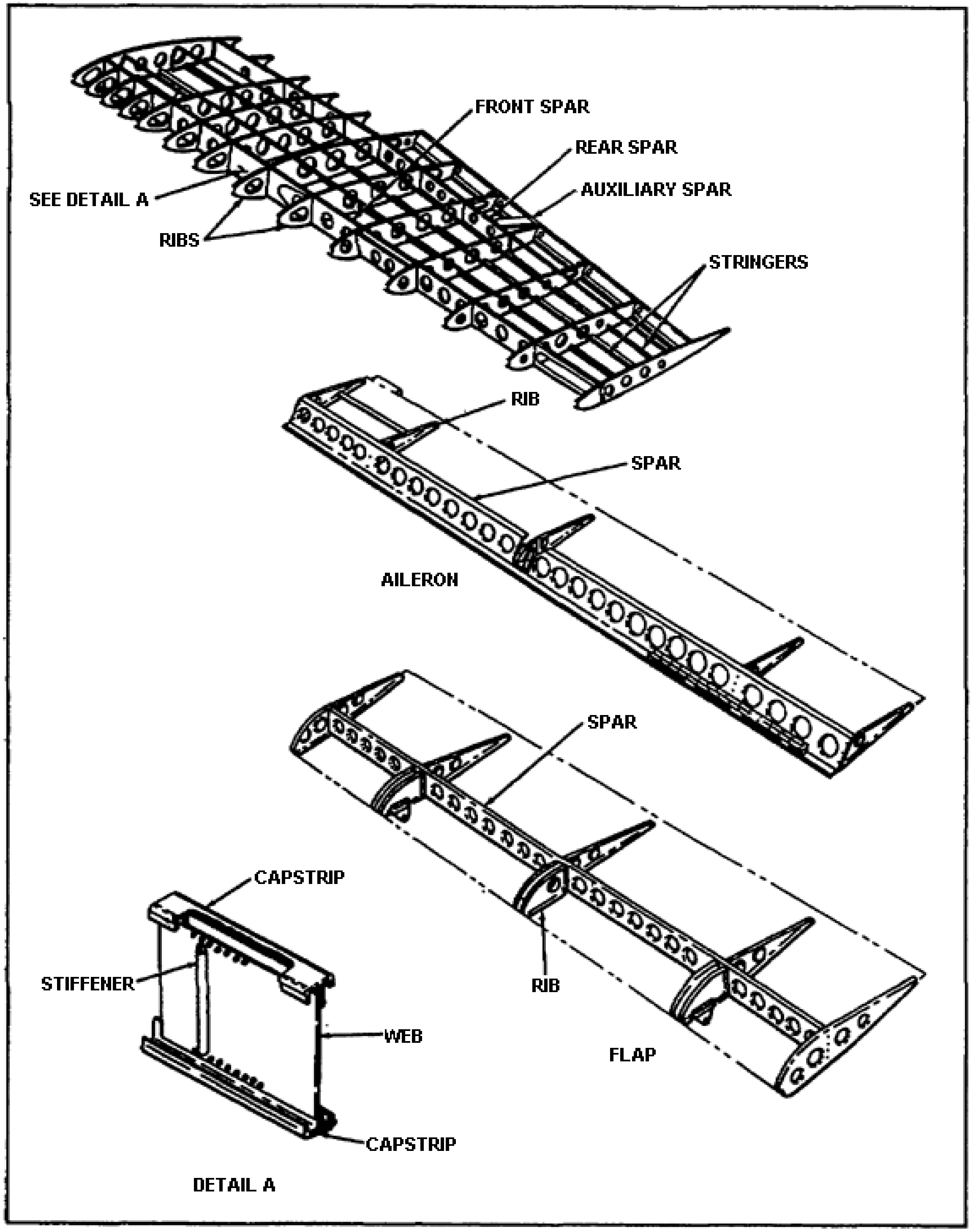

Figure 1-7. Wing Construction.

Spars are the principal structural members of the wing. They correspond to the longerons of the fuselage. Spars run from the base of the wing toward the tip and are usually attached to the fuselage by wing fittings, plain beams, or part of a truss system. The I-beam construction for a spar consists of a web, a deep wall plate, and capstrips. These are either extrusions or formed angles, as shown at Detail A in Figure 1-7. The web, the principal depth portion of the spar, is attached to the capstrips that carry the loads caused by the wings bending. When joined, the web and capstrips form a foundation for attaching the skin. Stiffeners give additional strength to the spar structure. These may be beads pressed into the web or extrusions or formed angles riveted to the web vertically or diagonally.

Wing Ribs. In the framework of a wing, ribs are the crosspieces running from the leading edge to the trailing edge of the wing. The ribs give the wing its contour and shape and transmit the load from the skin to the spars. Ribs are also used in ailerons, elevators, fins, and stabilizers. Figure 1-7 shows three general rib constructions: the former, reinforced, and truss ribs. Each type is discussed separately in the following paragraphs.

Former ribs, located at frequent intervals throughout the wing, are made of formed sheet metal and are very lightweight. The bent-up portion of a former rib is the flange and the vertical portion is the web. The latter is generally made with beads pressed between the lightening holes. These holes lessen the rib's weight without decreasing its strength. Lightening hole area rigidity is ensured by flanging the edges of the holes.

The reinforced rib is similar in construction to the spar, consisting of upper and lower capstrips joined by a web plate. Vertical and diagonal angles between the capstrips reinforce the web plate. The reinforced rib is used more frequently than the truss rib.

Vertical and diagonal cross members only are used to reinforce and join the capstrips in constructing truss ribs. These and reinforced ribs are heavier than former ribs and are used only at points where the greatest stresses are imposed.

Empennage. The aft end of the fuselage, or tail section of the aircraft, includes the rudder or rudders, elevators, stabilizers, and trim tabs, and it is called the empennage. Figure 1-8 shows the empennage construction. Airplane stabilizing units consist of vertical and horizontal surfaces at the aft end of the fuselage. In many respects, construction features are identical with those of wings. Empennage components are usually of all-metal construction and cantilever design. Both monospar and multispar construction are commonly used. Ribs develop the cross-sectional shape, and fairings are used to streamline angles between these surfaces and the fuselage. The vertical stabilizer, in addition to being the base for attaching the rudder, assists in maintaining the airplane's directional stability in flight. On propeller-driven airplanes, the vertical stabilizer is sometimes offset from the centerline to compensate for the torque developed by the engine and propeller. The horizontal stabilizer helps to maintain stability about the airplane's lateral axis, and it is the base for attaching the elevators. As with wings, many variations in size, shape, and placement, as well as number of components, are used by manufacturers in making an empennage.

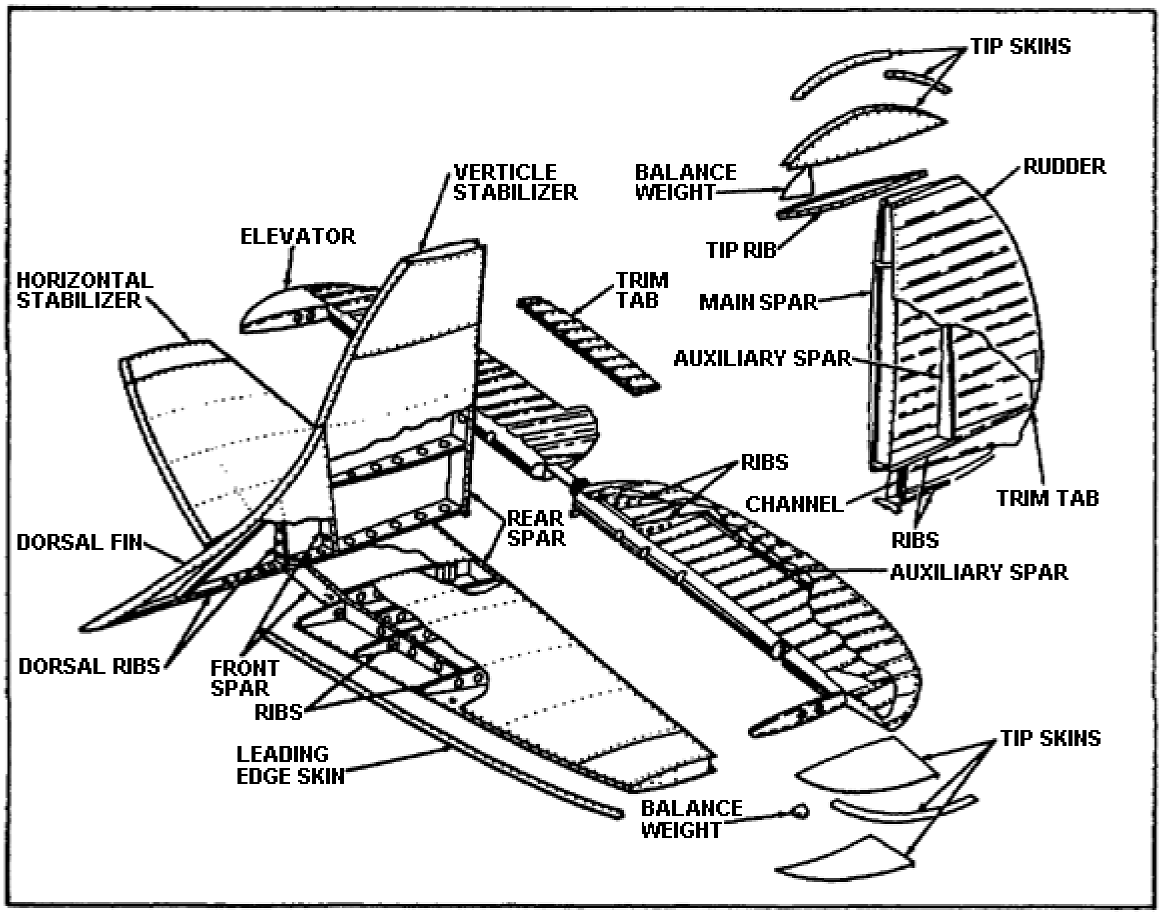

Figure 1-8. Empennage Construction.

PRINCIPAL AIRFRAME PARTS (HELICOPTER)

In general, the airframe structure for helicopters follows the basic principles of airframe structure for airplanes. For this reason, and to maintain simplicity in the descriptions, airframe discussion in the paragraphs that follow is limited to the single-rotor helicopter.

Cabin and Tail Cone Sections. A typical single-rotor helicopter is composed of two major sections: the cabin and tail cone. The cabin section contains compartments with space for the crew, passengers, cargo, fuel and oil tanks, controls, and powerplant. However, in multiengine helicopters the power plants may be mounted in separate engine nacelles. The tail cone section and landing gear are attached to the cabin section so that they can be removed, inspected, repaired when necessary, and replaced. The cabin is strong enough at points of attachment to withstand the forces involved in taking off, flying, and landing. The size and arrangement of compartments and the section construction vary with different types and manufacturers of helicopters. Figure 1-9 illustrates the cabin structure of a utility helicopter (UH-1). Notice that the structure is basically semimonocoque with variations to strengthen areas of high stress. The tail cone (boom), shown in Figure 1-10, attaches to the cabin and supports the tail rotor, tail-rotor drive shafting, and stabilizers.

Stabilizer. The airfoils attached to the tail cone to increase stability about the longitudinal and lateral axes of the aircraft during flight are stabilizers. Stabilizer construction is also semimonocoque.

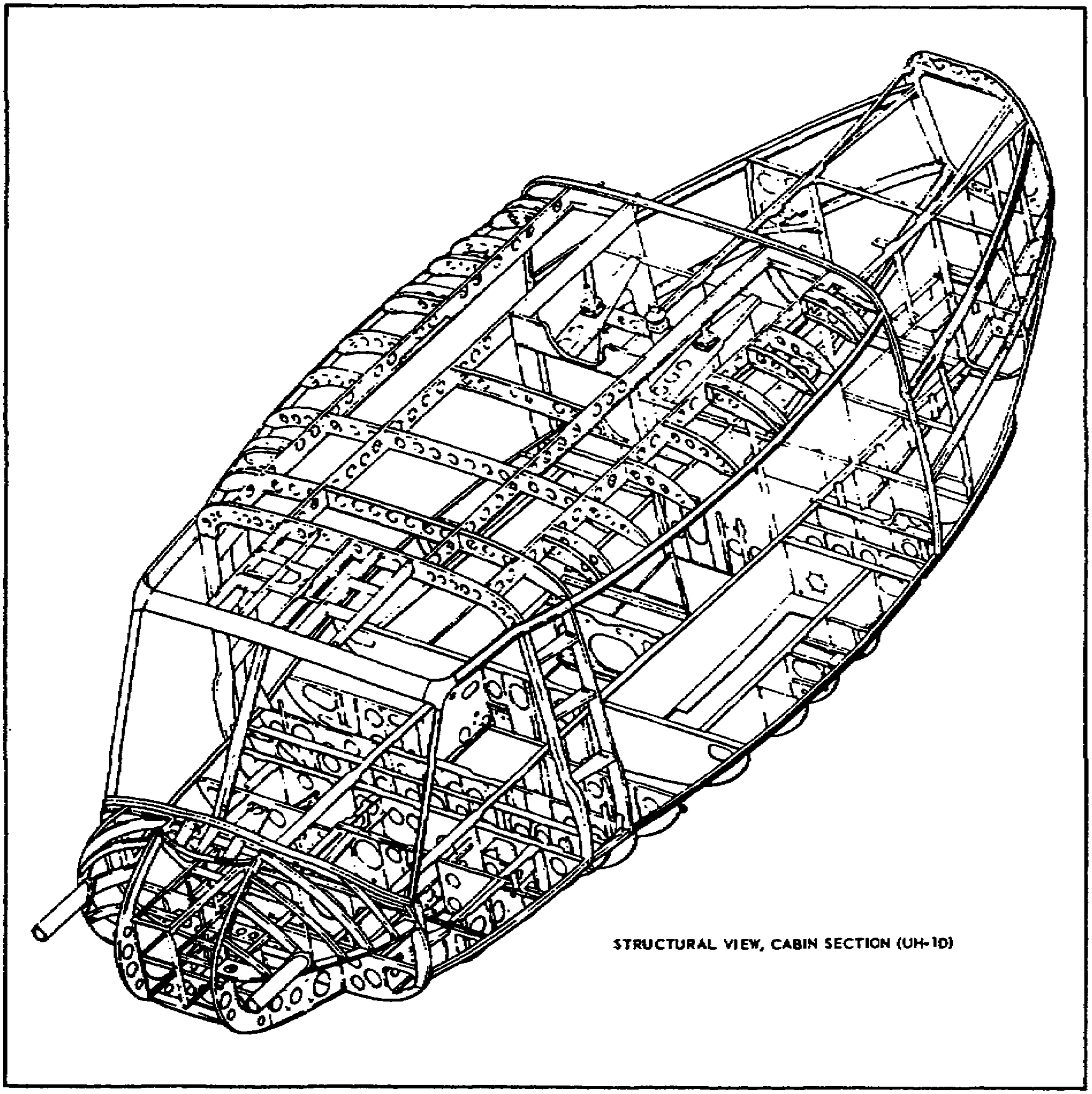

Figure 1-9. Cabin Section (UH-1D).

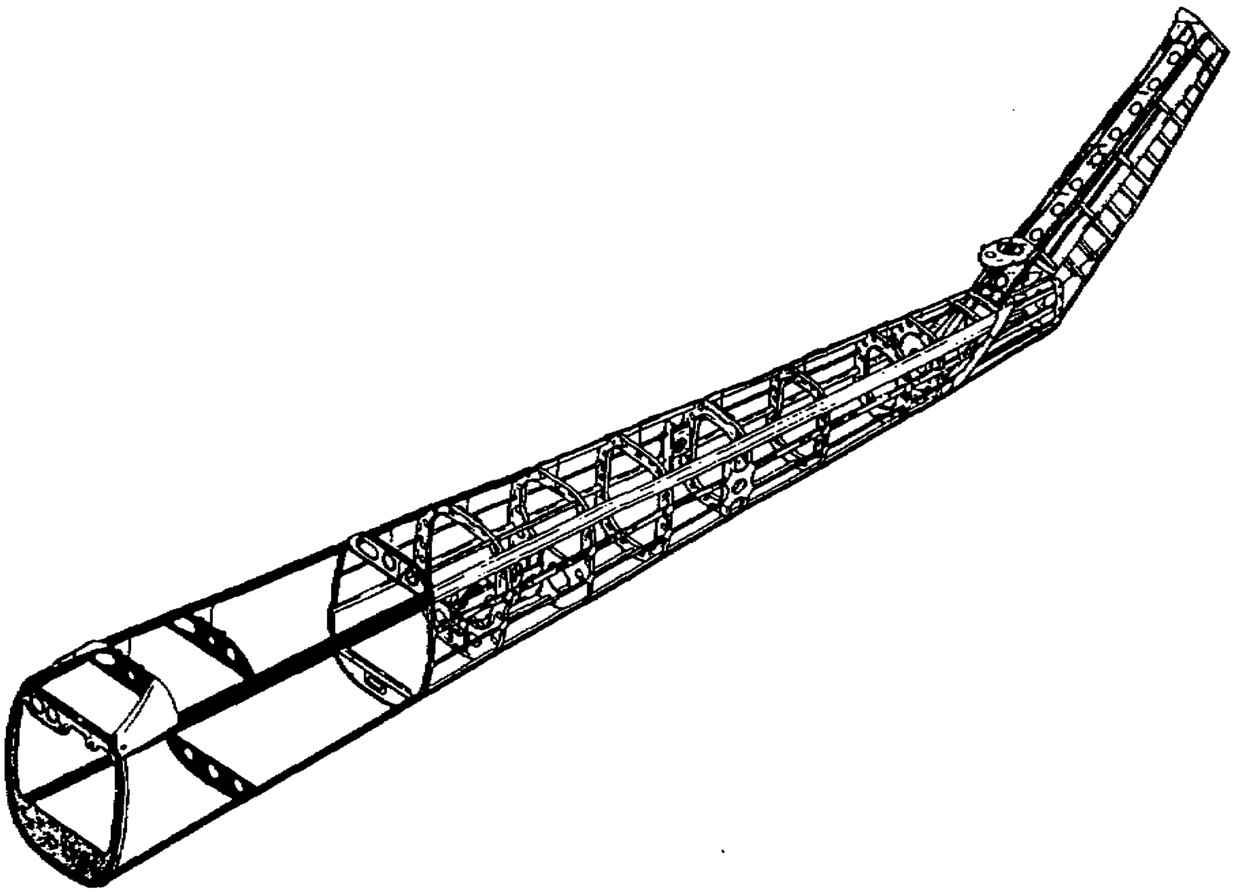

Figure 1-10. Tail Cone Section (UH-1).

SUMMARY

Aluminum alloys in the form of shells are most generally used in making the fuselage, nacelles, wings, and empennage. The basic fuselage constructions are the truss and monocoque. The truss is a rigid construction; and the monocoque is shell-like and gets its shape from formers, frame assemblies, and bulkheads. Maintaining strength while keeping weight down is the main problem in monocoque construction. The semimonocoque and reinforced shell are the most widely used fuselage constructions in present-day aircraft.

Formers, frame assemblies, and bulkheads are the structural members that give cross-sectional shape and strength to the construction. Frame assemblies used to separate areas are reinforced, disc-shaped, equipped with doors or access plates, and known as bulkheads. Channel members, hat-shaped sections, and built-up assemblies give the structure additional strength. Stringers and longerons are the principal lengthwise fuselage structural members. These joined to the formers, bulkheads, and assemblies make a rigid fuselage framework.

Nacelles are used primarily to house engines on multiengine aircraft. Generally, on twin-engine Army planes they house the main landing gear. Their repair fundamentals are essentially the same as for a fuselage. Nacelles must be kept within weight limits, built to withstand compression and shear loads, and aerodynamically suited for their location. Wings on military airplanes are generally without external bracing, and the skin is part of the wing structure, carrying some of the wing stresses. Monospar, multispar, and box-beam are the basic wing-construction designs. Monospar means that one main longitudinal member is used. The monospar wing is not in common use. Multispar wings have more than one main longitudinal member, and box-beam wings have two with connecting bulkheads for additional strength. Spars, ribs, bulkheads, and stringers are riveted or welded together. Spars run from the wing's base to its tip. Webs are deep wall plates and with their attached capstrips form the foundation for attaching the skin. Ribs are a wing's crosspieces, running from the leading edge to the trailing edge. They give the wing its shape and transmit the load from the skin to the spars. Ribs are also used in ailerons, elevators, fins, and stabilizers. Lightening holes in former ribs lessen their weight without decreasing their strength. Reinforced and truss ribs are heavier than former ribs and are only used at points where the greatest stress is imposed.

The empennage, the aft end of the fuselage, consists of the rudder, elevators, stabilizers, and trim tabs. These empennage components are usually of all-metal construction and cantilever design. In general, their construction features are the same as those of wings. The vertical stabilizer helps maintain directional stability in flight and supports the rudder. The horizontal stabilizer helps maintain stability about the airplane's lateral axis, and it is the base for the elevators.

Airframe structure for helicopters is generally the same as that for airplanes. The typical single-rotor helicopter has two major sections: the cabin and tail cone. Basically, the cabin structure is semimonocoque with strengthened high-stress areas. The tail cone supports the tail rotor, tail-rotor drive shafting, and stabilizers. The stabilizers give lateral and longitudinal stability to the aircraft during flight, and they are of semimonocoque construction.

PART B: METAL QUALITIES AND STRESSES

GENERAL

Each of the structural parts discussed is designed to meet requirements for that particular part. One of the important decisions to make in manufacturing, maintaining, and repairing the parts is selecting the metal to be used. Each metal or alloy has properties and characteristics that make it desirable for a particular use. However, if the metal has undesirable qualities, it is the metallurgist's job to build up the desirable qualities and tone down the undesirable ones. This is done by alloying (combining) metals and by various metal-working processes. It is not necessary for the airframe repairman to be a metallurgist. But, because it is advantageous to understand some metallurgical terms, this section explains the terms used to describe metal qualities or properties.

HARDNESS

The quality that permits relative resistance to abrasion, penetration, cutting action, or permanent distortion is hardness. This property can be increased by working the metal and, in the case of steel and certain aluminum alloys, by heat treatment and/or cold working. Structural parts are often formed from metals in their soft state and are then heat treated to harden them enough to develop the strength necessary to retain their finished shape. Hardness and strength are closely associated metal properties.

BRITTLENESS

The quality in a metal that permits breaking or cracking when the metal is stressed is brittleness. Brittle metal can break or crack without changing shape. Because structural metals are often heavily stressed, brittleness is an undesirable property. Cast iron, cast aluminum, and very hard steels are examples of brittle metals.

MALLEABILITY

The property in a metal that permits it to be hammered, rolled, or pressed into various shapes without the metal cracking or breaking is malleability. This property is required in sheet metal to be worked into curved shapes such as cowlings, fairings, and contoured skin. Copper is an example of a malleable metal.

DUCTILITY

When a metal can be permanently drawn, bent, or twisted into various shapes without breaking, it has ductility. This property is essential in metals used to make wire or tubing. Ductile metals are much preferred for aircraft because they are easily formed and resist failure under loads. For this reason, aluminum alloys are used for cowl rings, fuselage, wing skin, and formed or extruded parts such as ribs, spars, and bulkheads. Chrome-molybdenum steel is easily formed into the desired shapes. Although malleable and ductile are frequently shown as synonymous, the two differ in meaning. Malleable metals are generally shaped by compressive methods, and ductile metals are shaped by expansive methods.

ELASTICITY

The characteristic that enables a metal to return to its original shape when stresses are removed is elasticity. This quality, or property, is valuable because it is highly undesirable to have a part permanently distorted after an applied load is removed. However, each metal has a point, its elastic limit, beyond which it cannot be loaded without permanent distortion. Members and parts used in aircraft construction are designed so that the maximum loads to which they are subjected never stress them beyond their elastic limits. An example of a metal with a high elasticity limit is spring steel.

CONDUCTIVITY

The characteristic of a metal that enables it to transfer heat or electricity is conductivity. Heat conductivity in a metal is especially important in welding because it governs the amount of heat required for proper fusion. To a certain extent, a metal's conductivity determines the type of jig to be used to control expansion and contraction during repairs. Metals vary in how they conduct heat and electricity; to eliminate radio interference, careful thought should go into selecting metals to be bound together. For example, copper has a relatively high degree of heat conductivity, and its low resistance makes it a good electrical conductor. Aluminum, on the other hand, is a good heat conductor, but it is a poor electrical conductor.

DENSITY

The mass per unit volume of a substance is its density. In aircraft work the preferred unit of volume is the cubic inch. This unit is convenient in determining the weight of a part before manufacture. Give careful thought to the density of material to be used because it affects the weight and balance of an aircraft.

CONTRACTION AND EXPANSION

Heat applied to a metal causes it to expand or become larger, and cooling metal causes it to contract or shrink. Contraction and expansion affect the design of welding jigs, castings, and tolerances necessary for hot-rolled metal.

STRENGTH AND TOUGHNESS

When a metal can hold loads or withstand an applied force without breaking, it has strength. This is a property that encompasses many of the desirable qualities of metals. Strength with toughness is the most important combination of properties a metal can possess. Metals with this combination are used for vital structural members that may become overloaded in service. Toughness describes the resistance of a metal to tearing or shearing and permits the metal to be stretched or otherwise deformed without breaking.

STRESS

This paragraph discusses the stresses associated with the qualities or characteristics of metals. Stress is a force placed upon a body and is measured in terms of units of force per unit of area. The force is usually expressed in pounds and the unit of area in square inches. More simply, the expression is stated in pounds per square inch (psi). Stress can be in the form of compression, tension, torsion, bending, shearing, or a combination of two or more of these. All parts of an aircraft are subject to stresses. The various stresses acting on the aircraft parts while in flight have an important bearing on the choice of metals used. The paragraphs that follow describe the stresses. Refer to Figure 1-10a for examples.

Compression. Compression is the decrease of volume of a compressible substance because of pressure being applied. Compressive strength is the resistance to applied pressure. Examples of compression are the pressure applied to the fuel-air mixture in an engine cylinder and the pressure applied to an airplane's landing gear during landing.

Tension. Tension is the force or combination of forces that pulls or stretches a material. The measurement of a material's resistance to stretching or tearing is the material's tensile strength.

Torsion. Torsion is the force that causes a twisting motion. Torsional force is produced when an engine turns a crankshaft; and in that application, the force is called torque.

Bending. Bending is a combination of tension and compression forces. The inside curve of a bend is under compression, while the outside curve is under tension. Main rotor blades on helicopters and wings on airplanes are subjected to bending during flight. Main rotor blades also bend at rest, whether tied down or drooping, because of their weight and flexibility.

Shear. Shear is a stress applied to a body in the plane of one of its faces. The stress exerts a cutting force much the same as the two blades of a large scissors. Two layers of aircraft skin fastened together by a rivet can shear, or cut, the head off the rivet if one layer of skin is allowed to shift sufficiently.

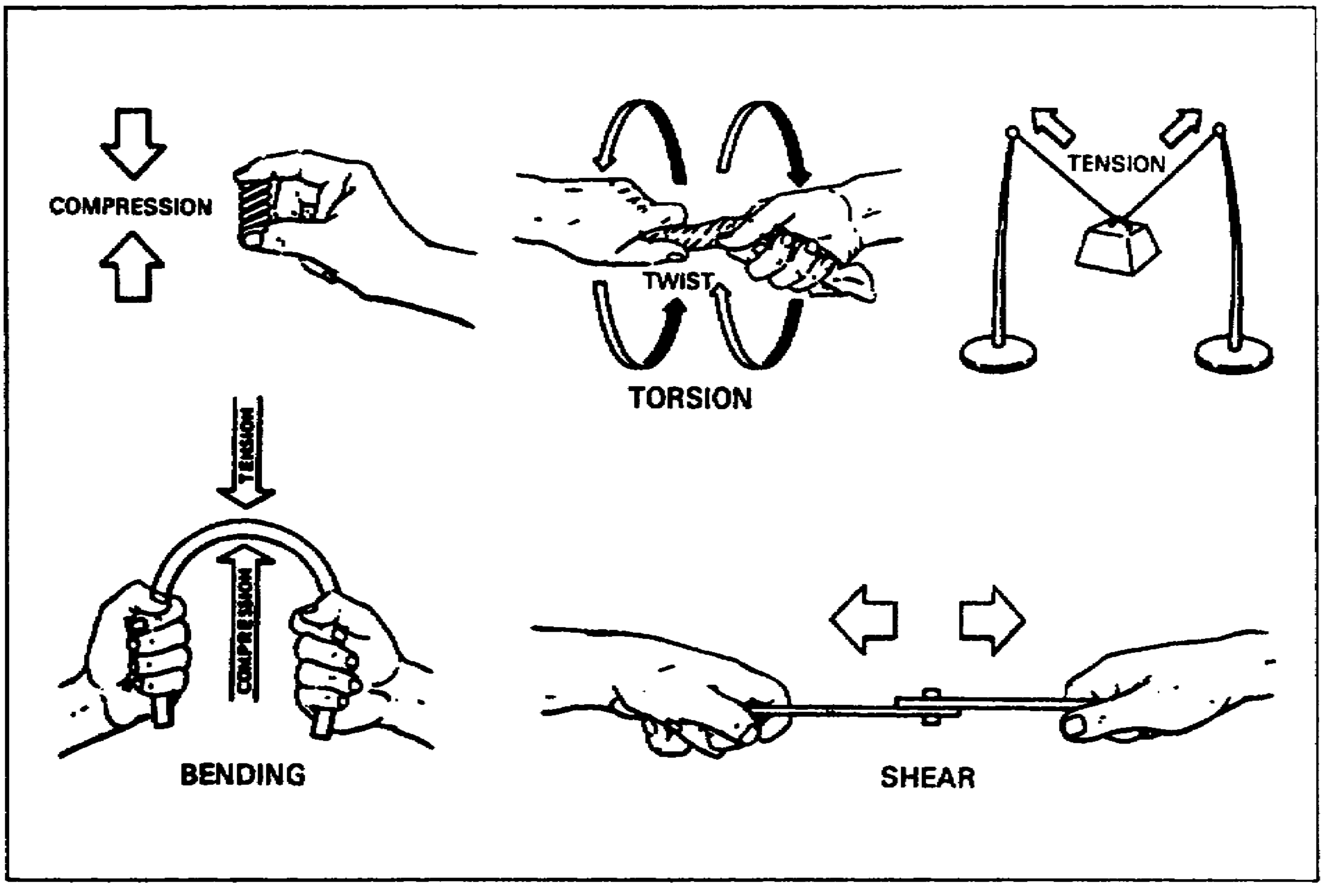

Figure 1-10a. Examples of Stress and Strain.

SUMMARY

Each metal or alloy has properties, qualities, or characteristics that make it desirable for a particular use. Undesirable qualities are toned down or compensated for by enhancing the desirable ones. This is done with alloys and metal processing.

Hardness is a metal's characteristic to resist penetration, cutting, or distortion. This quality can be enhanced by alloying, heat treatment, and cold working. Brittleness in a metal causes cracking or breaking under stress. Metal that can be shaped by hammering, rolling, or pressing is malleable. Ductility permits a metal to be drawn, bent, or twisted into various permanent shapes without breaking. This is a desirable quality in metal used for tubing or wire. Elasticity allows metal to return to its original shape when the force causing the change in shape is removed. Metal that conducts heat or electricity is conductive. Density is the mass per unit volume of a substance, and the preferred unit of volume expression is the cubic inch. Contraction and expansion are the qualities that describe a substance's reaction when heated or cooled. Strength is the measure of a metal's ability to hold loads or withstand an applied load. Toughness measures a metal's ability to withstand tearing, shearing, or stretching stresses. Stress, measured in pounds per square inch (psi), is the force or forces placed upon a metal, substance, or body. The different ways that stress forces can be applied are tension, compression, torsion, bending, and shear. Tension pulls or stretches a material, and resistance to tension is tensile strength. Compression describes a substance's decrease in volume under pressure. Torsion is the force that produces a twisting motion. Bending is a combination of tension and compression forces. Shear is a cutting force.

PART C: METAL-WORKING PROCESSES

GENERAL

Man's search for tools and better materials to make them from has led him from the random use of pieces of wood, bone, and stone through the Bronze and Iron Ages to the Industrial Age. Along the way, man discovered many metal-working processes and uses for the finished metals.

One of the earliest processes discovered was alloying copper with tin. This produced bronze and ushered in the Bronze Age. Practicable and economical ways to smelt iron ore and produce usable iron brought man into the Iron Age. Step by step, the way led to the Industrial Age. We now have many ways to process metal for particular uses.

This section discusses some of these processes. The first three paragraphs are introductory; they define an alloy, classify alloys, and describe the ways of preparing alloys. The paragraphs that follow discuss, in more detail, the metal-working processes most commonly used.

DEFINITION

An alloy is a metallic substance containing one or more metals and/or elements. If strictly applied, this definition would classify all metals as alloys since no metal refinement can produce an absolutely pure metal. The alloying of a metal is a concentrated effort to make it gain certain qualities or properties. Some of the metals used in alloying are nickle, chromium, molybdenum, aluminum, titanium, copper, and manganese. The alloying elements are silicon, sulfur, and carbon. Each metal or element will cause the base metal to take on different properties.

CLASSIFICATION

Industrial alloys are classed as ferrous (having an iron base) and nonferrous; the ferrous alloys are the larger group. The most important ferrous alloys are those made with carbon. When the carbon content is less than .13 percent by weight, the alloys are known as steels. The terms, alloy steel and special steel, are descriptive of steels with relatively large amounts of chromium and nickel. An example of such an alloy is stainless steel. Aircraft industry requirements have helped spur the development of important nonferrous lightweight alloys such as aluminum and magnesium. With increased flight, speed, and payload, much use is being made of titanium and titanium-based alloys. These have much higher melting points and strength-to-weight ratios than aluminum and its alloys.

ALLOY PREPARATION

The most common way to prepare alloys is to melt the constituent metals together. If the melting points of the metals differ widely, or if one is very reactive, it may be convenient to first prepare a master alloy, portions of which are then melted with the remaining metals. Depending upon the nature of the elements to be alloyed, the melting process may be carried out in furnaces fired by gas, coke, or oil. Electrical heating, by resistance, induction, or arc melting methods, is also used.

A few alloys are prepared directly by the process in which the metals are extracted from their ores. For example, pig iron is prepared by the reduction of iron ore in the blast furnace.

Steels are prepared by further purification (reduction) of pig iron. Alloys can also be prepared by mixing finely powdered portions of the constitutent metals, compacting the mixture under high pressure, and removing the impurities.

HEAT TREATMENT

Heat treatment can make a metal harder, stronger, and more resistant to impact. This process consists, in general, of a series of operations involving controlled heating and cooling of metals in a solid state. The purpose is to change the metal's property or combination of properties so that the metal is more useful, serviceable, or safe for a particular application or design. Heat treatment can also make a metal softer and more ductile. No one heat-treating operation can produce all of these characteristics. Some properties are often improved at the expense of others. In being hardened, for example, a metal can become brittle. The various heat-treating processes are similar in that they all involve heating and cooling the metals. However, they differ in three important ways. The first two ways are the temperatures to which the metal is heated and the rate at which it is cooled. The third difference is the finished metal.

The most common forms of heat treatment for ferrous metals are hardening, tempering, annealing, normalizing, case hardening, and hot-working. The paragraphs that follow discuss each of these treatments. Most nonferrous metals can be annealed and many of them can be hardened by heat treatment. However, only one nonferrous metal, titanium, can be case-hardened, and none can be normalized or tempered.

Hardening. For most steels the hardening treatment consists of heating the steel to the correct temperature and then cooling it rapidly by plunging the hot steel into oil or brine. Although most steels must be cooled rapidly for hardening, a few can be cooled from the hardening (specified) temperature by air. Hardening increases the durability and strength of the steel, but it makes it less ductile. Many nonferrous metals can also be hardened and strengthened by the same method.

Tempering. After the hardening treatment, steel is often harder than necessary and it is too brittle for most practical uses. In addition, rapid cooling from the hardening temperature causes internal stresses that can cause flaws in the metal. To relieve the internal stresses and reduce brittleness, steel is tempered after hardening. Tempering consists of heating the steel to a temperature below that at which it was hardened, holding the metal at that temperature for a predetermined time, and then cooling it, usually in still air. The resultant strength, hardness, and ductility depend upon the temperature to which the steel is heated during the tempering process.

Annealing. In general, annealing is the opposite of hardening. Metals are annealed to relieve internal stresses, soften them, make them more ductile, and refine their grain structure. Annealing consists of heating the metal to the proper temperature, holding it at that temperature for the required time, and then cooling the metal to room temperature. The big difference between hardening and annealing is the cooling rate. To produce maximum softness in steel, the metal must be cooled very slowly. This can be done by burying the hot metal in sand, ashes, or some other substance that does not conduct heat readily. Another method is to shut off the heat and allow the furnace and metal to cool together. The first method is called packing and the latter is called furnace cooling.

Normalizing. Only ferrous metals can be normalized. In the process, the metal is heated to the required temperature, held at that temperature until it is uniformly heated, and then removed to cool in still air. Steel parts are normalized to relieve the internal stress set up by machining, forging, bending, or welding.

Case Hardening. When a low-carbon steel is used where a hardened surface is desirable, the character of its surface can be altered to form a very hard case. The hard surface is obtained by adding carbon to the steel. This is done by keeping the steel at a sufficiently high temperature and in contact with a suitable material containing carbon. The steel is heated to 1,700° to 1,800°F for several hours. The prolonged heating at a high temperature develops a coarse grain in the core. To refine the structure, the metal must be reheated slightly above the critical temperature of the core and then quenched. It must then be reheated slightly above the critical temperature of the case, and again quenched. The double heat treatment produces a hardened case with a fine structure and a ductile core with a full measure of toughness.

Hot Working. Almost all steel is hot-worked from the ingot into some form from which it is either hot- or cold-worked to the finished shape. When an ingot is stripped from its mold, its surface is solid, but the core is still molten. The ingot is then placed in a soaking pit to retard heat loss so the core solidifies gradually. After soaking, the temperature is equalized throughout the ingot. Then, to make it easier to handle, the ingot is reduced to intermediate size by rolling. The rolled shape is called a bloom when its sectional dimensions are 6 x 6 inches or larger, and it is approximately square. The section is called a billet when it is almost square and its sectional dimensions are less than 6 x 6 inches. Rectangular sections that have widths greater than twice their thicknesses are called slabs. The slab is the intermediate shape from which sheets are rolled.

CASTING

Pouring a molten metal, or mixture of molten metals, into a mold where it is allowed to solidify is called casting. Two types of molds are used: single-purpose and permanent molds. Single-purpose molds have to be specially prepared, sometimes by machines, from patterns. Using metal or permanent molds offers many advantages where the process is applicable. For example, the constantly repeated cost of sand molding is eliminated; but the initial cost of the metal mold or die is high. The cost is justified only when the same casting is required in great numbers. However, for many metals, the metal mold has a distinct advantage: the structure and strength that result from the relatively rapid solidification in a metal or chill mold. For the nonferrous metals, chill casting is quite practical, especially with some aluminum alloys.

HOT ROLLING

Blooms, billets, or slabs are heated above the critical range and rolled into a variety of shapes of uniform cross section. The more common of these rolled shapes are sheet bars, channels, angles, and I-beams. Sheet bar and rods rolled from steel are used extensively in aircraft work. Hot-rolled material is frequently finished by cold rolling or drawing to obtain accurate finish dimensions and a bright, smooth surface.

FORGING

Complicated sections that cannot be rolled or sections of which only a small quantity is required are usually forged. Forging is an important hot-forming process. It is used in producing components of all shapes and sizes from quite small items to large units weighing several tons. The metal, preheated to the appropriate forging temperature, is shaped mainly by upsetting (compressive deformation) between impact surfaces or pressure surfaces, that is, by hammering or pressing the heated metal until the desired shape is obtained.

Hammering can be used only on relatively small pieces. Because hammering transmits its force almost instantly, its effect is limited to a small depth. Therefore, it is necessary to use a very heavy hammer or to subject the part to repeated blows to ensure complete working of the section. If the force applied is too weak to reach the center, the finished forged surface will be convex or bulged. The advantage of hammering is that the operator has control over both the amount of pressure applied and the finishing temperature, and he is able to produce parts of the highest grade. This kind of forging, also called smith forging, is used extensively where only a small number of parts are needed. Considerable machining and material are saved when a part is smith-forged to approximately the finished shape.

Pressing is used when the parts to be forged are large and heavy or where high-grade steel is required. Because a press is slow acting, its force is uniformly transmitted to the center of the section. This gives the interior and exterior grain of the metal the best possible structure throughout.

EXTRUSION

Forcing metal through an opening in a die causing the metal to take the shape of the die opening is called extrusion. Some metals, such as lead, tin, and aluminum, can be extruded cold; however, metals are generally heated before extrusion. The principal advantage of this process is its flexibility. For example, aluminum, with its ductile and malleable properties, can be economically extruded in more shapes and sizes than is practicable with many other metals. Extrusions are produced in simple as well as complex shapes. In addition, many structural parts, such as stringers, are made by the extrusion process.

COLD WORKING

Mechanically working metals at temperatures below the critical range (cold working) results in strain-hardening the metal. In fact, the metal becomes so hard that it is difficult to continue the shaping process without annealing the metal. Because the errors due to shrinkage are eliminated in cold working, a more compact and better metal is obtained than in hot-worked metal. The strength, hardness, and elastic limit are increased, but the metal's ductility is decreased. Because this makes the metal brittle, it must be heated from time to time during the working to remove the undesirable effects. A number of cold-working processes are used in industry; however, the ones of interest to airframe repairers are cold rolling, cold drawing, stamping, and pressing. Each is discussed in the paragraphs that follow.

<u>Cold Rolling</u>. Cold rolling is the process of reducing the cross-sectional area of pieces of metal by passing them between revolving cylinders or rolls at room temperature. In a steel mill, a rolling mill has, in addition to cranes and other handling equipment:

- Soaking pits where ingots are brought to the appropriate temperature.

- Reheating furnaces.
- Rolling stands.
- Straightening and cooling tables.
- Cut-off shears.
- Coilers and decoilers for strips.
- Roll-grinding machines.

A rolling stand consists of two or more rollers positioned one above the other and in groups of two or more stands side by side. The operation consists of passing a piece of metal between two or more rollers, subjecting it to compression. The compression compacts and lengthens or compacts and widens the particular piece of metal. The action depends on the rollers' dimensions and the compression applied.

In producing cold-rolled sheet and strip and cold-drawn rods and bars of various dimensions, the oxide is removed from the hot-rolled material by pickling; and the material is further reduced on cold-rolling mills. Bars, sheets, and strips are cold-rolled to obtain a desired surface finish, improve dimension tolerances, impart improved physical properties, and make lighter gauges than can be made on hot-strip mills.

Cold Drawing. Cold drawing is used in making seamless tubing, wire, streamlined tie rods, and other forms of stock. Wire is made from hot-rolled rods of various diameters. These rods are picked in acid to remove scale, dipped in lime water, and then dried in a steam room where they remain until ready for drawing. The lime coating adhering to the metal lubricates the rod during the drawing operation. The rod size used for drawing depends upon the diameter desired in the finished wire.

To reduce the rod to the desired size wire, the rod is drawn cold through a die. One end of the rod is filed or hammered to a point and slipped through the die opening. It is then gripped by the jaws of the draw and pulled through the die. This series of operations is done on a mechanism called a draw bench. To reduce the rod gradually to the desired size, the wire is drawn through successively smaller dies. Because each of these drawings reduces the wire's ductility, it must be annealed from time to time during the drawing operation. Although cold working reduces the wire's ductility, it increases the wire's tensile strength.

In making seamless steel aircraft tubing, the rod is cold drawn through a ring-shaped die with a mandrel, metal bar, inside the tubing to support the tube during the drawing operation. This forces the metal to flow between the die and the mandrel and controls the wall thickness and the inside and outside tube diameters.

Stamping and Pressing. Stamping and pressing sheet metal into molds or dies are methods of shaping or forming various-sized parts or complete pieces. In a broad sense, the two terms have little difference in meaning. However, stamping is generally applied to forming small objects that can be shaped by one rapid blow of a machine. Pressing, on the other hand, describes the process that uses a slow, steady stroke or movement to form a large piece or section. Making parts by stamping and pressing brings the aviation industry one step nearer to mass production. However, constant changes in aircraft design make it necessary to alter or replace dies frequently.

SUMMARY

In general, most alloys consist of two or more metals. Other elements such as carbon, silicon, and sulfur may be present. Industrial alloys are classed as ferrous (iron based) and non-ferrous. Ferrous alloys with less than 0.13 percent carbon by weight are steels. Cast and wrought iron have 2 to 5 percent carbon by weight. Alloy steel and special steel have relatively large amounts of chromium and nickel. The aircraft industry requires lightweight alloys such as aluminum and magnesium; titanium and titanium-based alloys are much used.

Alloys are usually prepared by melting the constituent metals together. The melting can be done in furnaces fired by gas, coke, or oil. Electrical heating is also used. Some alloys, such as pig iron, are prepared directly by the process used to extract the metal from the ore.

A metal can be made harder, stronger, and more resistant to impact by controlled heating and cooling. Heating (annealing) can make a metal softer. Metal properties are often improved at the expense of other properties. Heat-treating processes differ in three important ways: the temperature to which the metal is treated, the rate at which it is cooled, and the properties possessed by the finished metal. The most common forms of metal heat treatment are hardening, tempering, normalizing, case hardening, and hot working. Hardening consists of heating the steel to the appropriate temperature and then cooling it rapidly by quenching. Heating the steel below the critical point and then cooling it in still air tempers it. Annealing requires heating the metal to the proper temperatures, holding that temperature for the required time, and cooling the metal to room temperature. Normalizing consists of heating metal to the appropriate temperature until it is uniformly heated and then cooling it in still air. Only ferrous metals can be normalized, Case hardening consists of carbonizing steel at 1,700° to 1,800°F for several hours and reheating and quenching twice. Hot working consists, in general, of working steel while the core is still hot. Casting is the process of pouring molten metal into a single-purpose or permanent mold. Hot rolling is passing the metal between rollers while it is still hot. Forging is changing a metal's shape by compressive deformation through hammering or pressure. Extrusion is forcing metal to take the die opening's shape. Metal worked at temperatures below the critical range is being cold-worked. Cold rolling, cold drawing, and stamping and pressing are forms of cold working.

PART D: AVIATION HARDWARE

GENERAL

An aircraft made of the best materials and strongest parts is of no value unless those parts are firmly held together. Rivets and special-purpose fasteners are the primary hardware used for this on Army aircraft. Both are used to hold two or more metal sheets, plates, or formed pieces of material together. Heads are formed on one end of the rivet and special-purpose fastener when manufactured. Special-purpose fasteners are used where high strength or a special application of a fastener is required. The rivet is smooth-shanked; its tip, opposite the head, is reshaped upon use to take the place of a nut. The shank of the rivet is placed through matched (aligned) holes in two or more pieces of material, and the tip is then flattened to form a second head that clamps the pieces together.

The second head, formed either by hand or by pneumatic equipment, is called a shop head. The shop head works in the same manner as a nut on a bolt. This section discusses the variety of rivets and special-purpose fasteners in general use in Army aviation.

RIVETS

Many different metals and alloys of metals are used to make rivets. The material used for the majority of aircraft rivets is an aluminum alloy. Other metals used are steel and copper. Aluminum rivets have a silver-white color; steel rivets are a typical steel color; and copper rivets are copper color. Aside from their metal, rivets are divided into two main groups: solid-shank and blind rivets. The following paragraphs discuss the two groups in detail.

Solid-Shank Rivets. Rivets are manufactured in two head styles: universal and countersunk (Figure 1-11). Both head styles are used in interior and exterior locations. The universal head is shaped like a mushroom. Because of the added strength of the head style, the universal head rivet is used extensively throughout the aircraft. The countersunk rivet is used where flushness is required. The top of the countersunk head fits flush with the surface of the riveted material. This is accomplished because the rivet is flat-topped and undercut to allow the head to fit into a countersunk or dimpled hole. When aerodynamics or clearance is required, the countersunk rivet is used.

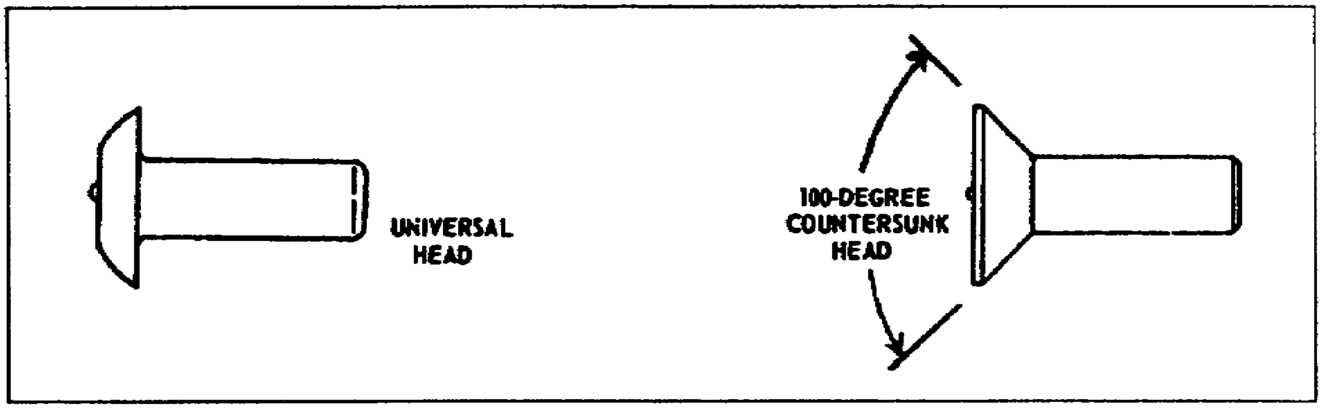

Figure 1-11. Head Styles for Solid-Shank Rivets.

Blind Rivets. This section covers only the most common types of self-plugging rivets. Information on other types of self-plugging rivets may be obtained from the United States Army Aviation Systems Command, 4300 Goodfellow Boulevard, St. Louis, MO 63120, or from the rivet manufacturer.

When access to both sides of a riveted structure or structural part is impossible or when limited space does not permit using a bucking bar, blind rivets must be used. These rivets have characteristics that require special installation tools and installation and removal procedures. Because these rivets are often installed in locations where one head, usually the shop head, cannot be seen, they are commonly called blind rivets. The blind rivets used on Army aircraft and discussed here are self-plugging (friction and mechanical lock).

Friction Lock. Self-plugging friction lock rivets consist of a rivet head with a hollow shank or sleeve and a stem that extends through the shank. The rivet head styles are the same as the solid-shank rivets. Two common styles, shown in Figure 1-12, are in use. The stem may have a knob on the upper portion or it may have a serrated portion.

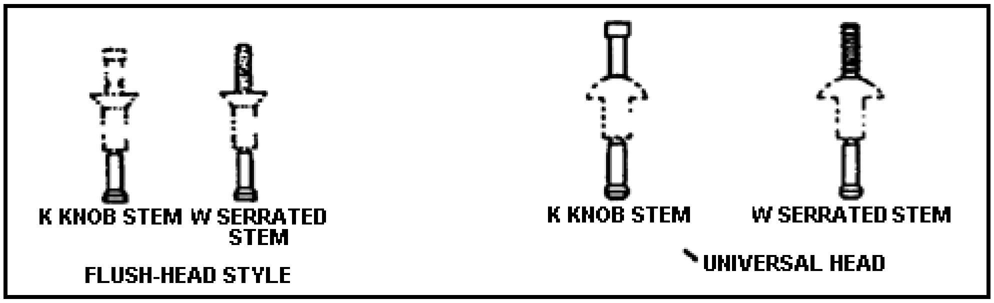

Figure 1-12. Mechanically Expanded
Rivet Head and Stem Styles.

<u>Mechanical Lock</u>. Self-plugging mechanical lock rivets include the 3000-series CherryMAX and the 2000-series Cherrylock. Mechanical lock rivets may be substituted for solid-shank rivets when a solid-shank rivet is inaccessible for bucking. When substituting 3000-series CherryMAX rivets for solid-shank rivets, the new rivet may be the same diameter as the solid rivet it replaces. When substituting 2000-series Cherrylock rivets or bulbed Cherrylock rivets for solid-shank rivets, the new rivet must be one diameter size larger than the solid rivet it replaces. In 1979 the Army began replacing all self-plugging rivets by attrition with the 3000-series CherryMAX rivet. The change will reduce the inventory of installation tools and types of rivets required in the Army supply system. The 2000-series Cherrylock rivet is made in three parts: a hollow shank, a stem, and a locking collar. The 3000-series CherryMAX rivet has an extra part attached to the rivet stem: the driving anvil (Figure 1-12a). The head styles of the shank are the same as those in solid-shank rivets. The head also has a conical recess to accept the locking collar. The stem has an extruded angle and land to expand the sleeve for hole filling, a breakneck groove, a locking groove, and a head. The pull grooves on the protruding end of the stem fit the jaws of the rivet tool. The mechanical lock between the stem and sleeve gives these rivets approximately the same strength as common solid-shank rivets.

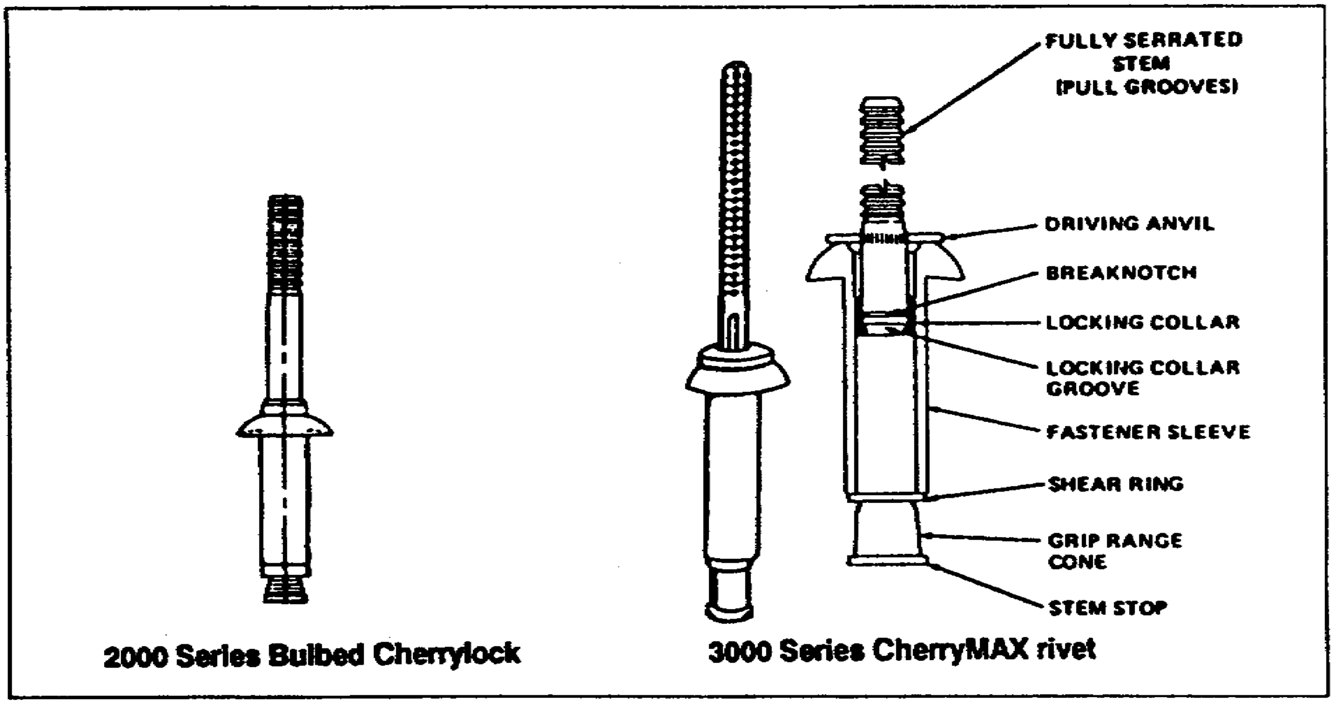

Figure 1-12a. Self-Plugging (Mechanical Lock) Rivets.

Rivet Removal. When a rivet has to be replaced, it must be removed carefully so that the rivet hole will retain its original size and shape and the rivet will not need to be replaced with one of the next larger size. If the rivet is not removed properly, the strength of the joint may be weakened. Hand tools, power tools, or a combination of both may be used to remove rivets.

Solid-Shank. To remove a solid-shank rivet, use a drill one size smaller than the rivet shank to drill through the rivet head. Be careful not to drill too deep because the rivet shank will then turn with the drill and cause a tear.

Insert a drift punch diagonally into the drilled hole and knock the rivet head off by lightly striking the drift punch.

Drive the rivet shank out with a drift punch slightly smaller than the diameter of the shank. On thin metal or unsupported structures, support the sheet with a bucking bar while driving out the shank. If the shank is unusually tight after the rivet head is removed, drill the rivet about two-thirds through the thickness of the material and then drive the rest of the shank out with a drift punch.

Mechanical-Locking. To remove a mechanical-locking rivet, use the following steps.

Use a small center drill to provide a guide for a larger drill on top of the rivet stem and drill away the upper portion of the stem to destroy the lock. See Figure 1-12b.

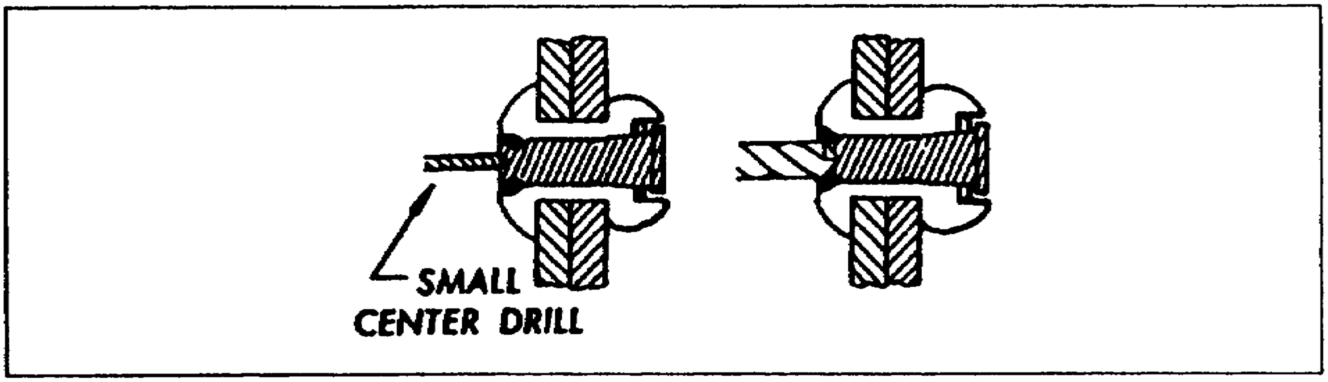

Figure 1-12b. Rivet Removal.

Drive out the rivet stem, using a tapered steel drift pin or a spent stem. See Figure 1-12c.

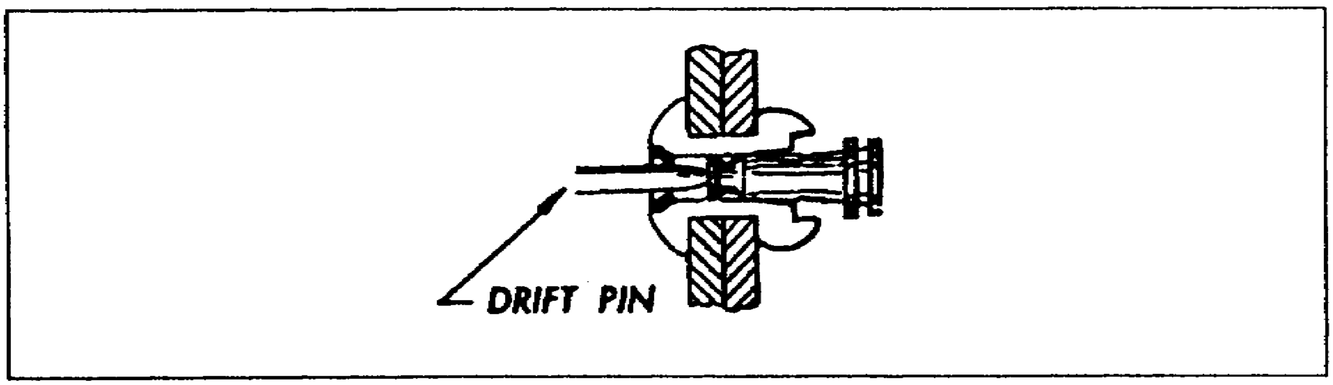

Figure 1-12c. Rivet Removal.

Drill nearly through the head of the rivet using a drill the same size as the rivet shank. See Figure 1-12d.

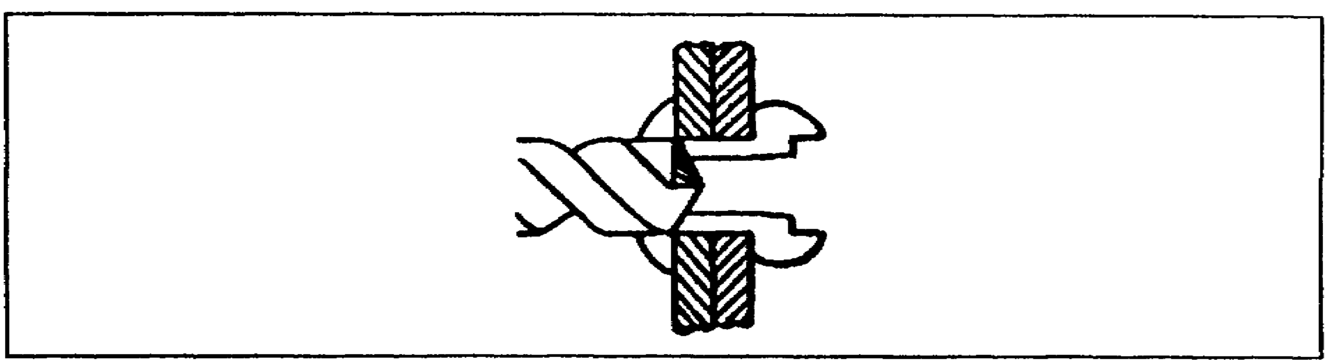

Figure 1-12d. Rivet Removal.

Break off the rivet head, using a drift pin as a pry. See Figure 1-12e.

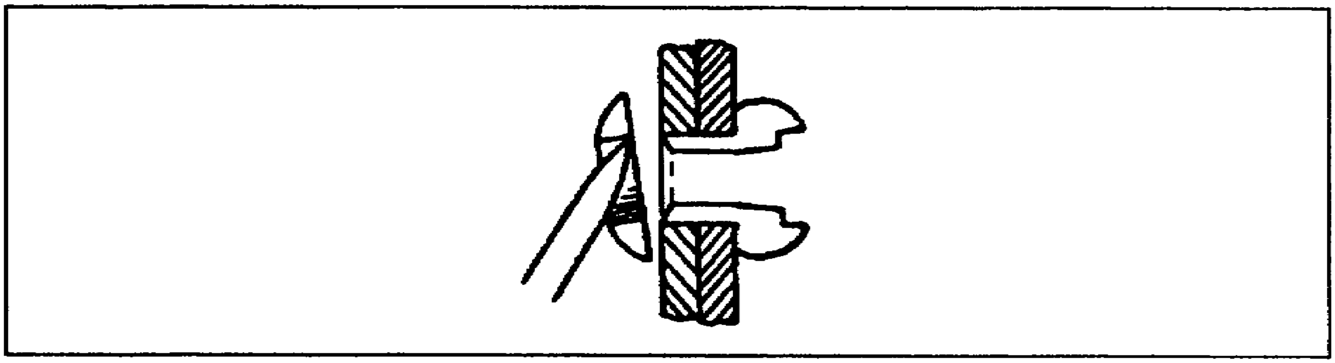

Figure 1-12e. Rivet Removal.

Drive out the remaining rivet shank with a pin that has a diameter equal to the rivet shank. See Figure 1-12f.

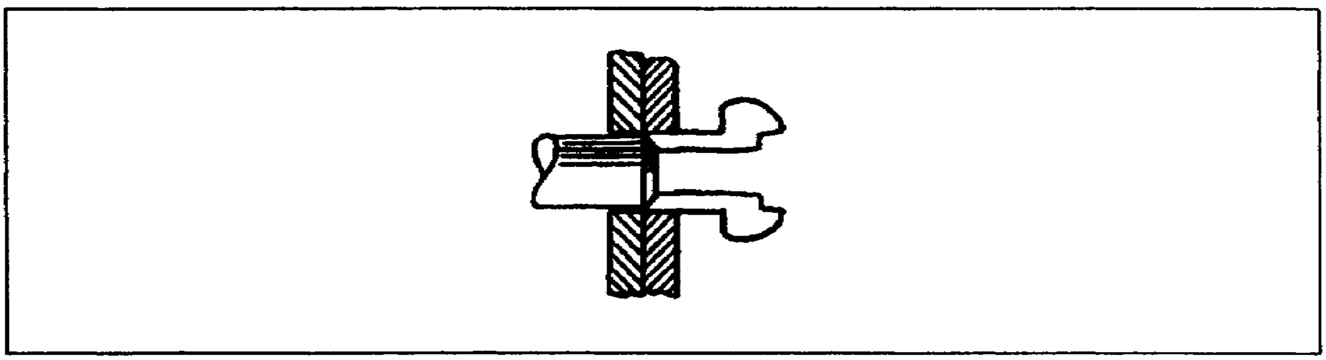

Figure 1-12f. Rivet Removal.

SPECIAL PURPOSE FASTENERS.

Where extra strength is required and weight is a factor, special purpose fasteners are used instead of rivets or nuts and bolts. Some of these areas are: where major structural units join together, where there is high stress, and where the substructures attach to the skin. We will discuss each fastener and its use in the following paragraphs.

Rivnuts. Rivnuts, shown in Figure 1-13, are tubular rivets internally threaded and counterbored and used with matching screws. They are applied blind, and they are used where nut plates cannot be installed. An example of such a location is the leading edge on wings where deicing boots are attached. Rivnuts are made in two head styles: flat and countersunk heads with open or closed ends. The keyed rivnut is used as a nut plate, and rivnuts without keys are used for blind riveting where torque loads are not imposed. Closed-end rivnuts are used when a sealed installation is required. The installation of a rivnut is not complete unless it is plugged, either with one of the plugs designed for that purpose or with a screw. A rivnut does not develop its full strength when left hollow.

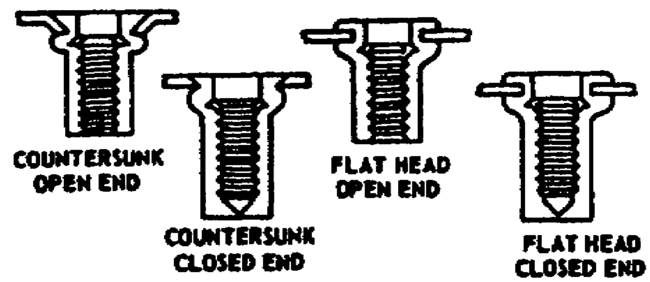

Figure 1-13. Countersunk and Flat Head Rivnuts.

Hi-Shear Rivets. The Hi-Shear rivet, essentially a threadless bolt, consists of two parts, the pin and the collar as shown in Figure 1-14. These rivets are classified as special rivets, but are not of the blind type. Access to both sides of the material is required to install the rivet. Hi-Shear rivets have the same shear strength as bolts of equal diameters and have about 40 percent of the weight of a bolt. In addition, they require only about one-fifth as much time to install as a bolt, washer, and nut combination. They are approximately three times as strong as solid shank rivets. The pin is headed at one end and is grooved about the circumference at the other. The collar is swaged onto the grooved end to make a firm, tight fit. Hi-Shear rivets are made from a variety of materials and are used only in shear applications. In addition, they must not be used where the grip length is less than the shank diameter.

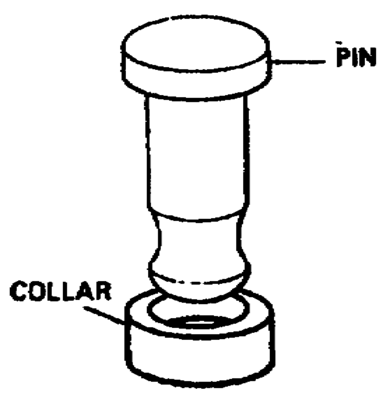

Figure 1-14. Hi-Shear Pin.

General Purpose Bolts. The mechanics and appearance of general purpose bolts and their accompanying washer and bolt combinations are not discussed here. They are described in detail in FM 1-563 (Fundamentals of Airframe Maintenance). The discussion here is limited to less familiar special-purpose bolts in general use in Army aircraft. These are Huck lock bolts and Jo-Bolts. Each is described in the paragraphs that follow.

Huck Lock Bolt. The Huck lock bolt combines the features of a high strength bolt and a rivet, with advantages over each. The Huck lock bolt is generally used in wing splices, landing gear, fuel cell fittings, longerons, beams, skin splice plates, and other major structural attachments. It is more easily and quickly installed than the conventional rivet or bolt, and it does not require lock washers, cotter pins, and special nuts. Like the rivet, the lock bolt is installed with a pneumatic or pull gun. The most commonly used Huck lock bolts are the pull, stump, and blind types, shown in Figure 1-15. Common features of the three are the annular (circular or ringed) locking grooves on the pin and the locking collar. Each one is discussed in the following paragraphs.

Pull-type. The pull-type lock bolt is mainly used in primary and secondary structural members. It is installed rapidly and has approximately one-half the weight of an equivalent general-purpose bolt and nut. These bolts are available with modified brazier, pan, and countersunk heads. A special pneumatic pull gun is required to install this lock bolt. The installation can be made by one man because bucking is not needed.

Stump-type. The stump-type lock bolt, although not having the extended stem with pull grooves, is a companion fastener to the pull-type lock bolt. It is used primarily where clearance will not permit effective installation of the pull type. These bolts are also available with modified brazier, pan, and countersunk heads. The stump-type lock bolt installation is made with a standard pneumatic riveting gun, a hammer set for swaging the collar into the pin-locking grooves, and bucking bar.

Blind-type. The blind-type lock bolt comes as a complete unit or assembly, and it has exceptional strength and sheet pull-together characteristics. These lock bolts are used where only one side of the work is accessible and generally where it is difficult to drive a conventional rivet.

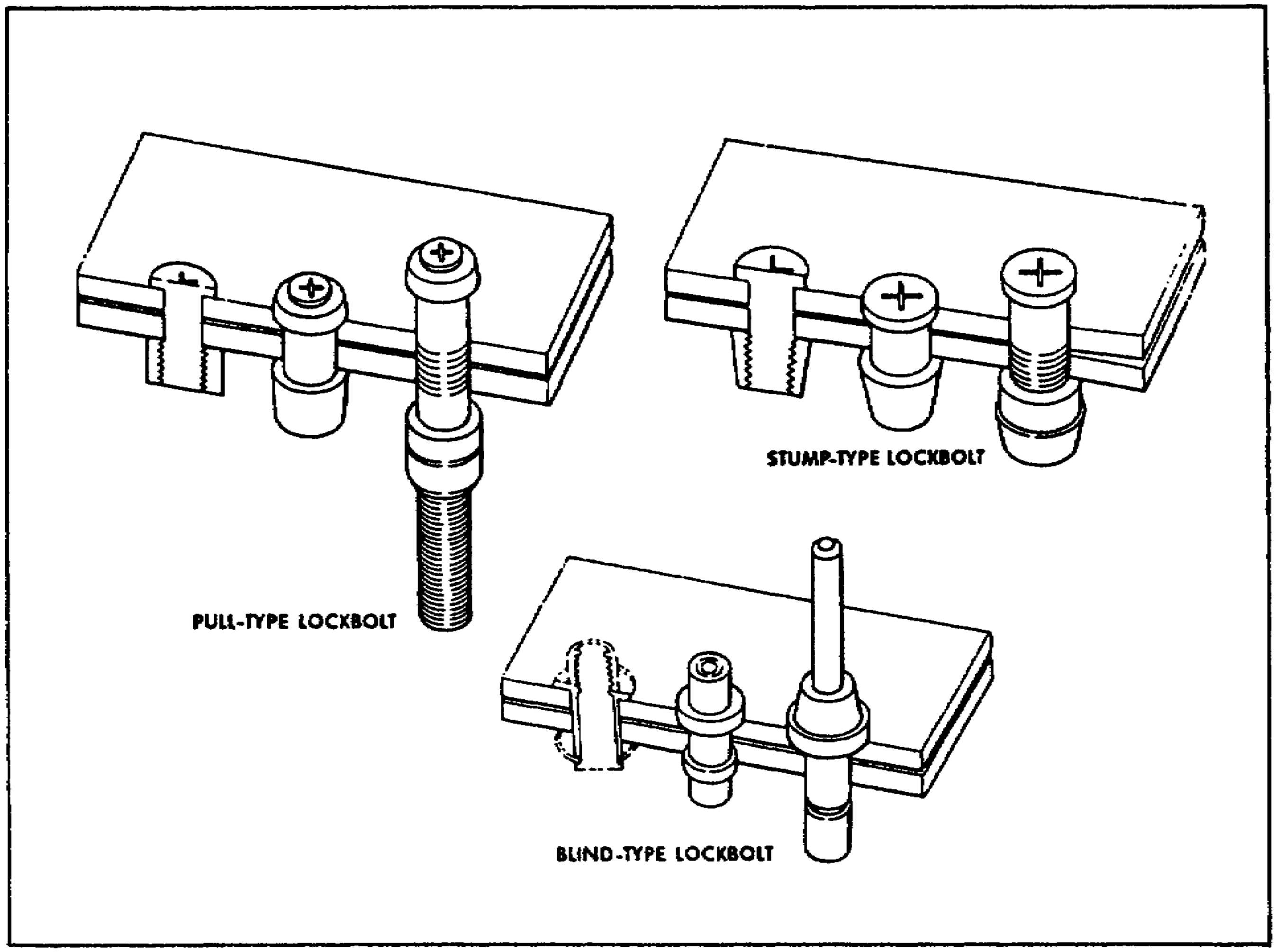

Figure 1-15. Huck Lock Bolts.

Jo-Bolts. Jo-Bolts are high-strength structural blind fasteners. They are used in close-tolerance holes or where Jo-Bolts may be required for weight-saving advantages. In all cases, Jo-Bolts are always considered to be a part of the permanent structure and primarily subject to shear loads. The Jo-Bolts, installed as a unit, consist of a bolt, nut, and sleeve. These bolts, identified by head types, are discussed in the following paragraphs and illustrated in Figure 1-16.

Flush-type. The flush-type Jo-Bolt has a head that fits flush with the surface being held. The bolt generally uses the same size countersink or dimple required for the correspondingly sized standard screwhead. The nut and bolt are made of alloy steel; however, the sleeve is made of annealed corrosion-resistant steel. All components for the flush-type Jo-Bolt are cadmium plated. In addition, a flush-type Jo-Bolt is available that is designed to fit into a countersunk or dimpled hole prepared for a precision rivet. Nut shank size and material specifications are the same as those just described.

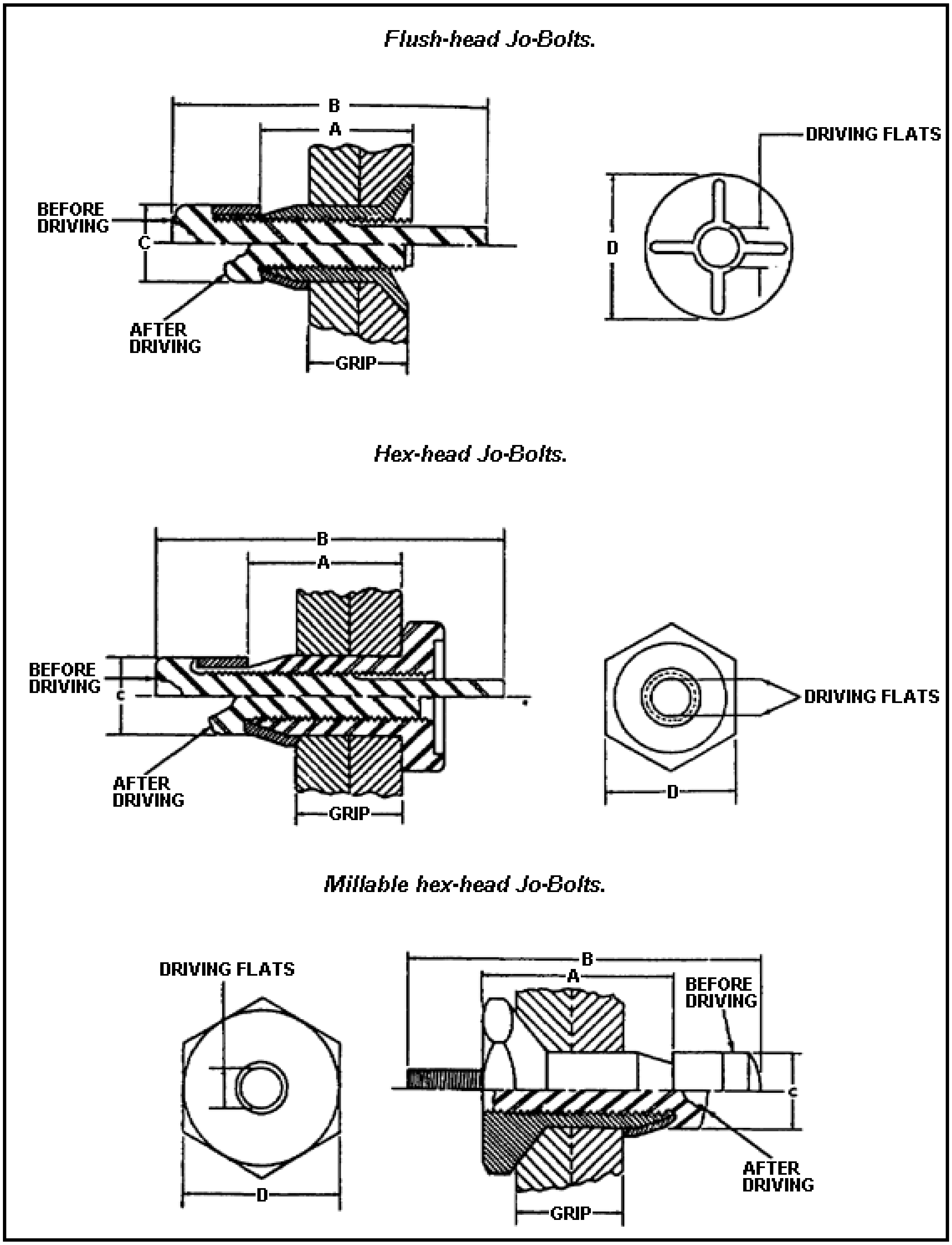

Figure 1-16. Jo-Bolt Head Styles.

Hex-type. Jo-Bolts with hexagon-shaped heads (hex type) are made of an alloy steel. Their sleeves are annealed and corrosion resistant. In addition, the bolt and sleeve are cadmium plated.

Millable hex-type. The millable hex-type Jo-Bolt usually takes the same size countersink or dimple used for the corresponding size rivet. The bolt is made of alloy steel and the sleeve of corrosion-resistant steel. Both are cadmium plated. The nut is made of an aluminum alloy, and, after installation, the nut head is milled flush.

Oversize-type. The oversize-type Jo-Bolt is used in special applications where the hole size has been exceeded and standard Jo-Bolts cannot be used. The head size and material specifications are the same as for the flush and hex types except for the size of the nut shank diameter.

SUMMARY

The majority of aircraft rivets are made of an aluminum alloy. Other metals used are steel and copper. Rivets used in Army aircraft are divided into two main groups: solid-shank and blind rivets. The solid-shank rivets are divided into universal- and countersunk-head styles. Countersunk rivets are used for a flush fit and for aerodynamic surfaces; universal-head rivets are used on exterior and interior locations and when clearances for adjacent members are not required. Blind rivets are used where one side of a riveted structure is not accessible or room for a bucking bar is not available. These rivets require special tools and installation and removal procedures. Blind rivets include friction and mechanical lock rivets. The head styles commonly used are the protruding and countersunk heads. The Hi-Shear rivet consists of a pin and a collar. Access to both sides of the held material is required to use these rivets. The pin is headed on one end and grooved about the circumference at the other. The collar is swaged onto the grooved end. The rivnut unit is composed of a rivnut and a screw, either attachment or plug type. They are used in blind locations, such as leading edges for deicer boot installation. Keyed rivnuts are used as nut plates and unkeyed ones are used for blind riveting where torque loads are imposed. Closed-end rivnuts are used where a sealed installation is required.

The special-purpose bolts in general use in Army aviation are Huck lock bolts and Jo-Bolts. The most commonly used Huck lock bolts are the pull, stump, and blind types. The pull type is mainly used in primary and secondary aircraft structure. The stump type is used where clearance is limited. The blind type is used where only one side of the work is accessible and where it is difficult to drive a conventional rivet.

Jo-Bolts are always considered to be a part of the permanent structure and subject to shear loads. These bolts are the flush, hex, millable hex, and oversize type.

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LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you have completed the exercise, check your answers with the answer key that follows. If you answer any question incorrectly, study again that part of the lesson which contains the portion involved.

1. What is the main structural unit of an aircraft?

_____A. Empennage.
_____B. Fuselage.
_____C. Nacelle.
_____D. Wing.

2. What part carries the primary stresses in the monocoque fuselage?

_____A. Bulkhead.
_____B. Frame.
_____C. Skin.
_____D. Stringer.

3. What aircraft structual unit gives the lifting force?

_____A. Wings.
_____B. Nacelle.
_____C. Fuselage.
_____D. Empennage.

4. What axis do the stabilizers help control while the aircraft is in flight?

_____A. Pitch and lateral.
_____B. Lateral and yaw.
_____C. Roll and yaw.
_____D. Longitudinal and lateral.

5. What metal property permits resistance to penetration?

_____A. Brittlenesss.
_____B. Hardness.
_____C. Malleability.
_____D. Strength.

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6. What stress is applied to the inside of a bend?

_____A. Compression.
_____B. Shear.
_____C. Tension.
_____D. Torsion.

7. What process is used to relieve internal stresses?

_____A. Alloying.
_____B. Tempering.
_____C. Annealing.
_____D. Cold working.

8. What is forcing metal through a die called?

_____A. Annealing.
_____B. Casting.
_____C. Extruding.
_____D. Hot working.

9. How many parts make up the friction lock rivet?

_____A. Two.
_____B. Three.
_____C. Four.
_____D. Five.

10. How many different types of Huck lock bolts are there?

_____A. Two.
_____B. Three.
_____C. Four.
_____D. Five.

11. What is the main structural member of the wing?

_____A. Rib.
_____B. Spar.
_____C. Stringer.
_____D. Stiffner.

12. What structural member is used to separate one area from another?

_____A. Bulkhead.
_____B. Frame.
_____C. Stringer.
_____D. Web.

LESSON 1

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. Fuselage.
	All other parts of an aircraft are attached to the fuselage. (Page 4)
2.	C. Skin.
	In aircraft design, the substructure gives shape only. (Page 4)
3.	A. Wings.
	When moving rapidly through the air, the wings are designed to provide lift to the aircraft. (Page 8)
4.	D. Longitudinal and lateral.
	Stabilizers keep the nose of the aircraft up or down (lateral) or from rolling over (longitudinal). (Page 12)
5.	B. Hardness.
	Hardness is associated with the grain boundaries of the outside of the metal. The closer the grain boundaries, the more resistence to abrasion. (Page 16)
6.	A. Compression.
	Two forces are in action at the same time on all bends or bending actions. Compression on the inside and torsion on the outside. (Page 19)
7.	C. Annealing.
	Annealing is the process used to make metals soft. It can then be worked and heat treated to harden it back up. (Page 22)

8. C. Extruding.

Extruding is the method used to form many of the parts used on aircraft. (Page 24)

9. A. Two.

The parts of a rivet are the hollow shank and stem. (Page 29)

10. B. Three.

The three styles of Huck lock bolt are pull, stump and blind. (Page 35)

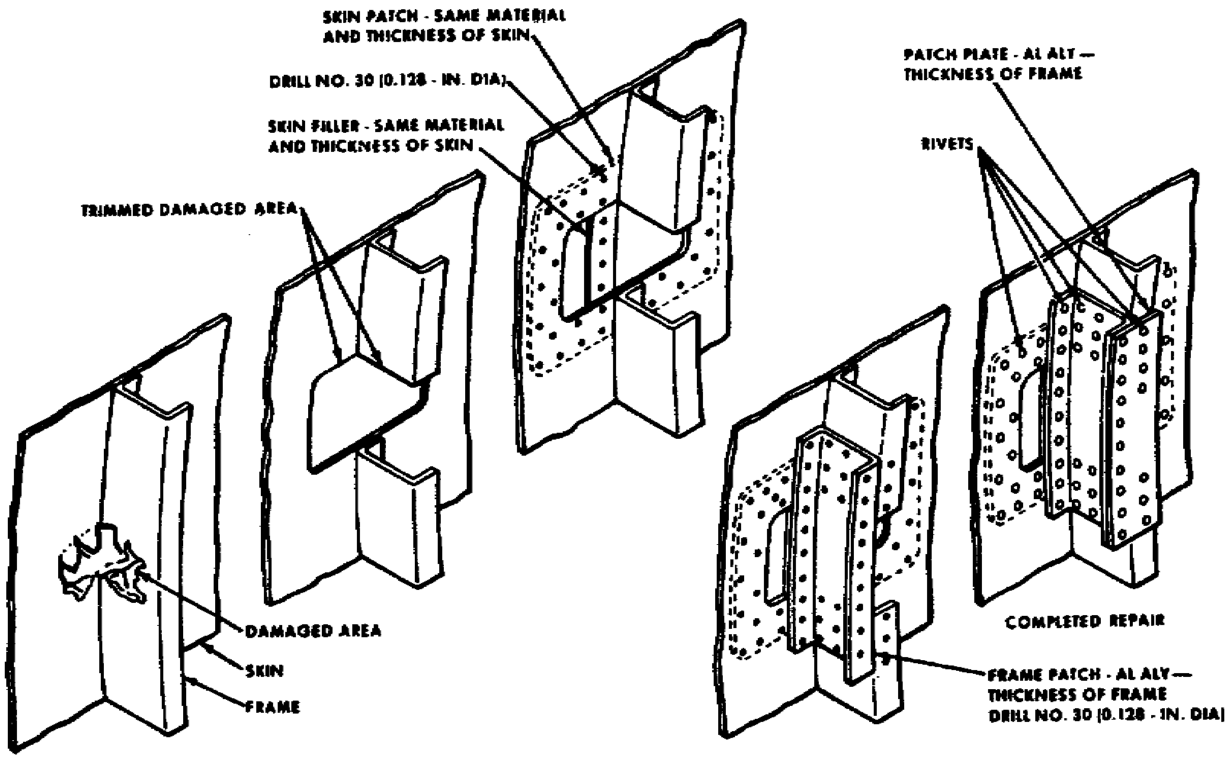
11. B. Spar.

The spar is the main load bearing member, while ribs, stringers and stiffeners transfer the loads and give shape to the wing. (Page 10)

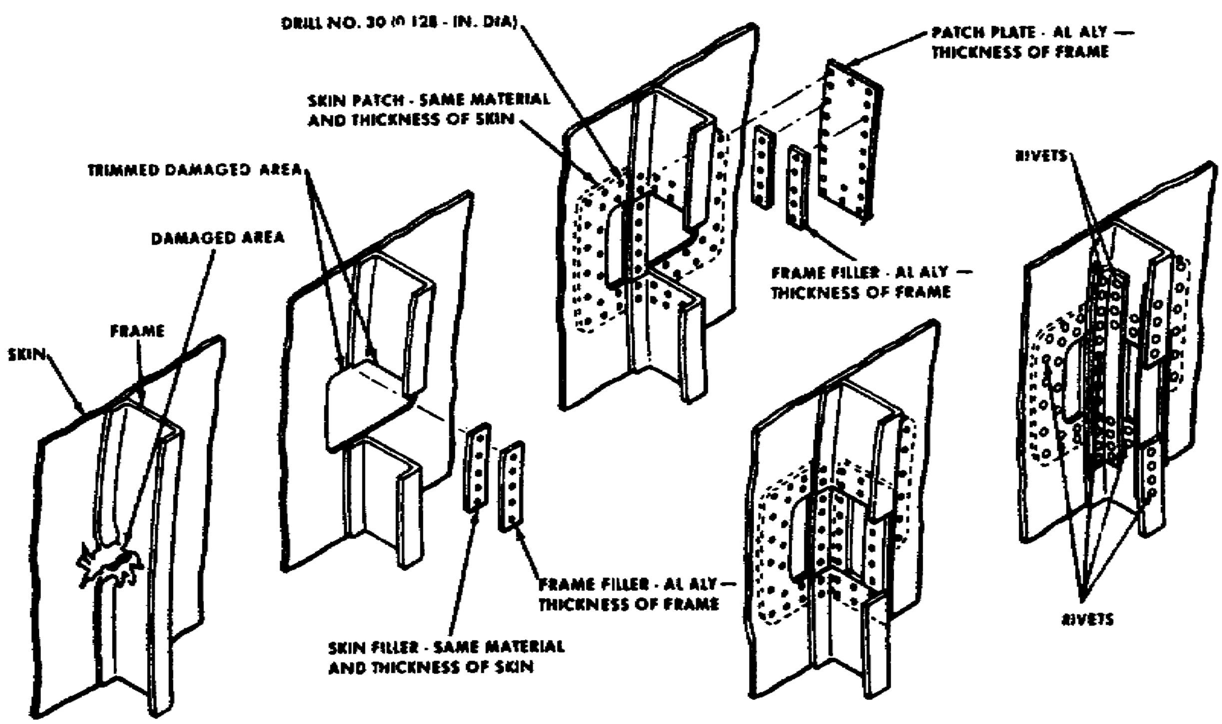
12. A. Bulkhead.

Bulkheads are frames with a reinforced disc-shaped section, with doors and access panels. (Page 6)

DAMAGE REPAIR



FRAME AND SKIN PATCH



LESSON 2

DAMAGE REPAIR

Tasks: 551-753-1002
551-753-1037
551-753-1039
551-753-1060

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn general damage repair.

LEARNING OBJECTIVE:

ACTION: You will apply the general repair principles of a structural repair, a stressed skin repair and structural sealing.

CONDITIONS: You will study the material in this lesson in a classroom environment or at home.

STANDARDS: You will correctly answer all the questions in the practice exercise before you go to the examination.

REFERENCES: The material contained in this lesson was derived from the following publications: FM 1-563 (Fundamentals of Airframe Maintenance) TM 1-1500-344-23 (Corrosion Control For Army Aircraft)

INTRODUCTION

The discussions in this chapter are important to you because they contain the fundamental information needed to support repair decisions. This information plus experience will help you to make valid judgments in assessing damage and deciding what is necessary to make trustworthy repairs.

Structural repair methods are numerous and varied, and no set of specific guidelines has been established that can be applied in all repair requirements. Therefore, damage repair problems are usually solved by duplicating the original part in material, strength, and dimensions.

This lesson, divided into five parts, discusses general repair principles, structural repair, stressed skin repairs, internal structure repair, and structural sealing. Because the discussions are general and describe typical repairs made in maintaining Army aircraft, specific repairs for specific aircraft must be made according to the applicable technical manual (TM).

PART A: PRINCIPLES OF REPAIR

GENERAL

This section covers maintaining original (design) strength, original contour, and minimum weight: the bases for airframe repairs. Again, the discussion in this section is basic. It is comparable to the form into which concrete will be poured to make a good foundation. This section is closely tied to damage assessment in the next section. Without a firm basis on which a valid assessment can be made, no worthwhile repair can be made.

MAINTAIN ORIGINAL STRENGTH

In so far as aviation maintenance is concerned, any repair must maintain the repaired member's original strength. Failure to maintain this strength can put a weakening strain on another member or members. The paragraphs that follow discuss five basic considerations in maintaining original strength.

Compression or Bending. If a member or fuselage skin is subject to compression and needs patching, put the patch on the outside to ensure higher resistance to compression or bending loads. If the patch cannot be placed on the outside, use material one gage thicker than the original material, and put the patch on the inside. The patch must have a cross-sectional area equal to, or greater than, the original damaged section. The general rule here is to regain, as near as possible, the original strength.

Cracking. Circular or oval patches must be used to reduce the danger of cracks starting at the corners. If a rectangular patch must be used, make the curvature radius at each corner no smaller than 1/2 inch. Buckled or bent members must be replaced or reinforced by putting splices over the affected areas.

Similarity of Material. Be certain that all replacement or reinforcement material used is similar to the original material used. If substitutions are necessary, use material of a gage heavy enough to give an equivalent cross-sectional strength. Substituting a lighter gage but stronger material for the original is dangerous. The danger is that one material can have greater tensile strength than another but less compressive strength. For example, the buckling and torsional strengths of some sheet metal and tubular parts are dependent primarily upon the thickness rather than the allowable compressive and shear strengths of the material. Therefore, a substitute thinner than the original will reduce the buckling and torsional strength of a part, even though the thinner substitute material has higher compressive and shear strengths.

> NOTE: Never substitute a material thinner than the original material or with cross-sectional area less than the original. The buckling and torsional strengths of many sheet metal and tubular parts are dependent primarily upon the thickness, rather than the allowable compressive and shear strength of the material. Therefore, a substitute thinner than the original will reduce the bucking and torsional strengths of a part considerably, even though the thinner substitute material has higher allowable compressive and shear strengths.

Forming. Be particularly careful when forming (shaping) alloys. Heat-treated and cold-worked alloys cannot take much bending without cracking. On the other hand, soft alloys can be easily formed without cracking; however, they are not strong enough for primary structures. Strong alloys can be formed in their annealed state first and then heat treated, in the desired shape, to develop their strength.

In some cases, if annealed metal is not available, the metal can be heated and quenched according to regular heat-treating practices and formed before hardening sets in. However, forming must be completed in approximately half an hour after quenching because the material may become too hard to work. When a brake is used to form the metal, be sure to use a thin piece of soft metal on the brake jaws to prevent the metal's surface from being marred.

Rivet Size and Number. The rivets in the next parallel row inboard on the wing or forward on the fuselage can be used to determine the size of rivets needed for any repair. Another method is to multiply skin thickness by three and use the nearest larger size rivet corresponding to that result. For example, if skin thickness is 0.040 inch, multiply that by three. The result is 0.120; use the next larger size rivet, 4/32 inch (0.125 inch).

Each repair takes a specific number of rivets to restore the original strength. This number will vary with the thickness of the material being repaired and the size of the damage.

However, the direct and general support (DS and GS) maintenance manual applicable to the particular aircraft gives essential information to accomplish direct or general support and depot maintenance on the complete airframe, including the kind, size, and number of rivets.

ORIGINAL CONTOUR

All repairs must be made so that the original contour is maintained exactly. This is especially true with patches on the external skin. Changes in external contour mean changes in air flow across the external skin. These changes can cause vibrations that might lead to other damage.

MAINTAIN MINIMUM WEIGHT

All repairs must be kept to a minimum weight. Keep the patch size as small as practicable and limit the number of rivets to what is necessary. In many cases, repairs disturb the structure's original balance. By adding weight in each repair, a control surface becomes so unbalanced that the trim and balance tabs will require adjusting.

SUMMARY

All repairs in aviation maintenance must maintain the original strength of the repaired part or member. For example, if the fuselage skin is subject to compression, put the patch on the outside; this ensures greater resistance to such loads. The patch cross-sectional area must be equal to, or greater than, the original damaged area or section. To reduce the danger of cracks starting at the corners, use circular or oval patches. If a rectangular patch must be used, you should ensure that the curvature radius at each corner is no smaller than 1/2 inch. Buckled or bent members are replaced or reinforced by putting splices over the affected areas. Replacement or reinforcement material must be similar to the original material. If substitutions must be made, be sure that the material's gage is heavy enough to give equivalent cross-sectional strength. Using a lighter gage, stronger material is dangerous. One material may have more tensile strength but less compressive strength than another. Buckling and torsional strengths of some sheet metal and tubular parts depend primarily upon thickness rather than allowable compressive and shear strengths. So, even though a thinner material has higher compressive and shear strength, it can have less buckling and torsional strength. Care must be used when forming heat-treated and cold-worked alloys. When subjected to much bending, such alloys will crack. Although soft alloys are easily formed without danger of cracking, they lack strength for use in primary structures. Strong alloys can be formed in their annealed state first and then heat treated, in the desired shape, to develop their strength. When using a brake to form metal, be sure that a thin piece of soft metal is placed on the brake jaws to prevent marring the metal's surface.

The best method for determining the size and number of rivets to use on a repair is to refer to the direct and general support manual applicable to the aircraft being repaired. This manual gives the essential information needed to perform direct and general support and depot maintenance on the complete airframe.

All repairs must be made so that the aircraft's original contour is maintained. In addition, all repairs must be kept to a minimum weight. This is accomplished by using patches as small as practicable and limiting the number of rivets to what is necessary. When weight is added in each repair, the aircraft's balance may be so disturbed that trim and balance tabs may have to be adjusted. A patch on the propeller spinner requires a balancing patch to keep the propeller assembly in balance.

PART B: STRUCTURAL REPAIR

GENERAL

In making aircraft structural repair, the primary objective is to restore the damaged parts to their original condition. Frequently, the only effective way is to replace the damaged part or parts. However, each damage must be studied carefully to determine if repairing or replacing is the course to follow. If a damaged part can be repaired, its purpose or function must be fully understood. The reason for this is that while strength may be the principal requirement in some structures, others might need totally different characteristics. For example, fuel tanks, floats, and hulls must be leak proof; however, cowlings, fairings, and similar parts must be smooth and streamlined.

This section discusses damage assessment, cracks, damage classification, corrosion control, corrosion inspection, structural member stresses, and repair practices.

DAMAGE ASSESSMENT

While inspecting damage, remember that all damage is not obvious or limited to an immediate location. For example, skin damage made by shells or shell fragments may be accompanied by damage to longerons, struts, cables, and so on. A hard landing can overload one of the landing gears. While inspecting a sprung shock strut, see if the damage extends to supporting structural members. When a shock occurs at one end of a member it is transmitted the entire length of that member. Therefore, all rivets, bolts, and attaching structures must be inspected for possible damage. Make a thorough inspection for rivets that have partially failed and for holes that have been distorted. Damage assessment includes looking for weathering or corrosion. Damage to aluminum by corrosion is detected by a white crystalline deposit that can be seen around loose rivets, scratches, bad dents, or some portion of the structure where moisture can collect. If a visual inspection of inside skin surfaces cannot be made without disassembly, rap your knuckles on the outside skin at various places. Severe corrosion exists if the light rapping causes dents or a white dust to appear.

INSPECTING FOR CRACKS

The existence or full extent of cracks in major structural members cannot be accurately determined by a visual inspection; therefore, several methods other than visual are used. They are ultrasonic waves, X rays, Zy-glo, and a penetrating dye. When using ultrasonic waves, only one side of the inspected metal need be accessible. With X-ray equipment both sides of the metal must be accessible. The Zy-glo method requires blacklight equipment. Penetrating dye requires no complex or expensive equipment, and it can be easily used in the field. The materials to make a dye-penetrant inspection consist of the penetrating dye, dye remover, and dye developer, all contained in an inspection kit. Individual items for the kit can be requisitioned to replace those which have been used. The paragraphs that follow describe how the kit is used.

<u>Preparation</u>. All coats of paint and surface dirt must be removed before the dye penetrant is applied. A thoroughly clean surface is required to ensure an accurate portrayal of the structural member's condition.

<u>Application</u>. The surface to be inspected is given a final cleaning by applying dye remover and wiping the surface with clean cloths. Then a coat of dye penetrant is applied by brushing or swabbing and allowed to penetrate for 3 to 15 minutes.

<u>Removal</u>. The dye penetrant on the surface is removed by wiping the excess off, first with a dry cloth and then with a cloth moistened with dye remover. If a water rinse is used, the inspected part must be thoroughly dried before applying the dye developer.

<u>Development</u>. A light, even coating of dye developer is applied with a brush or by spraying. Whichever method is used, be sure that the coating is free of runs or laps. The developer dries and forms a smooth, white coating. Cracks show up as red lines, and the extent is indicated by the length of the red

lines. Narrow or tight cracks show up as a series of red dots close together. Scattered dots that do not show a pattern indicate porousness. Because this method is so sensitive, evaluating the indicated cracks requires good judgment. After the flaws have been detected and marked, remove the developer with dye remover or an approved petroleum solvent.

Warning. Dye-penetrant materials are flammable, particularly the developer. They must be used only in well-ventilated areas away from sparks or flames. The fumes must not be breathed for prolonged periods; and gloves, goggles, and aprons are recommended for protection. Contaminated skin must be washed with soap and water, and contaminated clothing must be changed at once and laundered before reuse.

DAMAGE CLASSIFICATION

When the existence and extent of the damage has been evaluated, it must be classified. The classifications for damage are--

- Negligible.
- Repairable by patching.
- Repairable by insertion.
- Requiring replacement.

In many instances the availability, or scarcity, of repair materials and time determines whether or not a damaged part is repaired or replaced. The paragraphs that follow describe the four classifications.

Negligible Damage. Damage that does not impair the structural soundness of the member involved or that can be repaired without putting flight restrictions on the aircraft is negligible damage. Examples of negligible damage include small dents, scratches, cracks, or holes that can be repaired by smoothing, sanding, stop drilling, hammering, or other methods without additional materials.

Patch-Repairable Damage. Damage that exceeds limits set for negligible damage and can be repaired by bridging it with splice material is damage repairable by patching. Splice or patch material used to make internal or riveted and bolted repairs is usually the same kind of material as the original only one gage heavier. In patch repairs, filler plates identical to the gage and material of the damaged component can be used to return the damaged part to its original contour.

Damage Repairable by Insertion. Any damage that can be repaired by cutting away the damaged part, replacing it with a like portion, and securing the replacement with splices at each end is damage repairable by insertion.

Damage Requiring Replacement. Generally, damage that cannot be repaired or is so severe that the time needed to repair it is not warranted is classified as damage requiring replacement. Examples are--

- A complicated part which is extensively damaged.
- The surrounding structural members or inaccessibility makes repair impractical.
- The damaged part is relatively easy to replace.
- Forged or cast fittings are damaged beyond negligible limits.

CORROSION CONTROL

The act or process of dissolving or wearing metal away by a chemical action is corrosion. It can also be defined as the deterioration of a metal by reaction to its environment. Most metals are subject to such deterioration; however, the reaction can be minimized by using corrosion-resistant metals and finishes within the aircraft's design limits. In airframe structures this is done by using aluminum alloy sheets coated on both sides with pure aluminum (alclad). Internal structures are generally painted with an organic finish (carbon base). Cadmium or zinc plating, conversion coating, paint, or all three are used to protect steel (except most stainless steel), bronze, and brass.

The paragraphs that follow discuss briefly the need for corrosion control and the kinds of corrosion. For more detail, see TM 1-1500-344-23.

Need for Corrosion Control. Without protection from corrosion, an aircraft's capability and operational integrity are endangered. As a result, tactical and combat service support missions cannot be flown. Economy is another reason for corrosion control because in severe cases corrosion can weaken primary structures sufficiently to require their reinforcement or replacement. Either repair can be costly and time-consuming. Moreover, aircraft effectiveness is lost.

Common Types of Corrosion. Many ways have been used for classifying corrosion. For simplicity, corrosion is discussed here under the titles most generally used.

Uniform Etch Effect. Most direct chemical attacks, as by an acid, produce a uniform etch effect on the surface. This is first noticed on a polished surface as a general dulling or loss of polish. If the corrosion is not stopped, the surface becomes rough and possibly frosted in appearance.

Pitting. On aluminum and magnesium alloys, the usual effect of corrosion is pitting. A powdery white or gray deposit is the first sign of pitting corrosion. When the deposit is removed, shallow pits or holes can be seen in the surface. Pitting corrosion can occur on other alloys as well.

Intergranular. Intergranular corrosion occurs at the metal's grain boundaries. A magnified cross-sectional view of any alloy shows the metal's granular structure. Each grain has a clearly defined boundary differing chemically from the metal within the grain center. Adjacent grains of different elements reach an anode and cathode when in contact with a conductive medium such as moisture. Under this condition, rapid selective corrosion at the grain boundary takes place.

Exfoliation. Exfoliation, a form of intergranular corrosion, shows itself by lifting a metal's surface grains. The lift is produced by the force of expanding corrosion products at the grain boundaries just below the surface. Exfoliation corrosion is generally seen on extruded sections where grain thickness is usually less than in rolled forms.

Galvanic. Galvanic corrosion occurs when dissimilar metals are in contact and an external circuit is completed by moisture and contaminants. The result is a corrosion buildup at the bimetal juncture.

Concentration Cell. Concentration cell corrosion takes place when two or more metal surface areas are in contact with different concentrations of the same solution. In this corrosion, three general types of concentrations are recognized. They are the metal-ion cells, oxygen-concentration cells, and active-passive cells.

Stress. Stress corrosion cracking and fatigue corrosion are related in that the latter is a special case of the former. The simultaneous effects of tensile stress and corrosion cause stress corrosion cracking. Stresses can be internal or applied. Internal stresses are produced by nonuniform deformation during cold working, unequal cooling from high temperatures, and press and shrink fits, and application of rivets and bolts. The combined effects of cyclic stress and corrosion produce fatigue corrosion. No metal is immune to some reduction of its resistance to cyclic stressing if it is in a corrosive environment.

CORROSION INSPECTIONS

At periodic inspections all equipment must be examined for corrosion. Without such examinations and removal of any corrosion found, an aircraft can be seriously damaged. Locations to examine include unpainted aluminum surfaces, skin seams, and lap joints. Nicks and crevices where traces of cleaning compound may have accumulated and unexposed areas where moisture can accumulate must also be inspected for corrosion. Locations where corrosion can form and that require examination include possibly plugged drain holes, structures under floorboards, and jointed surfaces.

Fittings, braces, and compound parts inside the aircraft must be inspected for corrosion because of possibly faulty drainage or disposal outlets. Inspections for corrosion must be made where dissimilar metals contact or where spot welds, piano-type hinges, and exhaust-gas paths are located. Wheel wells, landing gear, dive brakes and similar areas, heavy or tapered aluminum skin surfaces, battery boxes and components, and relief tube outlets must also be inspected as possible sites for corrosion.

STRUCTURAL MEMBER STRESSES

An aircraft at rest or in flight is subject to applied forces throughout its entire structure. At rest, the weight (pull of gravity) of the wings, fuselage, engines, and empennage causes forces to act downward on the wing and stabilizer tips, along the spars and stringers, and on the bulkheads and formers. These forces are passed from member to member causing bending (tension and compression), twisting (torsion), compression, and shearing.

The five stresses in an aircraft are tension, compression, shear, bending, and torsion. The first three of these forces are generally called the basic stresses, and the last two are called the combination stresses. Stresses rarely act singly. Their action is usually combined. In airframe repair, the stresses most frequently encountered are bending, torsion, and shear. The paragraphs that follow describe the application of these forces.

Tension. Tension in airframe repair is the force that stretches a structural member. Notice in Figure 2-1 the conditions of the metal strap under the applied force. Under tension, the top of the metal strap is being pulled and the underneath side is being pushed together (compressive force). Some of the strap's material was removed by drilling a hole in it to receive the bolt. This reduced its cross-sectional area. Because the load is constant from one end of the strap to the other and the hole cannot carry any of the load, the stress in the reduced area is greatly increased per unit area. In other words, besides carrying its normal share of the load it is also carrying the load that would have been carried by the removed metal. If the force or load is increased until the strap breaks, the failure will occur at or near the hole.

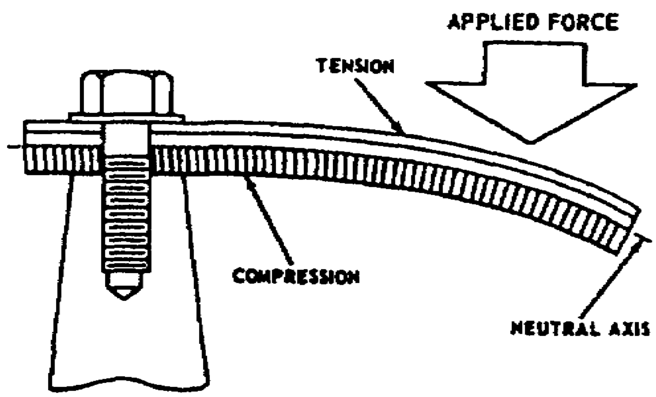


Figure 2-1. Combined Forces Applied.

A member's strength under tension is determined on the basis of its gross or total area; however, calculations involving tension must include the net area of the member. Net area is defined as the gross area minus that removed by drilling holes or by making other changes in the section. Putting rivets or bolts in the holes makes little or no difference in added strength. The rivets or bolts will not transfer tension force across the holes they are in.

Compression. Compressive stress (compression) in aircraft is the force per unit area that shortens or compresses a structural member at any cross section. Under compressive force, an undrilled member is stronger than an identical member that has holes drilled through it. However, if a plug of equivalent or stronger material is fitted tightly into a drilled member it will transfer compressive force across the hole, and the member can carry approximately as great a load as if there were no hole. Therefore, with compressive loads, the gross or total area can be used to determine stress in a member if all holes are tightly plugged with equivalent or stronger material.

Shear. Shear is the force per unit area that slides adjacent pieces of material past each other. The term shear is used because it is sideways stress of the type that is put on a piece of paper or a sheet of metal when it is cut with a pair of shears. For example, if two pieces of metal are bolted or riveted together and sufficient force is applied to opposite ends, the metal pieces will shear, cut, the bolt.

Bending. Bending is a combination of two forces. Notice in Figure 2-1 that the bending force produces tension on the top of the strap and compression on the bottom portion. The combined stresses produce a shear action at the neutral axis. This occurs because these forces act in opposite directions and are next to each other at the neutral axis. Shear action does not take place at the extreme upper and lower strap surfaces.

Torsion. Torsion in airframe repair is the force that twists a structural member. The stresses arising from this action are shear ones. They are caused by adjacent planes rotating past each other and around a common reference axis at right angles to these planes. As an example, assume a rod is fixed solidly at one end and is twisted by a weight placed on a lever arm at the other. This produces the equivalent of two equal and opposite forces acting on the rod at some distance from each other. These forces create a shearing action all along the rod, with the rod's centerline representing the neutral axis.

GENERAL REPAIR PRACTICES

During repair of any major structural member, the structure must be firmly supported. The support must enable the work to be completed without any misalignment or distortion. If special fixtures to support the aircraft or any of its components are not available, temporary supports must be made. In addition, repair materials, layout of parts for repair, rivet replacement, and rivet-hole reuse must be given careful selection and assessment. The paragraphs that follow discuss repair material, layout of parts for repair, rivet replacement, and rivet-hole reuse.

Repair Material Selection. When repairs must be made, the prime requirement is to duplicate the structure's original strength. To do this, the repair material must be as strong as that used in the original. If it is necessary to substitute a weaker alloy than originally used, a heavier gage metal must be used to secure equivalent cross-sectional strength. A lighter gage material must never be used, even when using a stronger alloy. If substituting a metal becomes necessary, always consult the applicable technical manual.

Layout of Parts for Repair. Before fitting them into the aircraft structure, new sections made for repairs must be laid out to the dimensions given in the applicable TM for that aircraft. "Laid out" is used here in the sense of being measured and marked. When marking, care must be taken to not scratch the material. Such scratches can weaken the material or possibly develop into cracks. All marks on aluminum except lines to be cut must be made with an aircraft marking pencil. Exposed metal parts of a repair and their contact surfaces must be given a coating of epoxy polymide primer.

Rivet Selection. In general, the rivet size and alloy in the repair must be the same as in the original. After reworking an enlarged or deformed rivet hole, the next larger size rivet must be used. When such rivets are used, proper edge distance must be maintained. Where blind rivets must be used in repairs, the applicable manual must be consulted for the type, size, spacing, and number of blind rivets needed to replace the original rivets.

Rivet Spacing and Edge Distance. The instructions in the applicable manual covering rivet patterns for a repair must be followed. As a general rule, existing rivet patterns are used when possible. However, rivet spacing is generally between 6 to 8 times the diameter (6D - 8D) of the rivet shank. The spacing must never be less than 3 times or more than 10 times the diameter (3D - 10D) of the rivet shank. For flush head rivets, edge distance must not be less than 2 1/2D and for all other rivets at least 2D. Edge distance greater than 4D must never be used.

SUMMARY

The primary objective in aircraft repair is to restore the damaged part to its original condition. Each damaged part must be studied to determine if repair or replacement is required. All damage is not obvious or limited to an immediate location. A thorough assessment of a damaged area includes inspecting supporting structural members and adjacent rivets and bolts to see if they have sustained damage also. The assessment of damage also includes looking for weathering and corrosion. A white crystalline deposit at loose rivets and bolts, scratches, dents, and places where moisture can collect is corrosion.

A visual inspection does not reveal the existence or extent of cracks. Methods used to locate cracks and their extent include ultrasonic waves, X rays, Zy-glo, and penetrating dye. Because dye does not need expensive or complicated equipment, it is used in the field. The area to be dyed must be thoroughly cleaned. The dye is applied by brushing or swabbing and allowed to penetrate for 3 to 15 minutes. An even coat of developer is applied and allowed to dry. Defects are indicated in red and cracks show up as red lines. Scattered, unpatterned dots indicate porosity. All the materials used in the dye test are flammable, and prolonged breathing of the fumes is injurious.

Damages are classified as negligible, repairable by patching, repairable by insertion, and repairable by replacement. Availability of repair materials and time can influence the decision to repair or replace a part.

Corrosion is the process of a metal deteriorating by chemical reaction. Such deterioration is minimized by coating, plating, or painting metals subject to corrosion. Control of this process is necessary to protect aircraft operational integrity, limit expenses, and reduce maintenance manhours. Corrosion classifications are uniform etch effect, pitting, intergranular, exfoliation, galvanic, concentration cell, and stress corrosion cracking, and fatigue corrosion. Inspections for corrosion must be made at all periodic inspections.

The five stresses an aircraft is subject to are tension, compression, shear, bending, and torsion. The first three are called basic stresses and the others are called combination stresses. Bending, torsion, and shear are the most frequently encountered in airframe repair.

The prime requirement in repair material selection is to duplicate the structure's original strength. Caution must be used if alloys must be substituted, and the applicable technical manual must be consulted. New sections for repair or replacement must be made to the dimensions given in the appropriate technical manual. In addition, material must be marked with an aircraft marking pencil to prevent harmful scratches being made on the metal.

In general, the rivet size and alloy used in the repair must be the same as the original. For reworked enlarged or deformed rivet holes the next size rivet must be used. If blind rivets are used, the applicable technical manual must be consulted for type, size, number, spacing, and edge distance.

PART C: STRESSED SKIN REPAIRS

GENERAL

Skin patches are divided into two general types: the lap and flush patches. A lap patch is externally applied and has its edges overlapping the skin. The patch's overlapping portions are riveted to the skin. This kind of patch is permitted in certain areas on some aircraft, but only where aerodynamic smoothness is unimportant. The flush patch, shown in Figure 2-2, is inserted into the repaired area and is riveted to a reinforcement plate (doubler) that in turn is riveted to the inside of the skin.

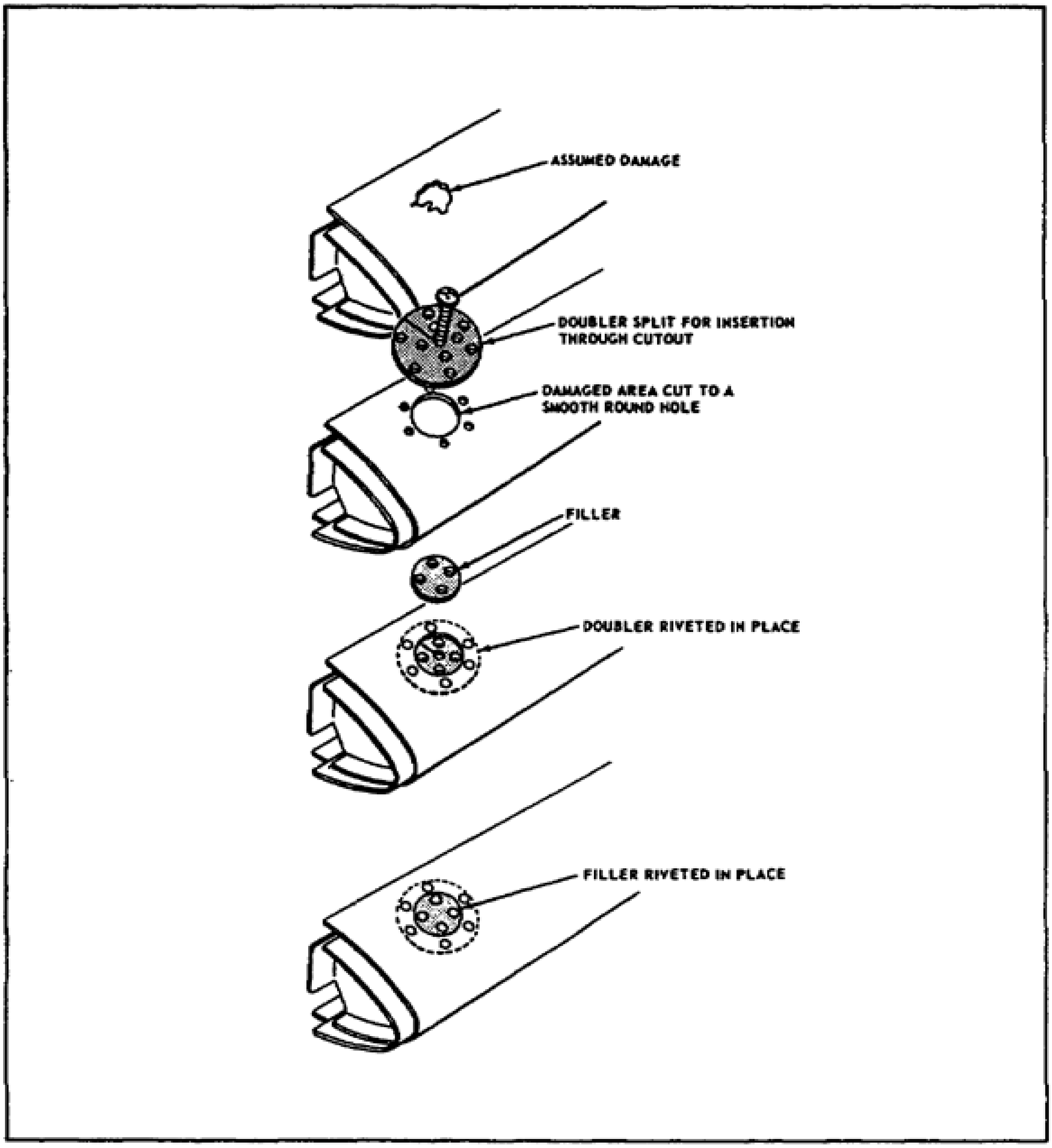


Figure 2-2. Flush Patch Repair of a Small Hole.

Accessibility to the damaged area and procedures outlined in the appropriate technical manual determine how damaged skin is to be repaired. Most of an aircraft's skin is inaccessible from the inside for making repairs. This skin is designated closed skin. Where aerodynamic smoothness is not required, this skin can be repaired conventionally, using specified standard rivets.

In general, however, closed-skin repairs require some kind of special fastener. The exact fastener depends on the kind of repair and the manufacturer's recommendation. This section discusses stress intensity, patching procedures, repairs on watertight and pressurized areas, flush access doors, and skin replacement.

STRESS INTENSITY

An important part of making a skin repair is the amount of stress intensity (strength) to be restored to the damaged panel. For example, some skin areas are designated as highly critical, other areas as semicritical, and still others as noncritical. Damage repairs to highly critical areas must restore 100 percent of original strength; semicritical areas must have 80 percent restoration of original strength; and noncritical areas need 60 percent restoration of original strength. To determine the requirements for making stressed-skin repairs, the applicable technical manual for the particular aircraft must be consulted and its instructions followed.

PATCHING PROCEDURES

By comparison, lap patching appears to be less complex than flush patching. However, all patch repairs must be made with careful attention to detail, and the technical manual appropriate to the aircraft must be consulted. The paragraphs that follow describe some details in both patching procedures.

Lap Patches. Lap patches can be used at authorized locations to repair cracks and small holes (Figure 2-3). When repairing cracks, always drill a small hole at each end of the crack with two stop holes, one at each end. To drill the holes use a Number 40 drill. These holes are important because they stop the crack from spreading. The patch size must be large enough to take the required number of rivets. The number is determined from the rivet schedule indicated for the gage of the material in the damaged area. The recommended patch can be cut in on a circular, square, rectangular or diamond shape. Patch edges must be chamfered, beveled, to an angle of 45°.

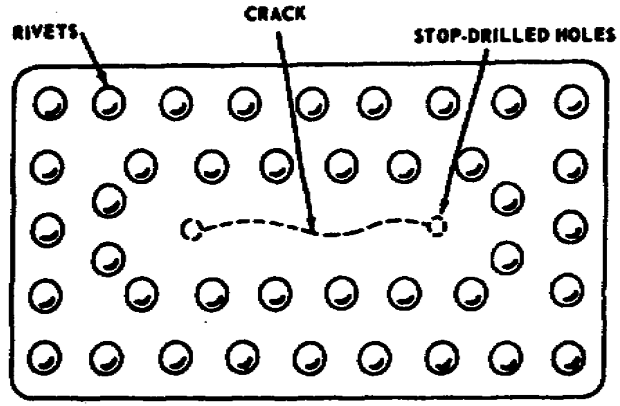


Figure 2-3. Lap Patch for a Crack.

Flush Patches. Flush patches in locations free of internal structures are relatively easy to install. This is especially true where there is an access door or plate through which rivets can be bucked. In inaccessible areas, the flush patch can be used by substituting blind rivets for standard rivets, where permitted. However, ways of inserting the doubler through the opening must be devised. A doubler is the piece of material used to back up, double, or strengthen the filler patch. One such method is illustrated in Figure 2-2. The doubler has been split. To insert the doubler, slip one edge under the skin and turn the doubler until it slides into place under the skin. Notice in the figure that a screw has been installed temporarily as a handle to help insert the doubler. This type of patch is generally recommended for holes up to 1 1/2 inches in diameter. Usually holes larger than 1 1/2 inches are trimmed to a rectangular or square shape. All corners must be rounded to at least a 1/2-inch radius. Figure 2-4 shows such rounded corners. In all flush patches the filler must be of the same gage and material as the original skin. Generally, the doubler must be of material one gage heavier than the skin. Figure 2-5 shows a flush patch over an internal structure.

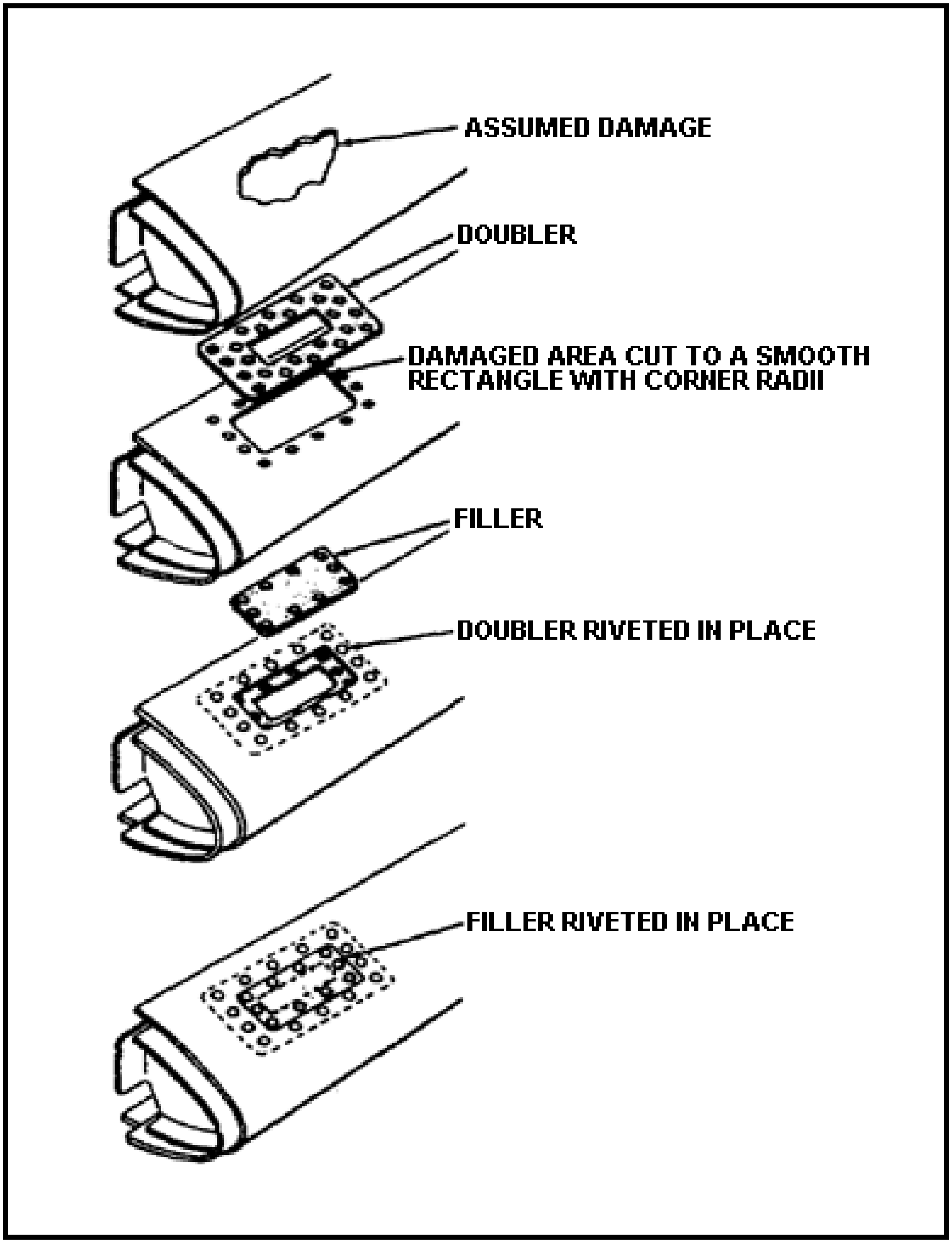


Figure 2-4. Rectangular Flush Patch.

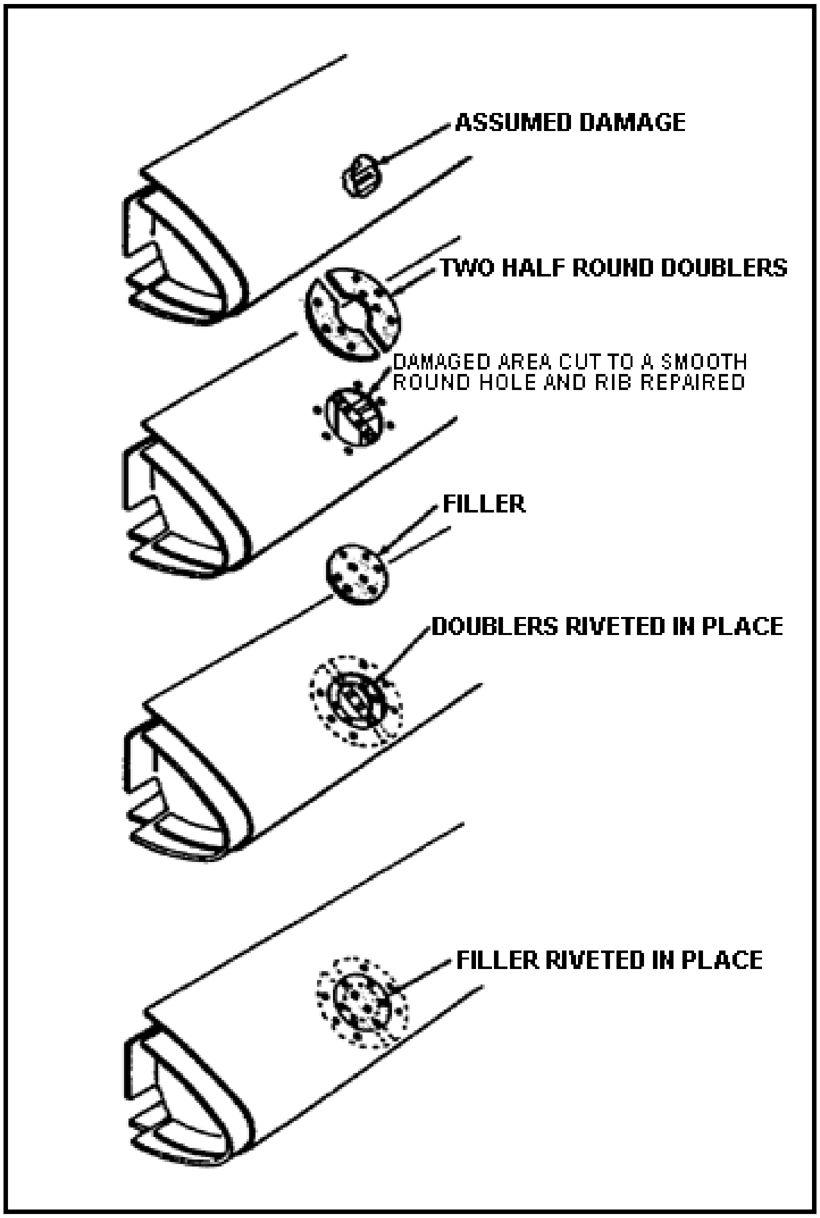


Figure 2-5. Internal Structure Flush Patch.

SEALING WATERTIGHT AND PRESSURIZED AREAS

Repairs on hulls and floats must be watertight, and repairs to pressurized compartments must be sealed against pressure loss. The same sealing method used by the manufacturer must be used whenever possible. A recommended method is to clean all contact surfaces with an approved naphtha. In addition, ensure that all burs, chips, and foreign materials are removed. Apply zinc-chromate sealing tape to both surfaces, and peel off the cloth backing strip. Brush on a coating of zinc-chromate paste, and draw the mating surfaces together with machine screws and nuts. Drive each rivet successively as a screw and nut is taken out, and remove any excess sealing compound.

FLUSH ACCESS DOOR

Sometimes installing flush access doors is permitted as the easiest and most efficient way to repair internal structures or certain skin areas. Notice in Figure 2-6 that the installation consists of a doubler and a stressed-access cover plate. Nut plates, in a single row, are riveted to the doubler; and the doubler is then riveted to the skin with two rows of rivets, staggered, as shown in Figure 2-6. The cover plate is attached to the nut plates on the doubler with machine screws to permit easy plate removal.

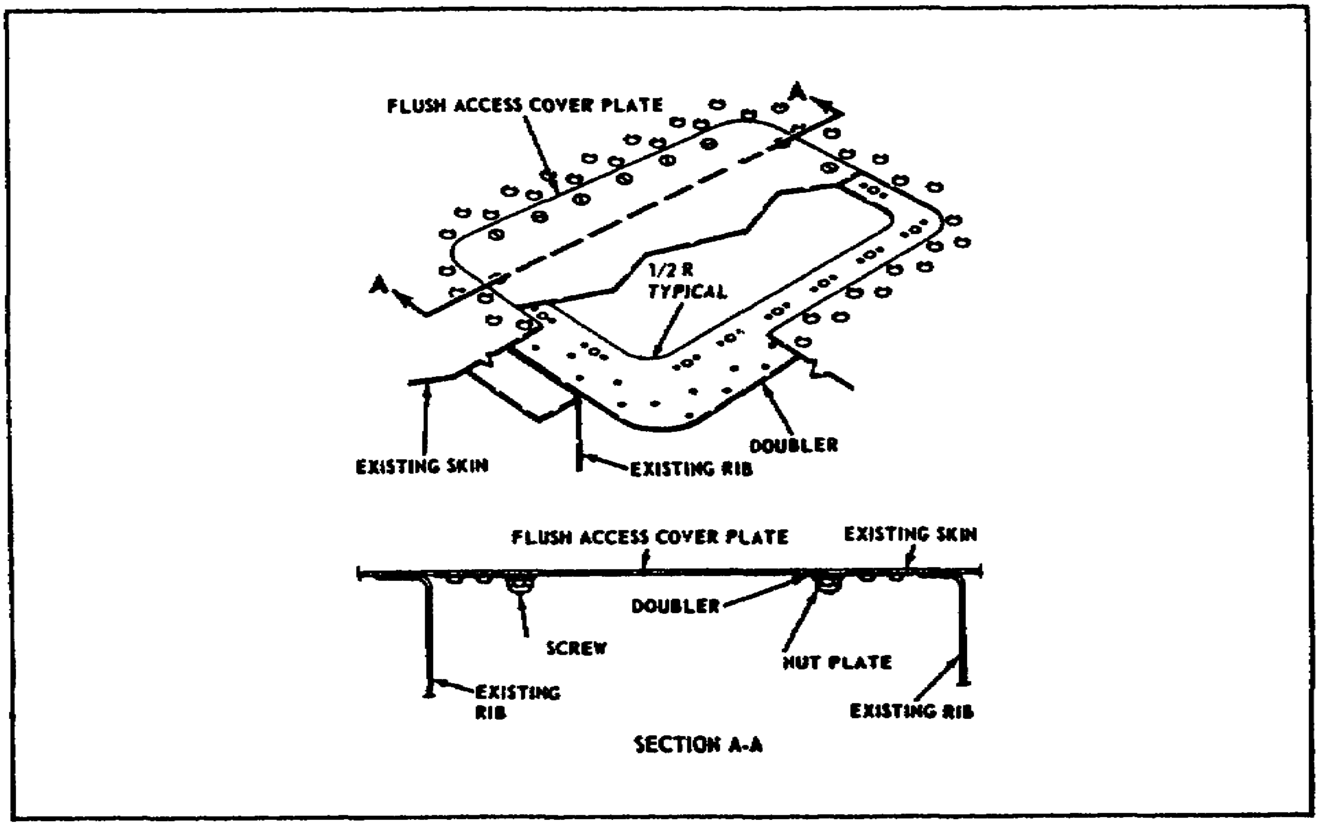


Figure 2-6. Flush Access Door Installation.

SKIN REPLACEMENT

Damage to an aircraft's skin is sometimes so extensive that an entire panel must be replaced. Also, a section or area of skin may have such a number of patches or minor repairs that a panel may have to be replaced. In either case, the first step, as in all other repairs, is to thoroughly inspect the damaged area to determine the full extent of the damage. This includes inspecting internal structures for damage or signs of strain. These members must be repaired or replaced if they are bent, fractured, or wrinkled. All rivets in the vicinity of such members must be inspected for signs of failure. They can be sheared without such a condition being externally evident. Under such circumstances, rivets at various points in the damaged area must be drilled out and examined. For this procedure the applicable TM for the particular aircraft must be consulted.

The paragraphs that follow discuss these aspects of skin replacement and the mechanics and techniques in measuring, cutting, and aligning new metal sheets, drilling new rivet holes, and bucking rivets.

Measuring, Cutting, and Aligning. In removing a panel, care must be taken to avoid further skin damage because frequently the old skin can be used as a template for the new skin. The gage and alloy of material to replace the panel is shown in the applicable manual for the specific aircraft. The size of the panel can be determined in either of two ways. The dimensions can be measured during the inspection, or the old skin can be used as a template for the layout of the new sheet of skin and the location of the holes. Because the latter method is more accurate, it is the preferred one. Whichever method is used, the new sheet must be large enough to replace the damaged area; and it can be cut with an allowance of 1 to 2 inches of material outside the rivet holes.

If the old sheet is not too badly damaged, it must be flattened out and can be used as a template. The new sheet, cut 1 to 2 inches larger than the old, is drilled near the center using the holes in the old sheet as a guide. The two sheets are then fastened together with sheet metal fasteners. Sheet metal screws are not recommended because they damage the edges of the rivet holes. Drilling must always start at the center and work to the outside of the sheet with sheeting metal fasteners inserted at frequent intervals.

If the old sheet cannot be used as a template, the holes in the new sheet must be drilled from the inside of the structure. The holes in the reinforcing members are used as guides for the drilling. Fasteners are inserted in the same manner as described before; this technique is called back drilling. Before the new sheet is placed on the framework to drill the holes, the reinforcing members must be in proper alignment and flush at the points where they intersect. Therefore, the new sheet must have the same contour as the old sheet.

Drilling New Rivet Holes. Much care must be taken in duplicating holes from reinforcing members, or the frame and skin can be ruined. Such care is necessary because most ribs, stringers, and bulkheads depend on the skin for some of their rigidity and they can be forced out of alignment during drilling. The pressure from drilling forces the skin away from the frame and causes the holes to be out of alignment. This can be prevented by holding a block of wood firmly against the skin while drilling. Also the drill must be held at a 90° angle to the skin during drilling or the holes will be out-of-round. A smaller pilot drill must be used first when drilling through anchor nuts. Care must be taken to avoid damaging the anchor nut threads. The pilot holes are then enlarged to the proper size.

Marking New Holes. An angle attachment or flexible-shaft drill may be necessary where a straight drill cannot be inserted. If neither of these drills can be used, mark the new section with a soft pencil through the holes in the old section. Another method for marking new hole locations is with a transfer or prick punch, shown in Figure 2-7. Center the punch in the old hole and then hammer lightly on the outside of the sheet with a mallet. The resulting mark can be used to locate the hole in the new sheet.

Another way to locate the rivet holes without a template is to use a hole finder similar to the one shown in Figure 2-8. This device makes a perfect alignment with the holes in the old section possible while drilling holes in the new section of skin. The hole finder illustrated is made in two sections, an upper and a lower part, bolted together at one end. A guide rivet, at the free end of the bottom section of the hole finder, drops into the old holes in the sheet still in place. The free end of the hole finder's top section has a hole that exactly matches the position of the guide rivet. The new hole is drilled through this opening. As the hole finder is moved along, the guide rivet drops into an old hole and automatically determines the new hole's location.

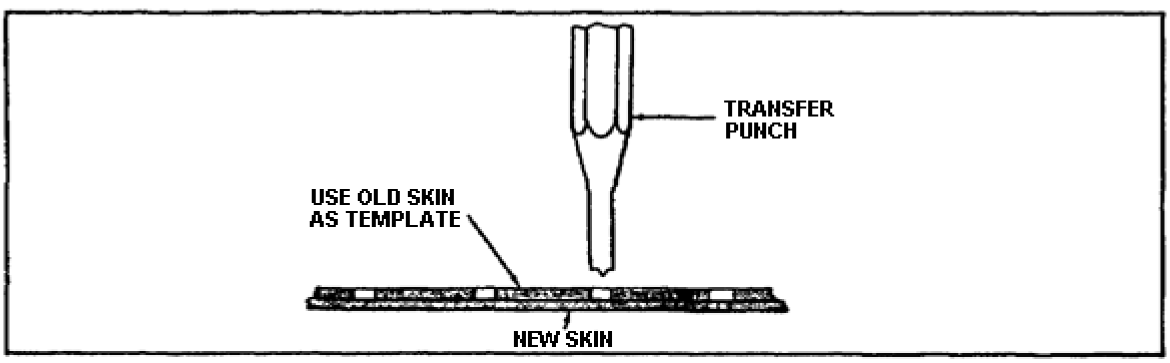


Figure 2-7. Transfer Punch.

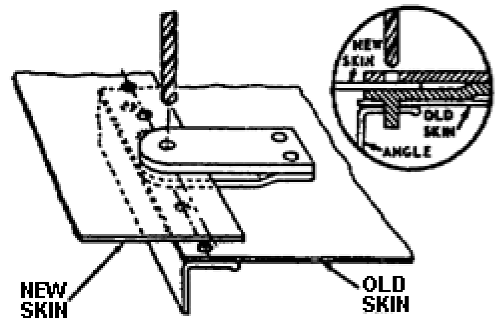


Figure 2-8. Hole Finder.

Removing Burrs. The temporary fasteners are taken out and the sheet is removed from the framework after all the holes are drilled. Burrs left by drilling must be removed from both sides of all holes in the skin, stringers, and rib flanges. Deburring can be done with a few light turns of a countersink drill. If the burrs are not removed, the joint may be tight; and the rivets can expand, or flash, between the parts being riveted.

Bucking Bar. Selecting and using a bucking bar of the correct type and weight is important to a successful riveting job. For example, a bucking bar for 1/8-inch rivets must weigh at least 2 pounds. Larger rivets require proportionately heavier bucking bars. A light bar requires too many blows to complete the riveting, and the blows tend to deform the rivet head.

A straight bar is preferred because its weight can be applied directly in line with the rivet's shank. If flanges on ribs or stringers do not permit using a straight bar, one that allows straight-line pressure must be used. Figure 2-9 shows two such bars, (A and B). The bar at (C) or a similar bar can, at best, only create more damage.

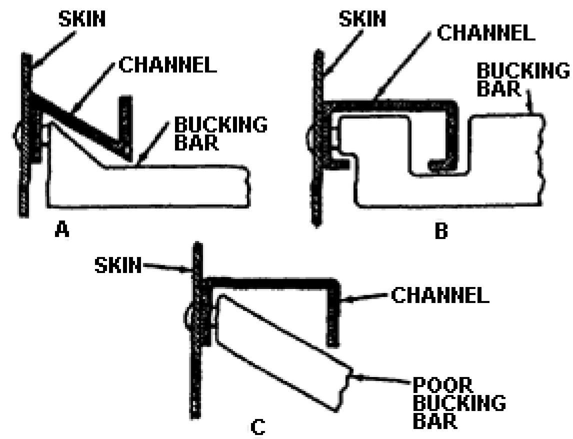


Figure 2-9. Correct and Incorrect Bucking Bars.

SUMMARY

Skin patches are divided into two types. The first, a lap patch, is applied externally with its edges overlapping the skin. This patch is used only where an aerodynamic surface is not needed. Flush patches, the second type, are inserted into the damaged area and riveted to a doubler that is riveted to the skin. Damaged-area accessibility and directions in the technical manual applicable to the aircraft determine the kind of patch to use. Most of an aircraft's skin is inaccessible from the inside, and such skin is designated as closed skin. That accessible from both sides is open skin.

An important aspect of making skin repairs is the amount of stress intensity (strength) to be restored. Repairs must restore highly critical areas to 100 percent, semicritical areas to 80 percent, and noncritical areas to 60 percent of original strength. For stressed-skin repairs, the applicable technical manual must be consulted and followed.

Lap patches are used at authorized locations to repair cracks and small holes. To repair cracks, a small hole is drilled at both ends of the crack to stop the crack from spreading. Patch sizes must be large enough to take the number of rivets prescribed in the applicable manual. Flush plates are relatively easy to install in locations free of internal structures. In inaccessible areas, blind rivets are substituted for standard ones. With these patches the doubler is usually split and inserted or rotated into position. In flush patches, the filler must be of the same gage and material as the original skin, and the doubler generally must be one gage heavier.

Repairs on hulls and floats must be watertight, and pressurized compartment repairs must be sealed against pressure loss. Whenever possible, the manufacturer's sealing method must be used. A recommended method includes cleaning contact surfaces, removing any burrs and chips, using zinc-chromate tape and paste, and bringing the mating surfaces together with machine screws and nuts to complete the seal.

Installing flush access doors is an easy and efficient way to repair internal structures and some skin areas. Such doors consist of a doubler and a stressed access coverplate. The doubler is riveted to the skin, and the plate is attached to the doubler with nut plates and machine screws.

The number of patches or repairs can be so numerous or the skin damage so extensive that panel replacement is required. Inspecting such areas includes a careful examination of internal structures. Bent, fractured, or wrinkled members must be repaired or replaced. Rivets in the vicinity must be inspected for failure. The technical manual for the particular aircraft must be consulted to determine the rivet inspection procedure.

The gage and alloy for the replacement panel is shown in the applicable manual for the specific aircraft. Either of two ways can be used to determine the new panel's size. Dimensions can be measured during inspection, or the old skin can be used as a template. The latter method is more accurate and is preferred. The new sheet is drilled near the center using the holes in the old sheet as a guide. The two sheets are held together with sheet metal fasteners as the holes are drilled outward from the center. Lacking a template the holes in the reinforcing members are used as guides to drill the new holes. Sheet metal fasteners are used here as with a template. Because most ribs, stringers, and bulkheads depend on the skin for some of their rigidity, duplicating holes from the frame or reinforcing members must be done with care. Drilling pressure can force the skin away from the frame and make the holes out of alignment. A wood block held firmly against the skin while drilling can prevent this. Unless the drill is held at a 90° angle, the holes will be out-of-round. Where a straight drill cannot be inserted, an angle attachment or flexible-shaft drill is necessary. New hole locations can be marked with a soft pencil, a prick punch, or a hole finder.

A straight bucking bar is preferred because its weight can be applied in a direct line with the rivet's shaft. Where internal structural members prevent using a straight bar, one allowing straightline pressure must be used.

PART D: INTERNAL STRUCTURE REPAIR

GENERAL

Contour (shape), rigidity, and strength for the semimonocoque fuselage are derived, for the most part, from its internal structural members. From time to time these members need repairs. This section describes some typical repairs for internal structural members. However, the appropriate technical manual for the particular aircraft must be consulted. What may be a simple repair on one aircraft can require special techniques and tools on another. The paragraphs that follow discuss repairs for stringers and longerons, spars and ribs, formers and bulkheads, and leading and trailing edges.

STRINGER REPAIR

Made from extruded or rolled metal alloy, stringers are generally in the form of C-channel, angle, or hat-shaped sections. Figure 2-10 shows one method of repairing a damaged stringer by patching. The repair elements consist of reinforcement and filler splices and rivets. The reinforcement splice must extend a minimum of four rivets plus edge distance on each side of the damaged area. The reinforcement splice's cross-sectional area and strength must be equal to or greater than the stringer's. The damage must be trimmed to a smooth contour with corner radii, and a filler patch of proper thickness and matching shape must be prepared. If possible, maintain the original rivet pattern in the repair. This can be done by having both ends of the trimmed damage lie midway between two rivets. Cut the filler splice 1/32 inch shorter in length than the trimmed out section. This allows a 1/64 inch clearance between each end of the filler splice and the stub ends of the stringer. This clearance prevents stress from developing through contact between the filler splice and the stub ends.

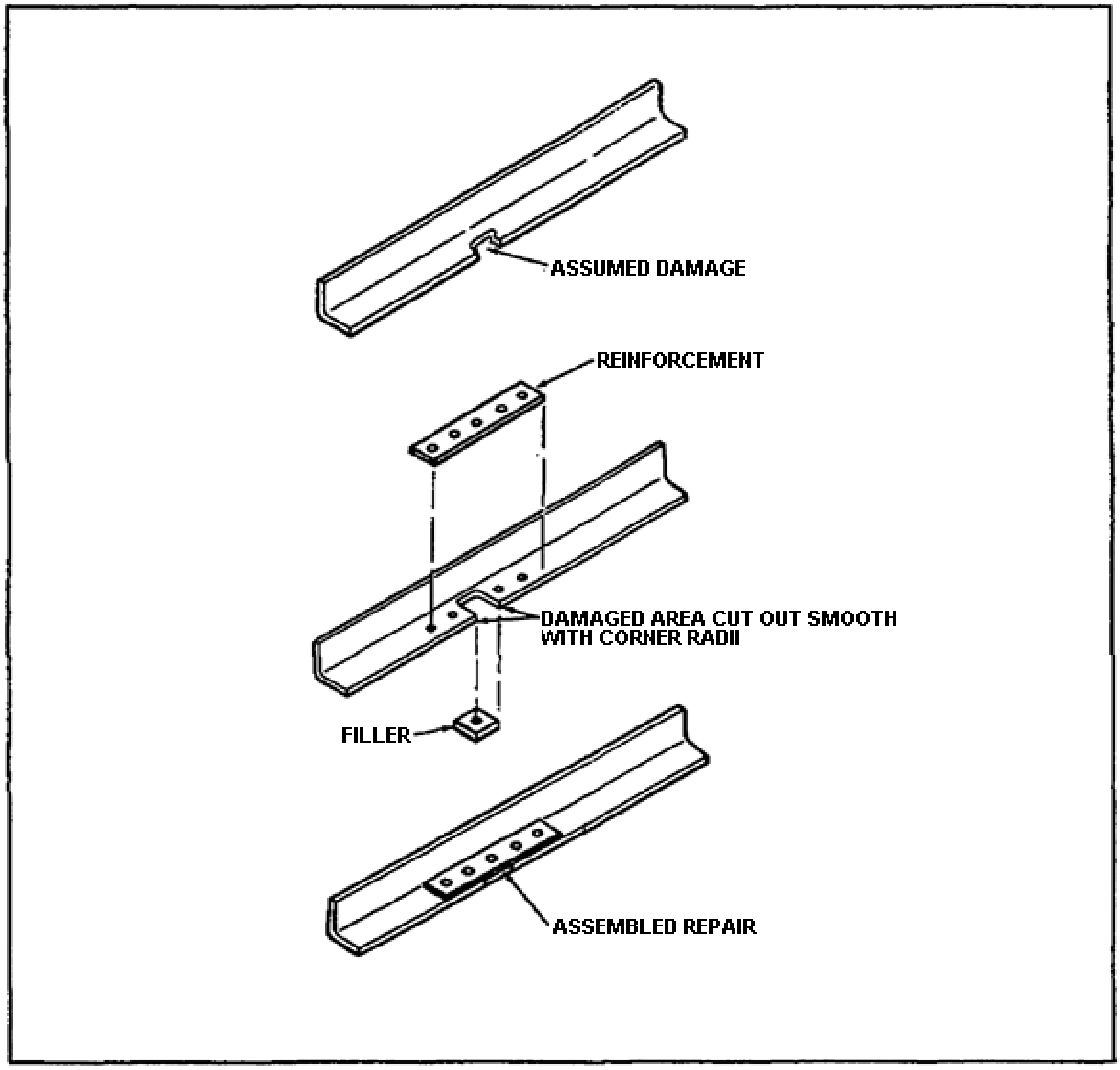


Figure 2-10. Patch Repair of Stringer (For Damage Less Than Two-Thirds of One Leg Width).

The repair just described is permissible when the damage does not exceed two-thirds of the width of one leg of the stringer and is not over 12 inches in length. When damage is greater than two-thirds of the leg width, use the method shown in Figure 2-11. A repair by insertion, shown in Figures 2-12 and 2-13, is required if the damage is so long that an unusual amount of material and work is required.

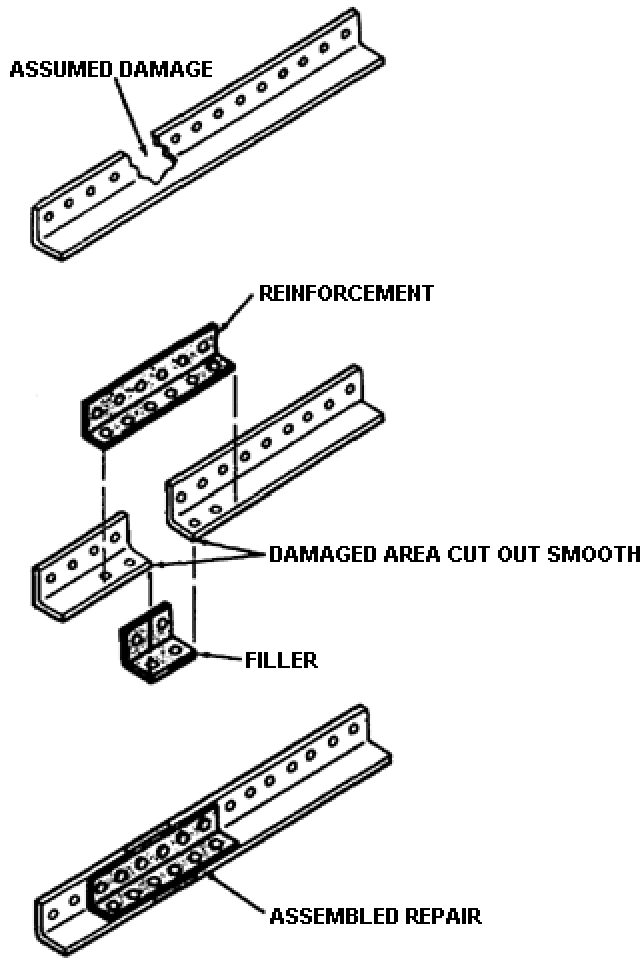


Figure 2-11. Patch Repair for Stringer (For Damage Greater Than Two-Thirds of One Leg Width).

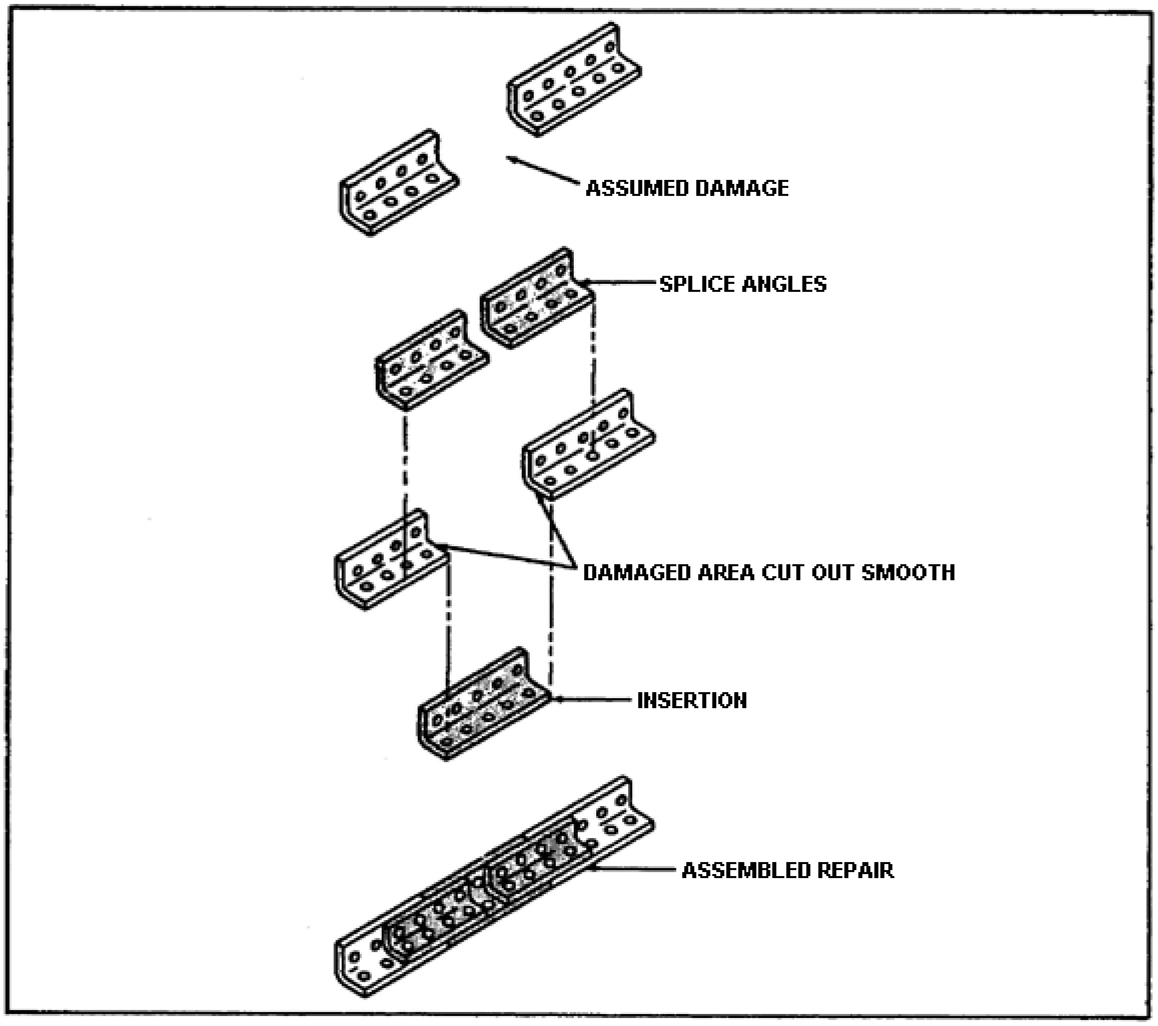


Figure 2-12. Insertion Repair (For One Stringer).

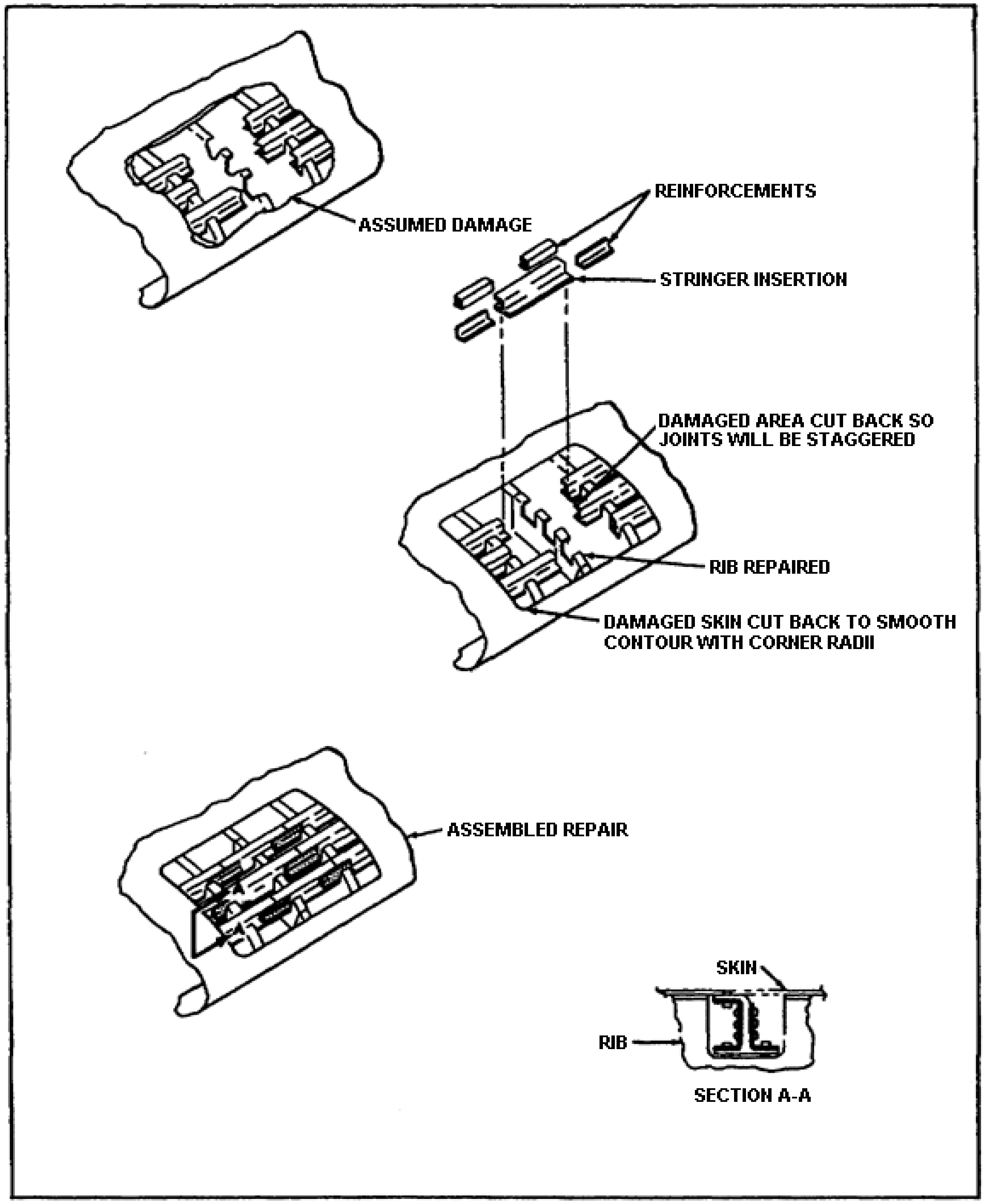


Figure 2-13. Insertion Repair (For More Than One Stringer).

LONGERON REPAIR

Generally, longerons are comparatively heavy members that do approximately the same work as stringers. The repair methods for longerons are somewhat similar; however, because of their weight, heavier rivets must be used in repairing longerons. Sometimes bolts are used in place of rivets; but it takes more time to install bolts, and greater accuracy in fit is required. For example, if bolts are used, the bolt holes must be drilled for a light drive fit. That is, the bolt must fit the hole tightly enough to require light hammering to be seated in the hole. For these reasons, bolts are not as suitable as rivets. If the longeron consists of a formed section and an extruded angle section, regard each section as separate. Make the repair using the same procedures as for stringers; however, keep the rivet spacing (pitch) between four and six rivet diameters.

SPAR REPAIR

The main spanwise members of the wings, stabilizers, and other airfoils are spars, sometimes called beams. They can extend the airfoil's entire length or only a portion of the length. Spars are designed primarily to take the bending loads on wings or other airfoils.

Figure 2-14 shows spar repair by insertion. The spar consists of extruded capstrips, a sheet metal web or plate, and vertical angle stiffeners or reinforcements. Repairs on spars may not be permitted because they are such highly stressed members. The repair, if it is permitted, must be of the highest quality workmanship and in strict conformity with the instructions in the applicable technical manual.

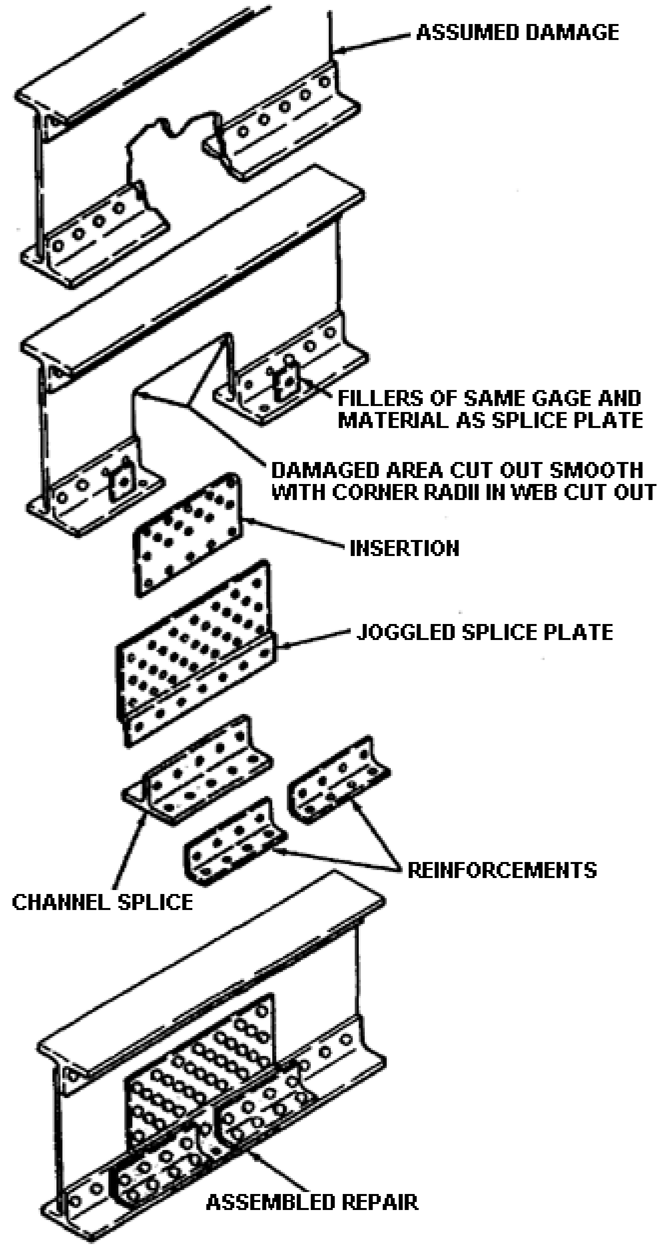


Figure 2-14. Insertion Repair for a Spar.

RIB REPAIR

The principal chordwise structural members in wings, stabilizers, and other airfoils are the ribs. They are the formers for airfoils, giving them shape and rigidity and transmitting stresses from the skin to the spars. Ribs are designed to resist compression and shear loads and come in three general types: reinforced, truss, and former. Reinforced and truss ribs are relatively heavy compared to former ribs, and they are used only at points of great stress. Former ribs are located at frequent intervals throughout the airfoil. Rib repair by patching and insertion is shown in Figures 2-15 and 2-16, respectively. Former ribs are made of formed sheet metal and are very lightweight. The bent-over portion of a former rib, shown in Figures 2-15 and 2-16, is the rib's flange. The vertical portion, generally made with lightening holes, is the web. Lightening holes lessen the rib's weight without loss of strength.

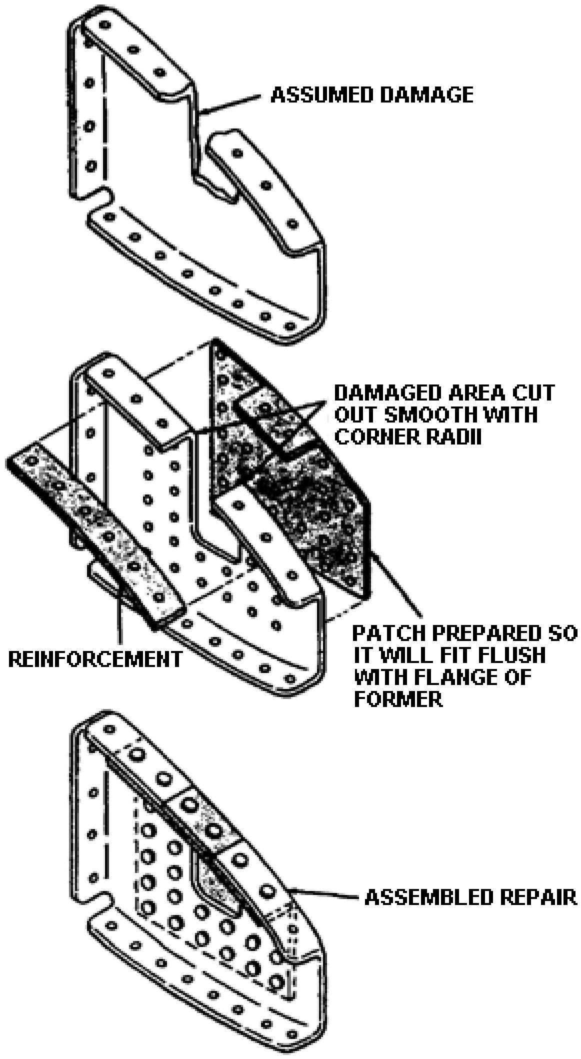


Figure 2-15. Rib Repair by Patching.

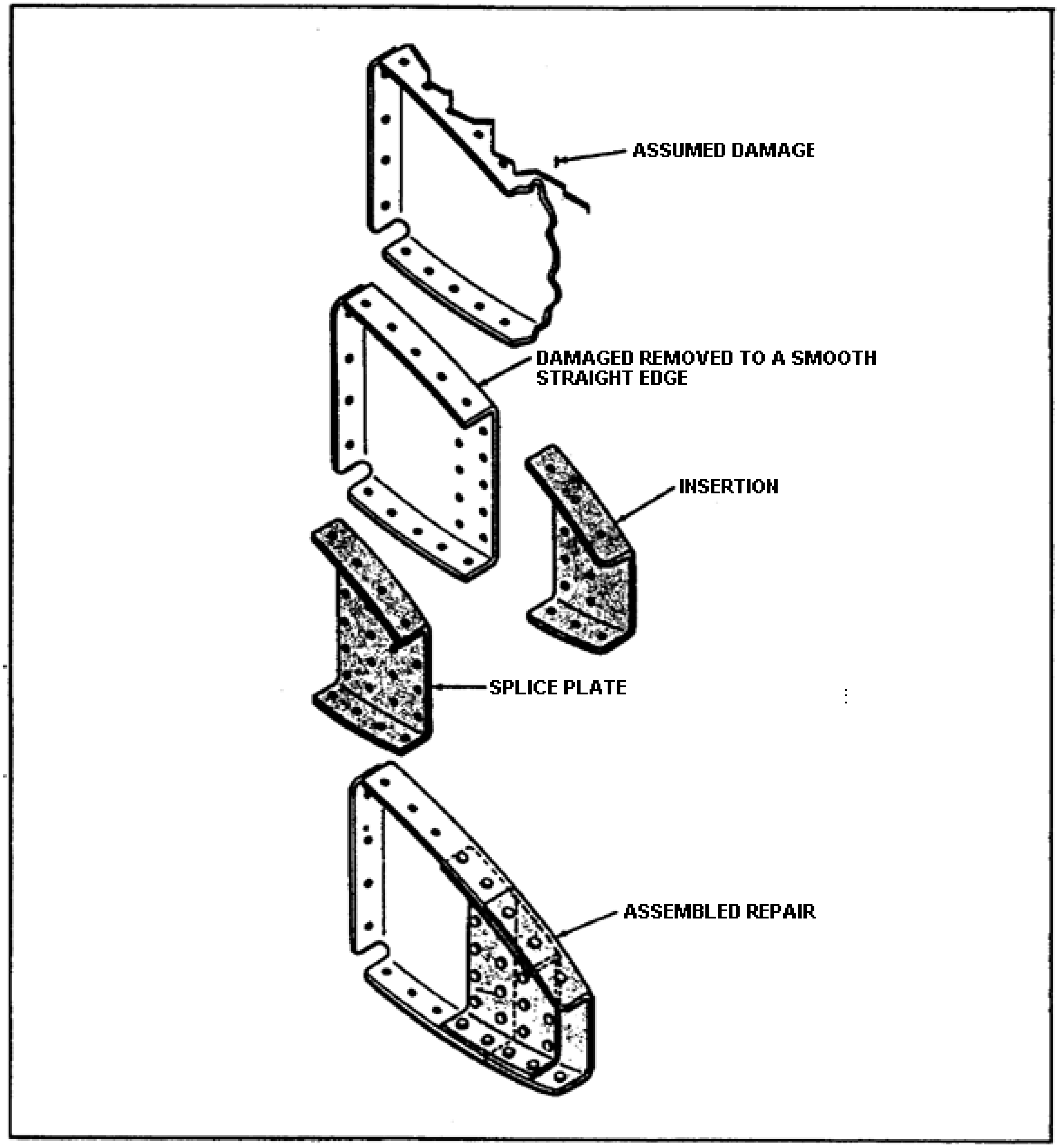


Figure 2-16. Rib Repair by Insertion.

FORMER OR BULKHEAD REPAIR

The oval-shaped members of the fuselage are bulkheads. These members give form to the fuselage and maintain the shape of its structure. Formers or bulkheads are often called forming rings, body frames, belt frames, and similar names. Their purpose is to carry concentrated stress loads.

Bulkhead damages are classified in the same manner as other damages. Specifications for each type of damage are given in the applicable manual for the aircraft. Bulkheads are identified with station numbers for ease in locating the damage area. The paragraphs that follow discuss repair categories and sheet metal stock strength.

Repair Categories. Repairs to these members are generally placed in one of two categories: one-third or less of the cross-sectional area damaged or more than one-third of the cross-sectional area damaged. A patch plate, reinforcing angle, or both may be used if one-third or less of the cross-sectional area is damaged. First, clean out (trim) the damage and consult the applicable technical manual for details on how many rivets to use to establish the patch plate size. For the length of the break, use the depth of the cutout area plus the length of the flange.

If more than one-third of the cross-sectional area is damaged, remove the entire section and make a splice repair. Consult the applicable technical manual for details on the splice repair and the number of rivets required. When removing the damaged section, be careful not to damage electric lines, plumbing, instruments, and so forth. Use a hand or rotary file, snips, or a drill to remove larger damages. To remove a complete section, use a hacksaw, key hole saw, drill, or snips.

Sheet Stock Strength. Most repairs to bulkheads are made from flat sheet stock if repair parts are not available. When fabricating the repair from flat sheet, remember that the substitute material must have cross-sectional tensile, compressive, shear, and bearing strength equal to the original material. Never substitute material that is thinner or has a cross-sectional area less than the original material. Curved repair parts made from flat sheet stock must be in an annealed condition before forming and then must be heat-treated before installation.

LEADING EDGE REPAIR

Usually several structural parts are involved in leading edge damages. Flying object damage generally involves the nose skin, nose ribs, stringers, and possibly the cap strip. Damage involving all of these members will require installing an access door to make the repair possible. First, the damaged area must be removed and repair procedures established. Such a repair will need insertions and splice pieces, and it may require repairing the cap strip and stringer and making a new nose rib and a skin panel. When repairing a leading edge, use only the procedures prescribed in the applicable manual.

TRAILING EDGE REPAIR

The rearmost part of an airfoil is the trailing edge. It is usually a metal strip that forms or shapes the edge by tying the ends of a rib section together and joining the upper and lower skins. Though not structural members, trailing edges are highly stressed and from time to time require repair. The paragraphs that follow discuss kinds of damage and damage inspection and location.

Trailing Edge Damage. A trailing edge's damage may be limited to one point or extended over the length between two or more rib sections. In addition to damage from collision or careless handling, trailing edges are particularly subject to corrosion from collected or trapped moisture.

Damage Inspection. Thoroughly inspect the damaged area before starting repairs; and determine the extent of damage, the type of repair needed, and the way the repair should be made. When repairing trailing edges, the repaired area must have the same contour and be the same material with the same composition and temper as the original section.

Repairs Between Ribs. Damage occurring in the trailing edge section between the ribs can be repaired as shown in Figure 2-17. Cut out the damage area and make a filler of either fiber or cast aluminum alloy to fit snugly inside the trailing edge. Then make an insert piece of the same material as the damaged section, and shape it to match the trailing edge. Assemble the pieces as shown and rivet them into place. Use countersunk rivets, and form countersunk shop heads to get a smoother contour.

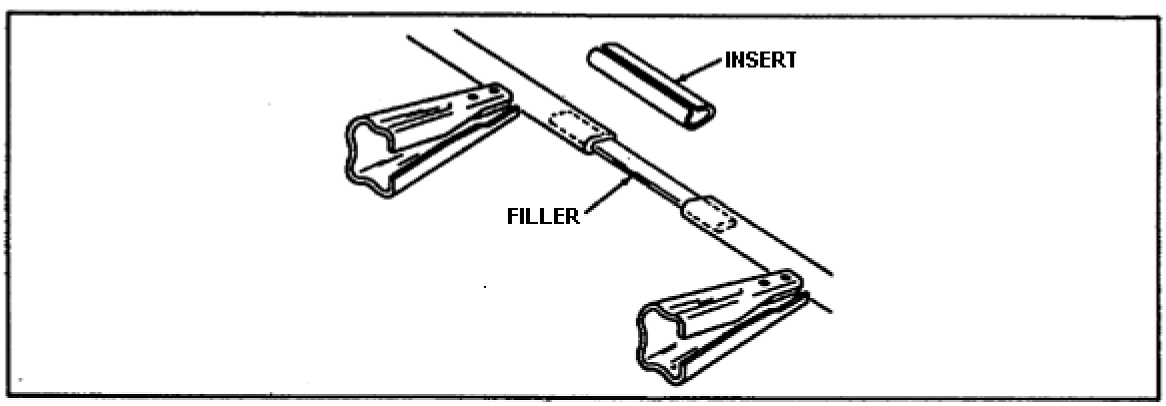


Figure 2-17. Trailing Edge Repair Between Ribs.

Repair Near a Rib. To repair damage occurring at or near a rib, first remove sufficient trailing edge material to allow a complete splice to fall between the ribs. This usually requires two splices joined by an insert piece of similar trailing edge material or of formed sheet stock. The repair is similar to that for damage between ribs. Figure 2-18 illustrates a trailing edge repair at a rib.

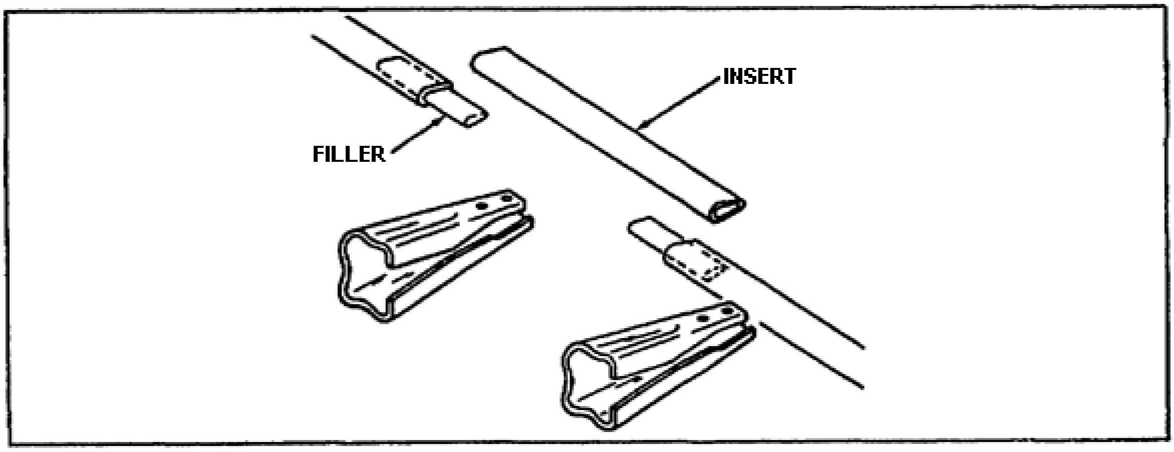


Figure 2-18. Trailing Edge Repair Near a Rib.

SUMMARY

The elements for stringer repair consists of reinforcement and filler splices and rivets. Reinforcement splices must extend at four times the width of the stringer leg on each side of the damaged area. A reinforcement splice's cross-sectional area strength must equal or exceed the stringer's. Damage must be trimmed to a smooth contour and corner radii. The filler patch must be of proper thickness and shape and 1/32 inch shorter in length than the trimmed out section. This allows 1/64 inch clearance between the stringer stub ends and the filler splice ends to prevent stress development between the ends. When possible, maintain the original rivet pattern in the repair. This is achieved by having the trimmed-out area lie midway between two rivets. This repair is authorized only when the damage does not exceed two-thirds of the width of one leg of the stringer and is not longer than 12 inches. If the damage is greater than two-thirds of the leg width, the repair method shown in Figure 2-11 must be used.

Longeron repair is somewhat similar to stringer repair; however, heavier rivets or bolts are used because of the longeron's greater weight. If bolts are used, bolt holes must be drilled for a light-drive fit. Rivet spacing on longeron repairs must be kept between four and six rivet diameters.

Repair on spars may not be permitted because spars are highly stressed members. If the repair is permitted, the workmanship must be of the highest quality and conform to applicable technical manual instructions. Rib repairs are made by patching and insertion. The bent over position of a rib's flange and the vertical portion is the web.

Specifications for each type of bulkhead damage are given in the applicable manual for the aircraft. Repair categories for bulkhead damages are one-third or less of the cross-sectional area or more than one-third of the cross sectional area damaged. If one-third or less of the cross-sectional area is damaged, a patch plate, reinforcing angle, or both many be used. Details on the required number of rivets can be obtained from the applicable technical manual. For damage greater than one-third the area's cross section, remove the entire section and make a splice repair. For details on the kind of splice and the number of rivets, consult the applicable technical manual.

When repairs are made from flat sheet stock, its cross-sectional tensile, compressive, shear, and bearing strength must be equal to or greater than the original material. Curved repair parts made from the flat sheet stock must be in an annealed state before forming and heat treated before installation.

Leading edge damage generally involves nose skin, nose ribs, stringers, and possibly the cap strip. In such a case, an access door is required to make the repair possible. Such a repair requires installing insertions and splice pieces; making repairs to the cap strip and stringer; and if the damage is severe, installing a new nose rib and skin panel. Leading edge repairs must be made as prescribed in the applicable manual.

Although trailing edges are not structural members, they are highly stressed, and their damage can be limited to one point or extended over the length between two or more rib sections. In addition to collision or careless handling, trailing edges are subject to corrosion from moisture.

Damage between ribs of the trailing edge is repaired with a filler and an insert. Fillers are made of hardwood, fiber, or cast aluminum alloy. Inserts are made of the same material as the damaged section and shaped to match the trailing edge. To secure the repairs, use countersunk rivets and countersink the shop heads for smooth contour. Damage at or near a rib is repaired in much the same way. Sufficient material must be removed for a complete splice between ribs. Generally, this takes two splices joined by an insert made of the same kind of material as the trailing edge or of formed sheet stock.

PART E: STRUCTURAL SEALING

GENERAL

This section discusses the three kinds of sealants in general use in Army aviation and sealant repair. The information in this section is important because some areas of an airframe structure are sealed compartments used for fuel tanks and others are for crew and passenger use. Fuel tank compartments are tightly sealed to keep fuel vapors from coming into the aircraft's interior. Crew and passenger compartments are sealed tightly to permit controlled ventilation. Because it is not possible to seal these areas tightly enough with only a riveted joint, a sealing compound is used. Sealants are also used to add aerodynamic smoothness to such exposed surfaces as seams and joints in the fuselage and wings.

KINDS OF SEALANTS

Rubber, sealing compound, and special seals are the three kinds of sealants generally used in Army aviation. The applicable technical manual for the aircraft being worked on must be consulted for details on sealer application. The paragraphs that follow describe each kind.

Rubber Seals. Rubber seals are used at all points where the seal is broken frequently for necessary repairs. Examples of such locations are canopies and access doors. Because the seal must be continuous around the joint, it cannot be repaired. Therefore, anytime a rubber seal is damaged or broken for repairs, it must be replaced.

Sealing Compounds. Sealing compounds are used at points where the seal is seldom broken except for structural maintenance or part replacement, as with riveted lap and butt seams and joints. They can also be used to fill gaps or holes up to 1/16 inch in width.

Special Seals. Special seals are required to pass cables, tubing, mechanical linkages, and wires into and out of sealed areas. Wires and tubing are passed through sealed-area bulkheads by using such bulkhead fittings as cannon plugs for wiring and couplings for tubing. These fittings are sealed to the bulkhead, and the wires and tubes are fastened to them from each side. All seals of moving components, such as flight controls, are subject to wear. Therefore, care must be taken when they are installed, and they must be inspected regularly.

SEALANT REPAIR

All surfaces that are to be sealed must be thoroughly cleaned to ensure maximum adhesion between the surface and the sealant. Only approved strippers, cleaners, and sealants can be used; and, even though approved, the stripper compound must be used with care. Details on cleaning and the sealant to be used can be found in the technical manual applicable to the aircraft. The paragraphs that follow give general information on cleaning techniques, safety practices, application, and curing.

Cleaning Techniques. Loose foreign material can be removed by using a vacuum cleaner on the area to be resealed. The old sealant can be scraped from the repair area with a sharp plastic, phenolic, or hardwood block. Care must be taken not to make any scratches. A stripper and cleaner are used next to remove all the old sealant. Cleaners in general use are aliphatic naphtha, ethyl acetate, or lacquer thinner. The naphtha can be used satisfactorily by dipping a clean cloth or brush into the naphtha and then scrubbing the surface. After using aliphatic naphtha, a clean cloth must be used to wipe metal surfaces dry. The cleaner must not be allowed to dry on a metal surface. The surface can be checked for cleanness by pouring clean water over it, after it has been wiped dry of the cleaner. If the surface is not free of an oily film, the water will separate into small droplets.

Safety Practices. In addition to protecting undamaged sealants and acrylic plastic from the stripper compound, users must practice personal safety. For example, if artificial lighting is used when a repair is being made, the light must be explosion proof. Clothing that prevents these chemicals from touching the skin and goggles to protect the eyes must be worn. Ventilation to dissipate fumes must be ensured, and no smoking regulations must be enforced.

Sealant Application. Rubber seals must be applied, or installed, immediately after the seal frame is cleaned. A clean paint brush can be used to apply an even coat of rubber cement upon the metal parts and the seal surfaces to be joined. If the cement needs thinning, apliphatic naphtha can be used. The cement must be allowed to dry until it becomes quite sticky before joining the seal to the metal. The seal is joined to the metal by pressing it firmly along all contact points. Next, the seal retainers are installed, and the seal is allowed to set for 24 hours before using. Toluene, or an approved solvent, can be used to clean the brushes used to apply the cement.

Sealing compounds are applied only when the contacting surfaces are clean. The compound must be spread from the tube by using a continuous forward movement to the pressure side of the joint. The compound is spread 3 inches beyond each end of the repair area. If the compound is in bulk form it is applied with a pressure gun.

Curing. Two layers or coats of compound are frequently required. If two coats are needed, the first coat must be allowed to cure before the second is applied. The compound must cure until it becomes tough and rubbery before the surfaces are joined. Curing time varies with temperature. High temperatures shorten and low temperatures lengthen curing time. Artificial heat can be used to speed curing, but care must be used to avoid damaging the sealant with too high a temperature. Warm circulating air, not over 120° F (49° C), or infrared lamps placed 18 inches or more from the sealants are satisfactory heat sources. If infrared lamps are used, adequate ventilation must be available to carry away solvent fumes.

SUMMARY

Some areas of airframe structures are sealed to prevent fuel fumes from entering the aircraft's interior. Pilot and crew compartments are tightly sealed to permit controlled ventilation. The three kinds of sealers in general use are rubber, sealing compound, and special seals. Rubber seals are used when the seal is frequently broken for repairs. Rubber seals are not repairable, and they must be replaced anytime the seal is damaged. Sealing compounds are used where the seal is seldom broken except for structural maintenance or part replacement. Special seals are used to pass cables, tubing, mechanical linkages, and wires into and out of sealed areas. Cannon plugs, couplings, and similar fittings are sealed to the bulkheads. All seals of moving components are subject to wear and must be inspected regularly.

Surfaces to be sealed must be clean, and only approved strippers and cleaners can be used. Cleaning techniques include using a vacuum cleaner to pick up loose dirt, a stripper to remove the old seal, and an approved solvent to scrub the repair area. Safety practices range from protecting undamaged sealants and acrylic plastics from the stripper to wearing protective clothing and goggles and using explosive-proof lighting.

Rubber seals must be applied immediately after a seal frame is cleaned. A clean paint brush can be used to apply an even coat of rubber cement. Rubber cement must be allowed to dry to a sticky consistency before joining the seal to the metal. Sealing compound can be applied directly from a tube or, if it is in bulk form, from a pressure gun. A sealing compound application overlaps each end of the repair area by 3 inches. The compound must be allowed to cure to a tough, rubbery consistency before joining the surfaces to be sealed. High temperatures, not more than 120° F, speed curing. Infrared lamps can be used if adequate ventilation is available to dispel the solvent fumes.

LESSON 2
PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check the answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. What is the criteria for making a worthwhile airframe repair?

_____A. Original strength and contour.
_____B. Original strength, contour, and minimum weight.
_____C. Original contour and minimum weight.
_____D. Original strength, contour and correct patch.

2. The general spacing for rivets is--

_____A. 3 to 10 rivet diameters.
_____B. 4 to 6 rivet diameters.
_____C. 4 to 10 rivet diameters.
_____D. 6 to 8 rivet diameters.

3. Of the basic principles of repair, which is the most important?

_____A. Strength.
_____B. Contour.
_____C. Minimum weight.
_____D. Correct patch.

4. How many classifications of damage are there?

_____A. Two.
_____B. Three.
_____C. Four.
_____D. Five.

5. When dissimilar metals make contact, the type corrosion that can develop is called--

_____A. galvanic.
_____B. intergranular.
_____C. stress.
_____D. pitting.

6. What type corrosion is present when you can see the lifting of the metal's surface grain?

_____A. Exfoliation.
_____B. Intergranular.
_____C. Metal-ion.
_____D. Stress.

7. Which type of stress is called a combination of stresses?

_____A. Compression.
_____B. Shear.
_____C. Tension.
_____D. Torsion.

8. When a rivet is cut into, the stress applied is called--

_____A. bending.
_____B. compression.
_____C. shear.
_____D. torsion.

9. What percentage of strength must be returned to a noncritical area when patching?

_____A. 50.
_____B. 60.
_____C. 65.
_____D. 70.

10. What drill size should you use when stop drilling a crack?

_____A. #11.
_____B. #21.
_____C. #30.
_____D. #40.

11. To what angle must you chamfer a patch edge?

_____A. 20°.
_____B. 30°.
_____C. 45°.
_____D. 55°.

12. What is the correct thickness for a patch doubler?

_____A. One gage thicker than the skin.
_____B. The same thickness as the skin.
_____C. One gage lighter than the skin.
_____D. .050 inch thick.

13. What is the technique called when the holes on a new sheet of metal are drilled from inside the structure?

_____A. Hole finding.
_____B. Templating.
_____C. Pilot drilling.
_____D. Back drilling.

14. Which type of sealant should you use on an area where the seal is seldom broken?

_____A. Rubber.
_____B. Sealing compound.
_____C. Special seals.
_____D. Metal seals.

15. How many degrees Fahrenheit should you apply to help speed up the curing of sealants?

_____A. No more than 120.
_____B. 140.
_____C. 150.
_____D. 160.

LESSON 2

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. Original strength, contour, and minimum weight.
	The three basic principles of repair are essential for a good sound repair job. (Page 48)
2.	D. 6 to 8 rivet diameters.
	6 to 8 rivet diameters will insure that you have a strong repair. (Page 59)
3.	A. Strength.
	Without maintaining the original strength, all other principles mean nothing. (Page 58)
4.	C. Four.
	Negligible, patching, insertion and replacement are the four classifications of damage. (Page 53)
5.	A. galvanic.
	The more dissimilar the metals, the quicker and more severe this type corrosion will be. (Page 55)
6.	A. Exfoliation.
	When you are able to see exfoliation corrosion, you must repair or replace the part. This type corrosion is beyond simple treatment. (Page 55)
7.	D. Torsion.
	Torsion is a twisting which combines both compression and tension. (Page 56)
8.	C. shear.
	Two sheets of metal will shear a rivet like a piece of metal being cut with a foot shear. (Page 58)

9. B. 60.

Noncritical repairs are satisfactory if they have 60 percent of the original strength restored. (Page 62)

10. D. #40.

Using the proper size drill will ensure that the hole stops the crack from getting larger. (Page 62)

11. C. 45°.

Chamfering or bending the edge of a patch helps to keep moisture from getting under the patch to cause corrosion. (Page 62)

12. A. One gage thicker than the skin.

Original strength is the most important repair principle. One gage thicker than the skin helps to do this. (Page 63)

13. D. Back drilling.

If the old sheet is too damaged to be used as a template, then back drilling may be the only way left to drill the holes to align with the original holes. (Page 67)

14. B. Sealing compound.

Sealing compounds are pliable rubber seals. Rubber seals are used as gaskets whereas sealing compounds are used as coatings. (Page 86)

15. A. No more than 120.

If a sealant is cured at too high a temperature, it can develop air bubbles or cure unevenly. (Page 88)

APPENDIX
GLOSSARY

Aerodynamic (adjective)--said of a body or object that is streamlined. In aviation, this represents the best ratio of lift-to-drag for airfoil.

Aileron--movable control surface on the trailing edge of an airplane wing.

Airfoil--aircraft part or surface, such as a wing, propeller blade, rotor, or rudder. The shape and orientation of such airfoils control stability, direction, propulsion, or lift.

Alloy--composition of two or more metals that make a compound, solid solution, mixture, or a combination of these.

Annealing--process to relieve metals of internal stresses set up during heating or other treatment. Annealing also is used to make metals softer and more ductile.

Anode--positively charged terminal in an electrolyte cell, storage battery, or electron tube.

Assembly--group of two or more physically connected or related parts capable of disassembly.

Bending--combining tension and compression forces.

Billet--bar of iron or steel in an intermediate stage of manufacture. A billet is almost square in shape with sectional dimensions generally less than 6 x 6 inches.

Blind rivet--in general, rivet whose shop head cannot be seen.

Bloom--bar of iron or steel in an intermediate size. Blooms, generally, are larger than 6 x 6 in their sectional dimensions.

Bond--firm adhesion of one substance to another, such as metal to metal or plastic to metal.

Brake (forming)--machine used to bend, flange, fold, or form sheet metal.

Brittleness (of metal)-- susceptibility to snapping or fracturing under pressure or strain because of metal's hardness plus a lack of elasticity.

Bucking bar--device used to back up a rivet while it is headed and clinched.

Bulkhead--as used here, an upright partition dividing a fuselage into compartments.

Cannon plug--patented plug designed to fit a matching receptacle to complete an electrical connection.

Cantilever design--as applied to airplane wings, the wing has no external support. All loads are resisted by the wing's internal structure.

Capstrips--extruded or formed angles placed at the top and bottom of a web.

Case hardening--hardening the surface of iron or steel by high temperature, shallow infusion of carbon, and quenching.

Cathode--negatively charged terminal in an electrolyte cell, storage battery, or electron tube.

Characteristic--distinctive quality or property of a substance.

Cold drawing--process where metal rods are drawn through a series of dies at room temperature to make wire of the desired size.

Cold rolling--process to reduce the cross-sectional area of a piece of metal by passing it between rollers at room temperature.

Cold working--mechanically working a metal at a temperature below that required for annealing.

Compression--decreases of volume of compressible substances as a result of applied pressure. Compressive strength is the resistance to such applied pressure.

Compression load--amount of pressure applied to a substance.

Conductivity (heat and electricity)--as used here, the ability of material to conduct electricity or heat.

Configuration--arrangement of parts or elements of something; its form, outline, or contour.

Contour--outline of a figure, body, or mass.

Cowling--removable covering for an aircraft engine.

Density--mass per unit volume of a substance under specified or standard conditions of pressure and temperature.

Draw--as used here, to shape metal by pulling it through a series of dies or holes in a draw plate.

Ductility--quality of a metal that permits it to be drawn into wire or hammered thin.

Elastic limit--extent to which a metal can be deformed and still return to an initial form or state following deformation.

Elevator--movable control surface, generally attached to the horizontal stabilizer, and used to move the nose of the aircraft up or down.

Empennage--aft portion of the fuselage.

Extruding--forcing metal through an opening in a die, and causing it to take the desired shape.

Fairing--auxiliary structure on the external surface of an aircraft serving to reduce drag.

Ferrous--of, pertaining to, or containing iron.

Fin--in aviation, a fixed or movable airfoil used to stabilize an aircraft in flight.

Flange--protruding rim, rib, collar, or edge used to strengthen an object, hold it in place, or attach it to another object.

Fuselage--central body of an airplane to which the wings and tail assembly are secured.

Fusing--merging different elements into one.

Gage--thickness or diameter of a material such as sheet metal or wire.

Grain boundaries--minute separations between the grains of metal, visible under powerful magnification.

Hardness--relative resistance of metal to denting, scratching, or bending.

Hardening--process for increasing the durability and strength of steel. For nonferrous metals the same process is called heat treatment.

Huck lock bolt--special purpose bolt that combines the features of a bolt and rivet.

I-beam construction--construction using beams with cross sections formed like the capital letter I.

Inerted--made chemically inactive; said of a fuel tank that is free of all fuel and fumes.

Load--as used here, the overall force to which an object is subjected or the resistance to an externally applied force or system of forces.

Jig (as in welding)--device for holding work in place or for guiding work to be done.

Lateral axis--reference line that runs from side to side through an aircraft's center of gravity. The aircraft pivots about this axis when it climbs or dives.

Lending edge--edge of an airfoil in motion (a wing, propeller, or stabilizer) that first meets or bites the air.

Lightening holes--hole drilled or cut out of a web, plate, or partition to lighten the weight of the material used.

Longeron--structural member passing from front to rear of an aircraft's fuselage.

Longitudinal axis--reference line that runs front to rear through the center of gravity of an aircraft. The aircraft pivots about this axis when it banks or rolls.

Malleability--quality of a metal that permits it to be shaped or formed by hammering or pressure.

Molybdenum--hard gray metallic element used to toughen steel and soften tungsten alloys.

Monocoque--metal structure of an aircraft in which the covering (skin) absorbs a large part of the stresses to which the body is subjected.

Monospar wing--wing with only one main longitudinal member. Ribs or bulkheads give the needed shape or contour.

Nacelle--separate stream-lined enclosure on some aircraft that is used primarily to house engines. Nacelles can be designed to house landing gear and related equipment, crew, or cargo.
Normalizing--cooling ferrous metals in still air to relieve integral stresses set up by working the metal.

Primary structural members--wings or rotor blades, fuselage, flight control surfaces, stabilizers, nacelles, and landing gear.

Property--quality that defines or describes a characteristic or an object or substance.

Radome (radar dome)--a plastic dome-shaped housing on the exterior surface of an aircraft. It is used to shelter a radar set's antenna assembly.

Rib--any or many formed transverse pieces along the length of an airplane wing used to give shape or contour.

Rivnut--tubular rivet internally threaded and counterbored. They are applied blind and where bucking space is not available.

Reciprocating engine--engine having a crankshaft turned by linear action of pistons.

Rudder--vertically hinged device at the tail of an aircraft used to make horizontal changes in a course.

Shafting--system of shafts in a mechanical device for transmitting motion or power.

Shear--applied force or system of forces that tends to produce a deformation by opposite but parallel sliding motion.

Shear load--overall shear force applied to an object.

Shop head--head formed on a rivet by hand or by pneumatic hammering.

Skin--outer metal covering of the principal parts of an aircraft.

Slab--rectangular section of steel that has a width greater than twice its thickness.

Splice--as used here, to join two sections or pieces of a repair site with an insert and an overlapping piece. The insert and overlapping piece must be of the same material as the original.

Stabilizer--airfoil used to give balance to an aircraft in flight.

Station web--web located at a point in the wing that corresponds with a stated number of inches from the reference datum line.

Stress--force or system of forces that tends to strain or deform that to which it is applied.

Stressed skin--outer metal covering of the principal parts of an aircraft that receives applied force or forces.

Stringer--structural member of the fuselage that runs fore and aft. Stringers are lighter weight than longerons.

Strut--generally a rod, bar, or structural member used to strengthen or to resist longitudinal thrust.

Swaged--past tense of to swage. Swaging material is to shape it to some desired form by compressive force or by a cast or die.

Swept-back wing--wing angled rearward from the attaching points.

Tempering--hardening, strengthening, or toughening a metal by heating or by alternate heating and cooling processes.

Template--pattern or gage used as a guide in making something accurately.

Tension--force that tends to produce elongation or extension.

Titanium--strong, low-density, highly corrosion-resistant, lustrous white metallic element. It is used as an alloy in aircraft metals.

Tolerance--permissible deviation from specified value or dimension.

Torque--in general, a turning or twisting force.

Torsion--the stress caused when one end of an object is twisted in one direction and the other end is held motionless or twisted in the opposite direction.

Trailing edge--rearmost edge or an airfoil.

Truss construction--as used here, a framework of wood or metal bars generally arranged in triangles to give structural support.

Upsetting--compressive deformation, generally by hammering.

Void--as used here, an open space resulting from a break in sealing continuity.

Web--metal sheet or plate connecting the heavier sections, ribs, or flanges or a structural element.

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