CHAPTER 4

AIRCRAFT BASIC CONSTRUCTION

INTRODUCTION

Naval aircraft are built to meet certain specified requirements. These requirements must be selected so they can be built into one aircraft. It is not possible for one aircraft to possess all characteristics; just as it isn't possible for an aircraft to have the comfort of a passenger transport and the maneuverability of a fighter. The type and class of the aircraft determine how strong it must be built. A Navy fighter must be fast, maneuverable, and equipped for attack and defense. To meet these requirements, the aircraft is highly powered and has a very strong structure.

The airframe of a fixed-wing aircraft consists of the following five major units:

1. Fuselage
2. Wings
3. Stabilizers
4. Flight controls surfaces
5. Landing gear

A rotary-wing aircraft consists of the following four major units:

1. Fuselage
2. Landing gear
3. Main rotor assembly
4. Tail rotor assembly

You need to be familiar with the terms used for aircraft construction to work in an aviation rating.

STRUCTURAL STRESS

LEARNING OBJECTIVE: Identify the five basic stresses acting on an aircraft.

The primary factors to consider in aircraft structures are strength, weight, and reliability. These factors determine the requirements to be met by any material used to construct or repair the aircraft. Airframes must be strong and light in weight. An aircraft built so heavy that it couldn't support more than a few hundred pounds of additional weight would be useless. All materials used to construct an aircraft must be reliable. Reliability minimizes the possibility of dangerous and unexpected failures.

Many forces and structural stresses act on an aircraft when it is flying and when it is static. When it is static, the force of gravity produces weight, which is supported by the landing gear. The landing gear absorbs the forces imposed on the aircraft by takeoffs and landings.

During flight, any maneuver that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage.

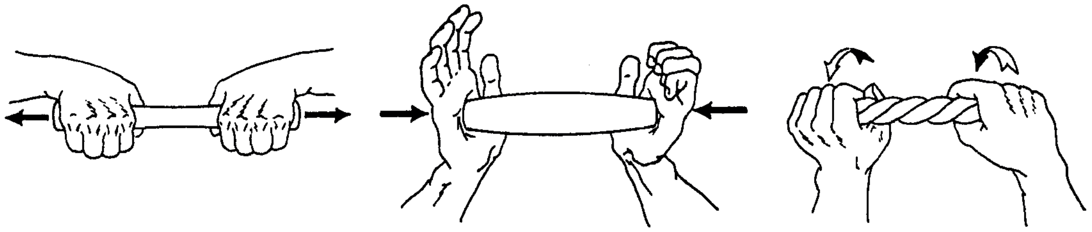
Stresses on the wings, fuselage, and landing gear of aircraft are tension, compression, shear, bending, and torsion. These stresses are absorbed by each component of the wing structure and transmitted to the fuselage structure. The empennage (tail section) absorbs the same stresses and transmits them to the fuselage. These stresses are known as *loads*, and the study of loads is called a *stress analysis.* Stresses are analyzed and considered when an aircraft is designed. The stresses acting on an aircraft are shown in figure 4-1.

TENSION

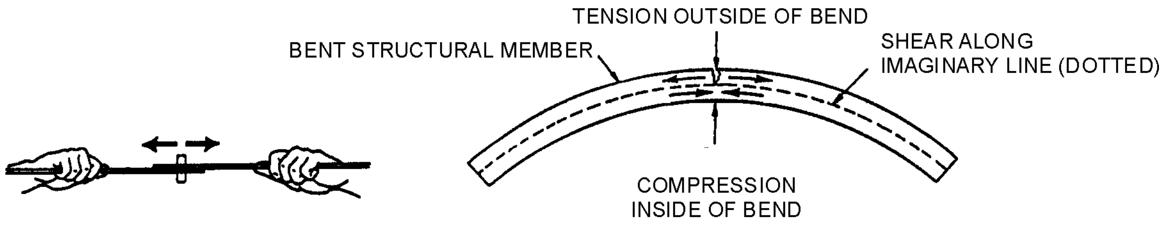
Tension (fig. 4-1, view A) is defined as *pull*. It is the stress of stretching an object or pulling at its ends. Tension is the resistance to pulling apart or stretching produced by two forces pulling in opposite directions along the same straight line. For example, an elevator control cable is in additional tension when the pilot moves the control column.

COMPRESSION

If forces acting on an aircraft move toward each other to squeeze the material, the stress is called *compression*. Compression (fig. 4-1, view B) is the opposite of tension. Tension is **pull**, and compression is **push**. Compression is the resistance to crushing produced by two forces pushing toward each other in the same straight line. For example, when an airplane is on the ground, the landing gear struts are under a constant compression stress.



(A) TENSION (B) COMPRESSION (C) TORSIONAL



(D) SHEAR (E) BENDING (THE COMBINATION STRESS)

Figure 4-1.—Five stresses acting on an aircraft.

SHEAR

Cutting a piece of paper with scissors is an example of a shearing action. In an aircraft structure, shear (fig. 4-1, view D) is a stress exerted when two pieces of fastened material tend to separate. Shear stress is the outcome of sliding one part over the other in opposite directions. The rivets and bolts of an aircraft experience both shear and tension stresses.

BENDING

Bending (fig. 4-1, view E) is a combination of tension and compression. For example, when bending a piece of tubing, the upper portion stretches (tension) and the lower portion crushes together (compression). The wing spars of an aircraft in flight are subject to bending stresses.

TORSION

Torsional (fig. 4-1, view C) stresses result from a twisting force. When you wring out a chamois skin, you are putting it under torsion. Torsion is produced in an engine crankshaft while the engine is running. Forces that produce torsional stress also produce torque.

VARYING STRESS

All structural members of an aircraft are subject to one or more stresses. Sometimes a structural member has alternate stresses; for example, it is under compression one instant and under tension the next. The strength of aircraft materials must be great enough to withstand maximum force of varying stresses.

SPECIFIC ACTION OF STRESSES

You need to understand the stresses encountered on the main parts of an aircraft. A knowledge of the basic stresses on aircraft structures will help you understand why aircraft are built the way they are. The fuselage of an aircraft is subject the fives types of stress—torsion, bending, tension, shear, and compression.

Torsional stress in a fuselage is created in several ways. For example, torsional stress is encountered in engine torque on turboprop aircraft. Engine torque tends to rotate the aircraft in the direction opposite to the direction the propeller is turning. This force creates a torsional stress in the fuselage. Figure 4-2 shows the effect of the rotating propellers. Also, torsional stress on the fuselage is created by the action of the ailerons when the aircraft is maneuvered.

When an aircraft is on the ground, there is a bending force on the fuselage. This force occurs because of the weight of the aircraft. Bending increases when the aircraft makes a carrier landing. This bending action creates a tension stress on the lower skin of the fuselage and a compression stress on the top skin. Bending action is shown in figure 4-3. These stresses are transmitted to the fuselage when the aircraft is in flight. Bending occurs because of the reaction of the airflow against the wings and empennage. When the

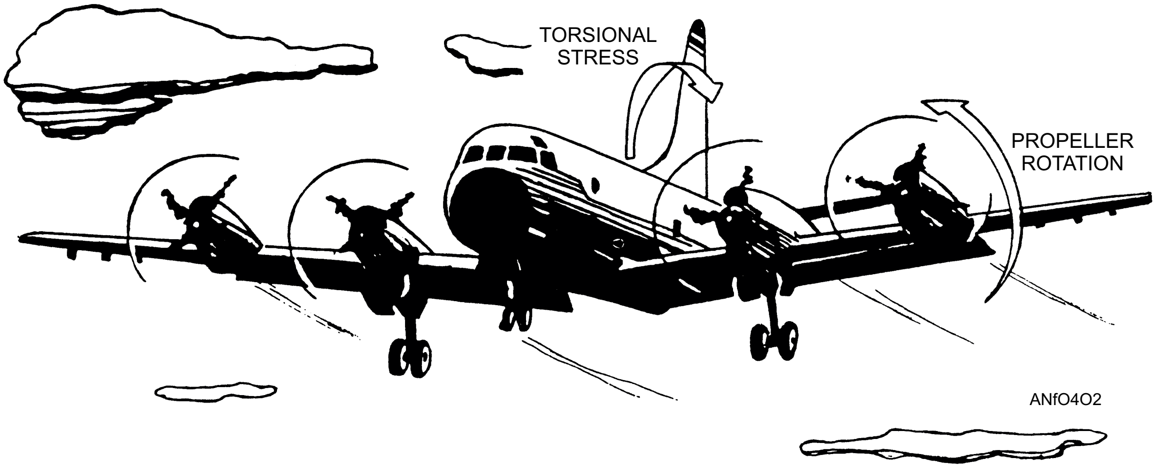


Figure 4-2.—Engine torque creates torsion stress in aircraft fuselages.

aircraft is in flight, lift forces act upward against the wings, tending to bend them upward. The wings are prevented from folding over the fuselage by the resisting strength of the wing structure. The bending action creates a tension stress on the bottom of the wings and a compression stress on the top of the wings.

Q4-1. The resistance to pulling apart or stretching produced by two forces pulling in opposite directions along the same straight lines is defined by what term?

Q4-2. The resistance to crushing produced by two forces pushing toward each other in the same straight line is defined by what term?

Q4-3. Define the term shear as it relates to an aircraft structure.

Q4-4. Define the term bending.

Q4-5. Define the term torsion.

CONSTRUCTION MATERIALS

LEARNING OBJECTIVE: Identify the various types of metallic and nonmetallic materials used in aircraft construction.

An aircraft must be constructed of materials that are both light and strong. Early aircraft were made of wood. Lightweight metal alloys with a strength greater than wood were developed and used on later aircraft. Materials currently used in aircraft construction are classified as either metallic materials or nonmetallic materials.

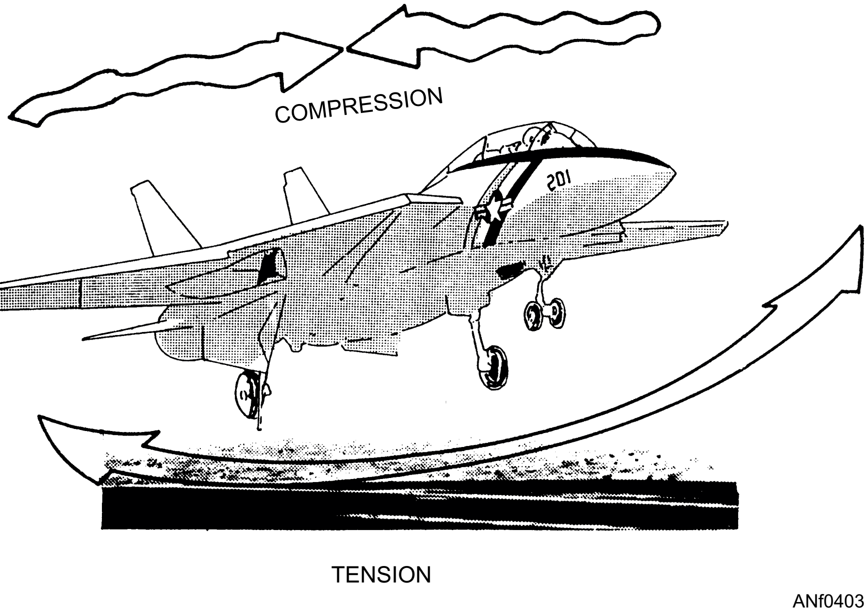


Figure 4-3.—Bending action occurring during carrier landing.

METALLIC MATERIALS

The most common metals used in aircraft construction are aluminum, magnesium, titanium, steel, and their alloys.

Alloys

An alloy is composed of two or more metals. The metal present in the alloy in the largest amount is called the *base metal*. All other metals added to the base metal are called *alloying elements*. Adding the alloying elements may result in a change in the properties of the base metal. For example, pure aluminum is relatively soft and weak. However, adding small amounts or copper, manganese, and magnesium will increase aluminum's strength many times. Heat treatment can increase or decrease an alloy's strength and hardness. Alloys are important to the aircraft industry. They provide materials with properties that pure metals do not possess.

Aluminum

Aluminum alloys are widely used in modern aircraft construction. Aluminum alloys are valuable because they have a high strength-to-weight ratio. Aluminum alloys are corrosion resistant and comparatively easy to fabricate. The outstanding characteristic of aluminum is its lightweight.

Magnesium

Magnesium is the world's lightest structural metal. It is a silvery-white material that weighs two-thirds as much as aluminum. Magnesium is used to make helicopters. Magnesium's low resistance to corrosion has limited its use in conventional aircraft.

Titanium

Titanium is a lightweight, strong, corrosion-resistant metal. Recent developments make titanium ideal for applications where aluminum alloys are too weak and stainless steel is too heavy. Additionally, titanium is unaffected by long exposure to seawater and marine atmosphere.

Steel Alloys

Alloy steels used in aircraft construction have great strength, more so than other fields of engineering would require. These materials must withstand the forces that occur on today's modern aircraft. These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum. High-tensile steels will stand stress of 50 to 150 tons per square inch without failing. Such steels are made into tubes, rods, and wires.

Another type of steel used extensively is stainless steel. Stainless steel resists corrosion and is particularly valuable for use in or near water.

NONMETALLIC MATERIALS

In addition to metals, various types of plastic materials are found in aircraft construction. Some of these plastics include transparent plastic, reinforced plastic, composite, and carbon-fiber materials.

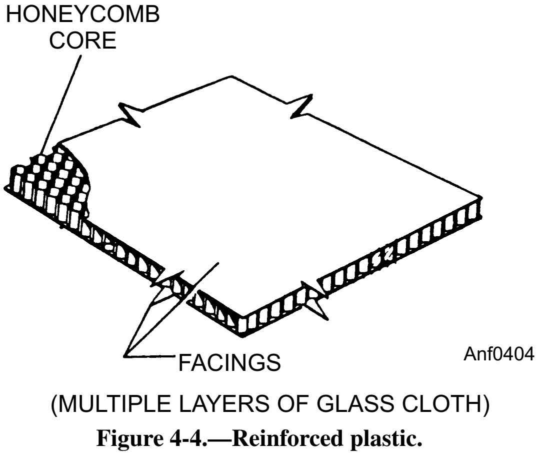
Transparent Plastic

Transparent plastic is used in canopies, windshields, and other transparent enclosures. You need to handle transparent plastic surfaces carefully because they are relatively soft and scratch easily. At approximately 225°F, transparent plastic becomes soft and pliable.

Reinforced Plastic

Reinforced plastic is used in the construction of radomes, wingtips, stabilizer tips, antenna covers, and flight controls. Reinforced plastic has a high strength-to-weight ratio and is resistant to mildew and rot. Because it is easy to fabricate, it is equally suitable for other parts of the aircraft.

Reinforced plastic is a sandwich-type material (fig. 4-4). It is made up of two outer facings and a center layer. The facings are made up of several layers of glass cloth, bonded together with a liquid resin. The core material (center layer) consists of a honeycomb



(MULTIPLE LAYERS OF GLASS CLOTH)

Figure 4-4.—Reinforced plastic.

structure made of glass cloth. Reinforced plastic is fabricated into a variety of cell sizes.

Composite and Carbon Fiber Materials

High-performance aircraft require an extra high strength-to-weight ratio material. Fabrication of composite materials satisfies this special requirement. Composite materials are constructed by using several layers of bonding materials (graphite epoxy or boron epoxy). These materials are mechanically fastened to conventional substructures. Another type of composite construction consists of thin graphite epoxy skins bonded to an aluminum honeycomb core. Carbon fiber is extremely strong, thin fiber made by heating synthetic fibers, such as rayon, until charred, and then layering in cross sections.

Q4-6. Materials currently used in aircraft construction are classified as what type of materials?

Q4-7. What are the most common metallic materials used in aircraft construction?

Q4-8. What are the nonmetallic materials used in aircraft construction?

FIXED-WING AIRCRAFT

LEARNING OBJECTIVE: Identify the construction features of the fixed-wing aircraft and identify the primary, secondary, and auxiliary flight control surfaces.

The principal structural units of a fixed-wing aircraft are the fuselage, wings, stabilizers, flight control surfaces, and landing gear. Figure 4-5 shows these units of a naval aircraft.

NOTE: The terms *left* or *right* used in relation to any of the structural units refer to the right or left hand of the pilot seated in the cockpit.

FUSELAGE

The fuselage is the main structure, or body, of the aircraft. It provides space for personnel, cargo, controls, and most of the accessories. The power plant, wings, stabilizers, and landing gear are attached to it.

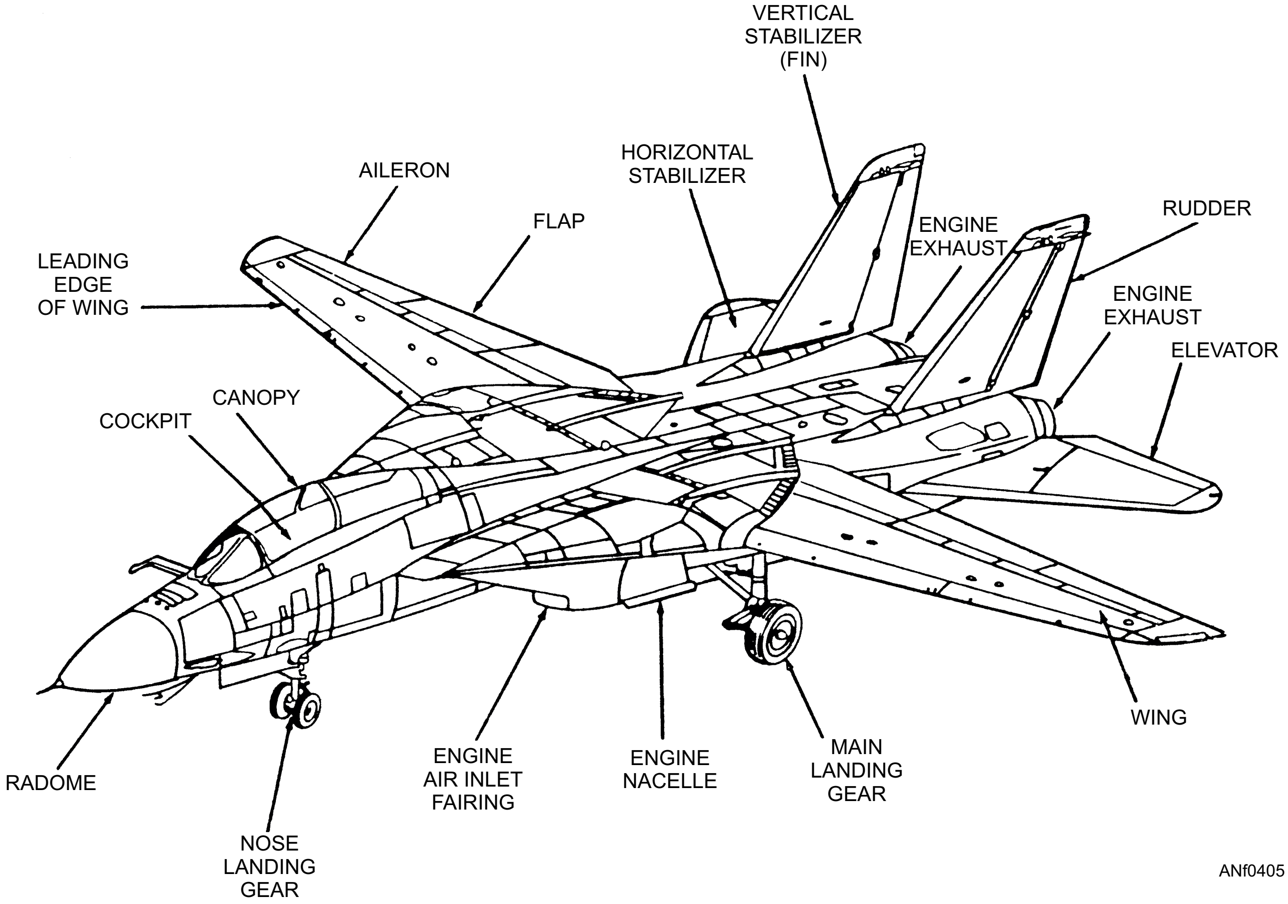


Figure 4-5.—Principal structural units on an F-14 aircraft.

There are two general types of fuselage construction—welded steel truss and monocoque designs. The welded steel truss was used in smaller Navy aircraft, and it is still being used in some helicopters.

The monocoque design relies largely on the strength of the skin, or covering, to carry various loads. The monocoque design may be divided into three classes—monocoque, semimonocoque, and reinforced shell.

- The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. However, the skin carries the primary stresses. Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. The biggest problem in monocoque construction is maintaining enough strength while keeping the weight within limits.
- Semimonocoque design overcomes the strength-to-weight problem of monocoque construction. See figure 4-6. In addition to having formers, frame assemblies, and bulkheads, the semimonocoque construction has the skin reinforced by longitudinal members.
- The reinforced shell has the skin reinforced by a complete framework of structural members. Different portions of the same fuselage may belong to any one of the three classes. Most are considered to be of semimonocoque-type construction.

The semimonocoque fuselage is constructed primarily of aluminum alloy, although steel and titanium are found in high-temperature areas. Primary bending loads are taken by the longerons, which usually extend across several points of support. The longerons are supplemented by other longitudinal members known as *stringers*. Stringers are more numerous and lightweight than longerons.

The vertical structural members are referred to as *bulkheads*, *frames*, and *formers*. The heavier vertical members are located at intervals to allow for concentrated loads. These members are also found at points where fittings are used to attach other units, such as the wings and stabilizers.

The stringers are smaller and lighter than longerons and serve as fill-ins. They have some rigidity but are chiefly used for giving shape and for attachment of skin. The strong, heavy longerons hold the bulkheads and formers. The bulkheads and formers hold the stringers. All of these join together to form a rigid fuselage framework. Stringers and longerons prevent tension and compression stresses from bending the fuselage.

The skin is attached to the longerons, bulkheads, and other structural members and carries part of the load. The fuselage skin thickness varies with the load carried and the stresses sustained at particular location.

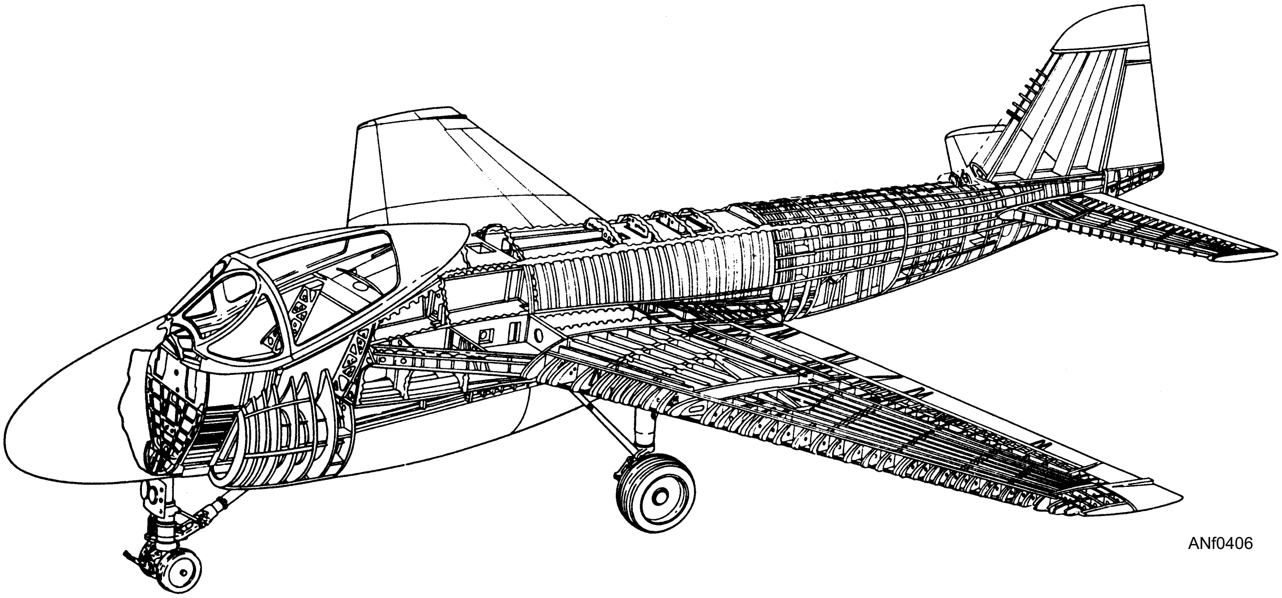


Figure 4-6.—Semimonocoque fuselage construction.

There are a number of advantages in using the semimonocoque fuselage.

- The bulkhead, frames, stringers, and longerons aid in the design and construction of a streamlined fuselage. They add to the strength and rigidity of the structure.
- The main advantage of the semimonocoque construction is that it depends on many structural members for strength and rigidity. Because of its stressed skin construction, a semimonocoque fuselage can withstand damage and still be strong enough to hold together.

Points on the fuselage are located by station numbers. Station 0 is usually located at or near the nose of the aircraft. The other stations are located at measured distances (in inches) aft of station 0. A typical station diagram is shown in figure 4-7. On this particular aircraft, fuselage station (FS) 0 is located 93.0 inches forward of the nose.

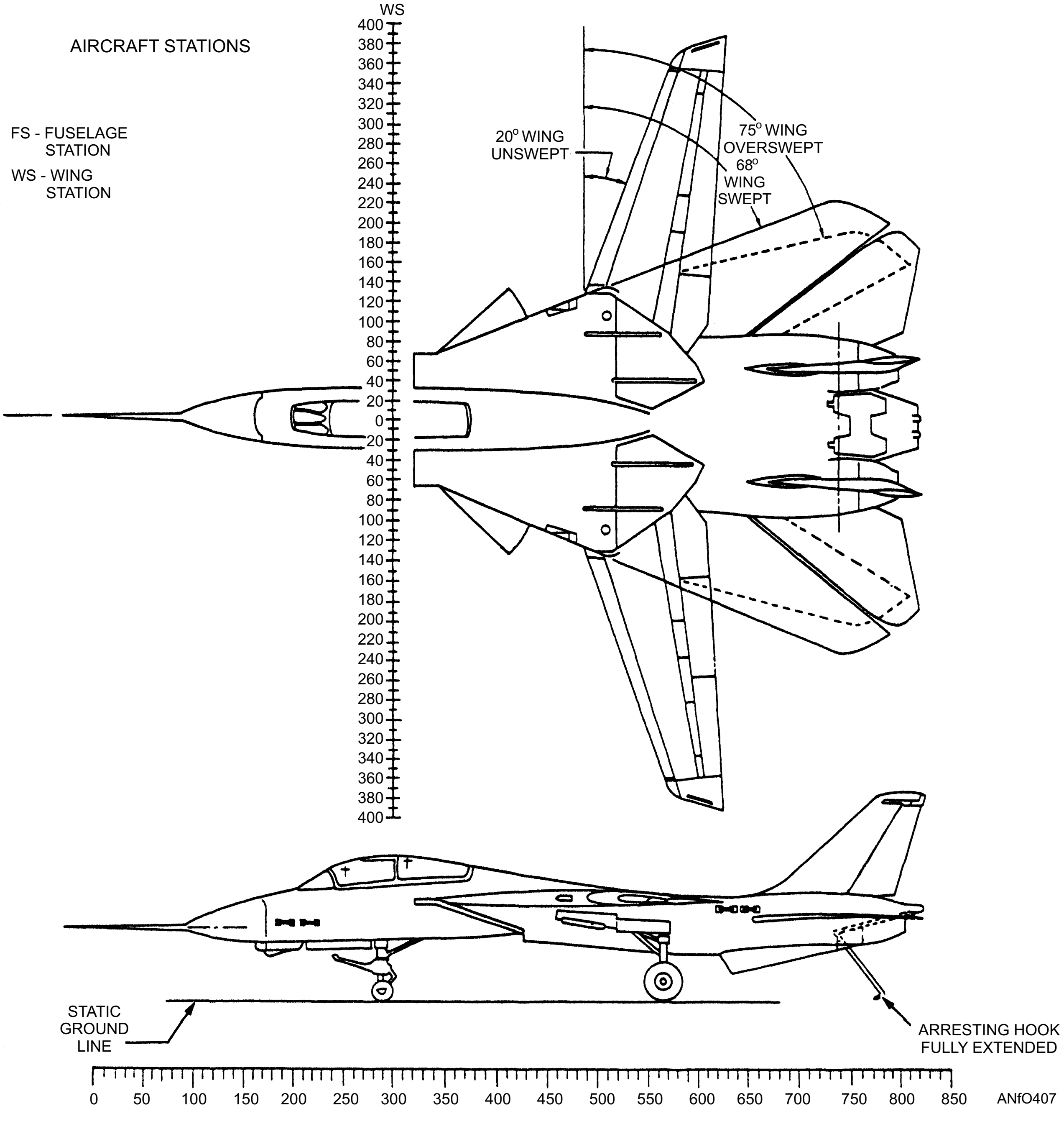


Figure 4-7.—Fuselage station diagram of an F-14 aircraft.

WINGS

Wings develop the major portion of the lift of a heavier-than-air aircraft. Wing structures carry some of the heavier loads found in the aircraft structure. The particular design of a wing depends on many factors, such as the size, weight, speed, rate of climb, and use of the aircraft. The wing must be constructed so that it holds its aerodynamics shape under the extreme stresses of combat maneuvers or wing loading.

Wing construction is similar in most modern aircraft. In its simplest form, the wing is a framework made up of spars and ribs and covered with metal. The construction of an aircraft wing is shown in figure 4-8.

Spars are the main structural members of the wing. They extend from the fuselage to the tip of the wing. All the load carried by the wing is taken up by the spars. The spars are designed to have great bending strength. Ribs give the wing section its shape, and they transmit the air load from the wing covering to the spars. Ribs extend from the leading edge to the trailing edge of the wing.

In addition to the main spars, some wings have a false spar to support the ailerons and flaps. Most aircraft wings have a removable tip, which streamlines the outer end of the wing.

Most Navy aircraft are designed with a wing referred to as a *wet wing*. This term describes the wing that is constructed so it can be used as a fuel cell. The wet wing is sealed with a fuel-resistant compound as it is built. The wing holds fuel without the usual rubber cells or tanks.

The wings of most naval aircraft are of all metal, full cantilever construction. Often, they may be folded for carrier use. A full cantilever wing structure is very strong. The wing can be fastened to the fuselage without the use of external bracing, such as wires or struts.

A complete wing assembly consists of the surface providing lift for the support of the aircraft. It also provides the necessary flight control surfaces.

NOTE: The flight control surfaces on a simple wing may include only ailerons and trailing edge flaps. The more complex aircraft may have a variety of devices, such as leading edge flaps, slats, spoilers, and speed brakes.

Various points on the wing are located by wing station numbers (fig. 4-7). Wing station (WS) 0 is located at the centerline of the fuselage, and all wing stations are measured (right or left) from this point (in inches).

STABILIZERS

The stabilizing surfaces of an aircraft consist of vertical and horizontal airfoils. They are called the

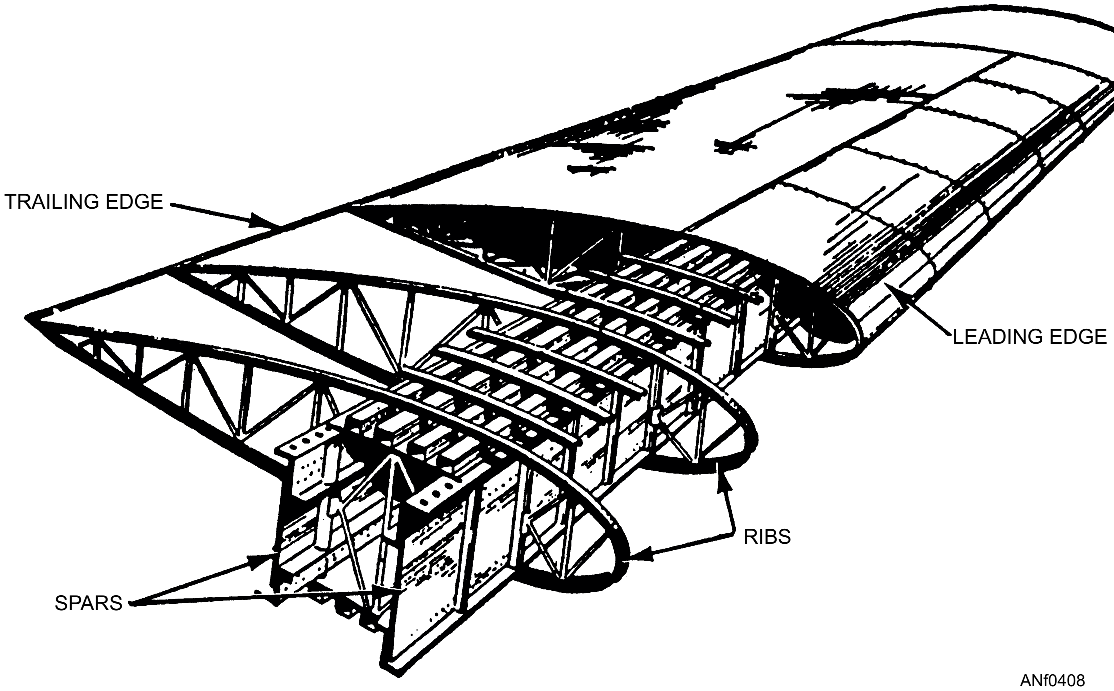


Figure 4-8.—Two-spar wing construction.

vertical stabilizer (or *fin*) and *horizontal stabilizer.* These two airfoils, along with the rudder and elevators, form the tail section. For inspection and maintenance purposes, the entire tail section is considered a single unit called the *empennage*.

The main purpose of stabilizers is to keep the aircraft in straight-and-level flight. The vertical stabilizer maintains the stability of he aircraft about its vertical axis (fig. 4-9). This is known as *directional stability.* The vertical stabilizer usually serves as the base to which the rudder is attached. The horizontal stabilizer provides stability of the aircraft about its lateral axis. This is known as *longitudinal stability.* The horizontal stabilizer usually serves as the base to which the elevators are attached. On many newer, high-performance aircraft, the entire vertical and/or horizontal stabilizer is a movable airfoil. Without the movable airfoil, the flight control surfaces would lose their effectiveness at extremely high altitudes.

Stabilizer construction is similar to wing construction. For greater strength, especially in the thinner airfoil sections typical of trailing edges, a honeycomb-type construction is used. Some larger carrier-type aircraft have vertical stabilizers that are folded hydraulically to aid aircraft movement aboard aircraft carriers.

FLIGHT CONTROL SURFACES

Flight control surfaces are hinged (movable) airfoils designed to change the attitude of the aircraft during flight. These surfaces are divided into three groups—primary, secondary, and auxiliary.

Primary Group

The primary group of flight control surfaces includes ailerons, elevators, and rudders. The ailerons attach to the trailing edge of the wings. They control the rolling (or banking) motion of the aircraft. This action is known as *longitudinal control*.

The elevators are attached to the horizontal stabilizer and control the climb or descent (pitching motion) of the aircraft. This action is known as *lateral control*.

The rudder is attached to the vertical stabilizer. It determines the horizontal flight (turning or yawing motion) of the aircraft. This action is known as *directional control*.

The ailerons and elevators are operated from the cockpit by a control stick on single-engine aircraft. A yoke and wheel assembly operates the ailerons and elevators on multiengine aircraft, such as transport and

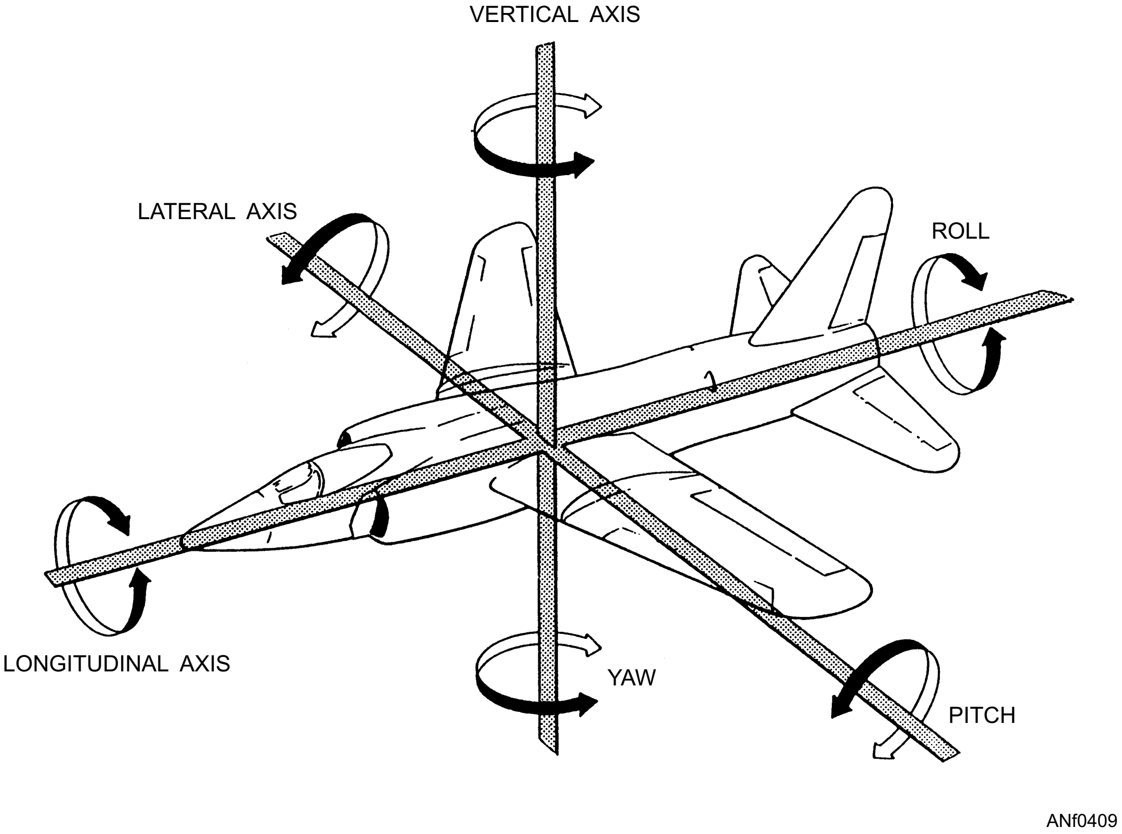


Figure 4-9.—Axes and fundamental movements of the aircraft.

patrol aircraft. The rudder is operated by foot pedals on all types of aircraft.

Secondary Group

The secondary group includes the trim tabs and spring tabs. Trim tabs are small airfoils recessed into the trailing edges of the primary control surface. Each trim tab hinges to its parent primary control surface, but operates by an independent control. Trim tabs let the pilot trim out an unbalanced condition without exerting pressure on the primary controls.

Spring tabs are similar in appearance to trim tabs but serve an entirely different purpose. Spring tabs are used for the same purpose as hydraulic actuators. They aid the pilot in moving a larger control surface, such as the ailerons and elevators.

Auxiliary Group

The auxiliary group includes the wing flaps, spoilers, speed brakes, and slats.

WING FLAPS.—Wing flaps give the aircraft extra lift. Their purpose is to reduce the landing speed. Reducing the landing speed shortens the length of the landing rollout. Flaps help the pilot land in small or obstructed areas by increasing the glide angle without greatly increasing the approach speed. The use of flaps during takeoff serves to reduce the length of the takeoff run.

Some flaps hinge to the lower trailing edges of the wings inboard of the ailerons. Leading edge flaps are used on the F-14 *Tomcat* and F/A-18 *Hornet.* Four types of flaps are shown in figure 4-10. The **plain flap** forms the trailing edge of the airfoil when the flap is in the up position. In the **split flap**, the trailing edge of the airfoil is split, and the lower half is hinged and lowers to form the flap. The **fowler flap** operates on rollers and tracks, causing the lower surface of the wing to roll out and then extend downward. The **leading edge flap** operates like the plain flap. It is hinged on the bottom side. When actuated, the leading edge of the wing actually extends in a downward direction to increase the camber of the wing. Landing flaps are used in conjunction with other types of flaps.

SPOILERS.—Spoilers are used to decrease wing lift. The specific design, function, and use vary with different aircraft. On some aircraft, the spoilers are long narrow surfaces, hinged at their leading edge to the upper surfaces of the wings. In the retracted position, they are flush with the wing skin. In the raised position, they greatly reduce wing lift by destroying the smooth flow of air over the wing surface.

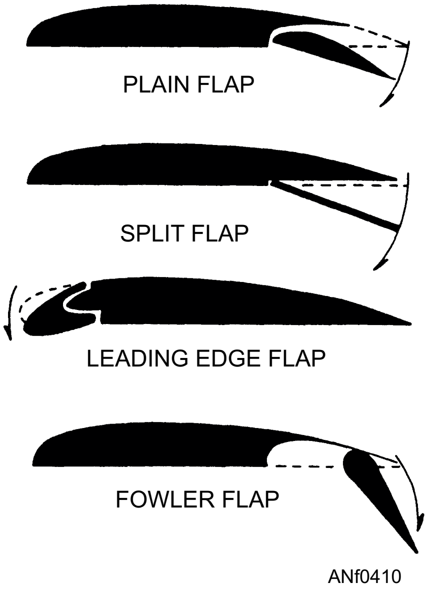


Figure 4-10.—Types of flaps.

SPEED BRAKES.—Speed brakes are movable control surfaces used for reducing the speed of the aircraft. Some manufacturers refer to them as *dive brakes*; others refer to them as *dive flaps*. On some aircraft, they're hinged to the sides or bottom of the fuselage. Regardless of their location, speed brakes serve the same purpose—to keep the airspeed from building too high when the aircraft dives. Speed brakes slow the aircraft's speed before it lands.

SLATS.—Slats are movable control surfaces that attach to the leading edge of the wing. When the slat is retracted, it forms the leading edge of the wing. When the slat is open (extended forward), a slot is created between the slat and the wing leading edge. High-energy air is introduced into the boundary layer over the top of the wing. At low airspeeds, this action improves the lateral control handling characteristics. This allows the aircraft to be controlled at airspeeds below normal landing speed. The high-energy air that flows over the top of the wing is known as *boundary layer control air.* Boundary layer control is intended primarily for use during operations from carriers. Boundary layer control air aids in catapult takeoffs and arrested landings. Boundary control air can also be accomplished by directing high-pressure engine bleed air across the top of the wing or flap surface.

Figure 4-11.—Push-pull tube assembly.

FLIGHT CONTROL MECHANISMS

The term *flight control* refers to the linkage that connects the control(s) in the cockpit with the flight control surfaces. There are several types of flight controls in naval aircraft; some are manually operated while others are power operated.

Manually operated flight control mechanisms are further divided into three groups—cable operated, push-pull tube operated, and torque tube operated. Some systems may combine two or more of these types.

In the **manually operated cable system**, cables are connected from the control in the cockpit to a bell crank or sector. The bell crank is connected to the control surface. Movement of the cockpit controls transfers force through the cable to the bell crank, which moves the control surface.

In a **push-pull tube system**, metal push-pull tubes (or rods) are used as a substitute for the cables (fig. 4-11). Push-pull tubes get their name from the way they transmit force.

In the **torque tube system**, metal tubes (rods) with gears at the ends of the tubes are used. Motion is transmitted by rotating the tubes and gears.

On all high-performance aircraft, the control surfaces have great pressure exerted on them. At high airspeed, it is physically impossible for the pilot to move the controls manually. As a result, power-operated control mechanisms are used. In a power-operated system, a hydraulic actuator (cylinder) is located within the linkage to assist the pilot in moving the control surface.

A typical flight control mechanism is shown in figure 4-12. This is the elevator control of a lightweight trainer-type aircraft. It consists of a combination of push-pull tubes and cables.

The control sticks in the system shown in figure 4-12 are connected to the forward sector by push-pull tubes. The forward sector is connected to the aft (rear) sector by means of cable assemblies. The aft sector is connected to the flight control by another push-pull tube assembly.

LANDING GEAR

Before World War II, aircraft were made with their main landing gear located behind the center of gravity. An auxiliary gear under the fuselage nose was added. This arrangement became known as the *tricycle type of landing gear*. Nearly all present-day Navy aircraft are equipped with tricycle landing gear. The tricycle gear has the following advantages over older landing gear:

- More stable in motion on the ground
- Maintains the fuselage in a level position
- Increases the pilot's visibility and control
- Makes landing easier, especially in cross winds

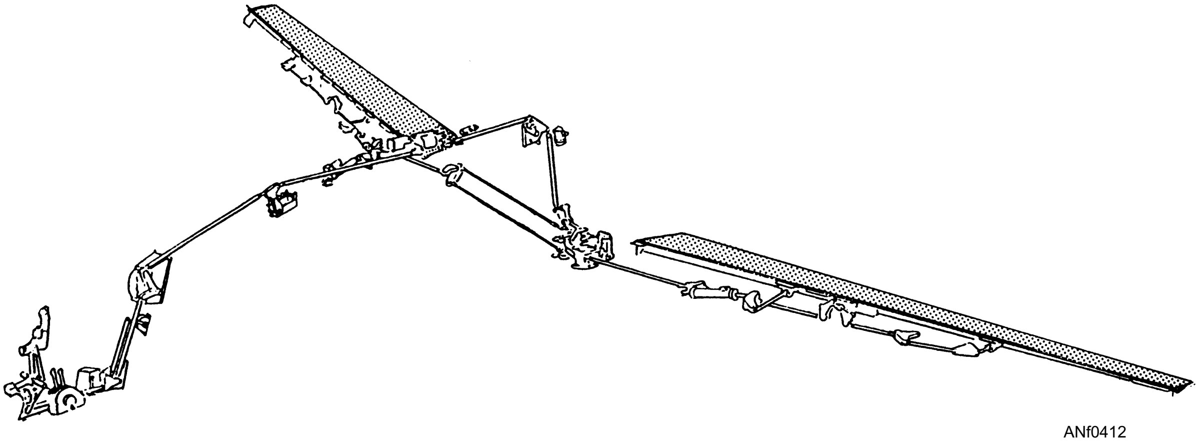
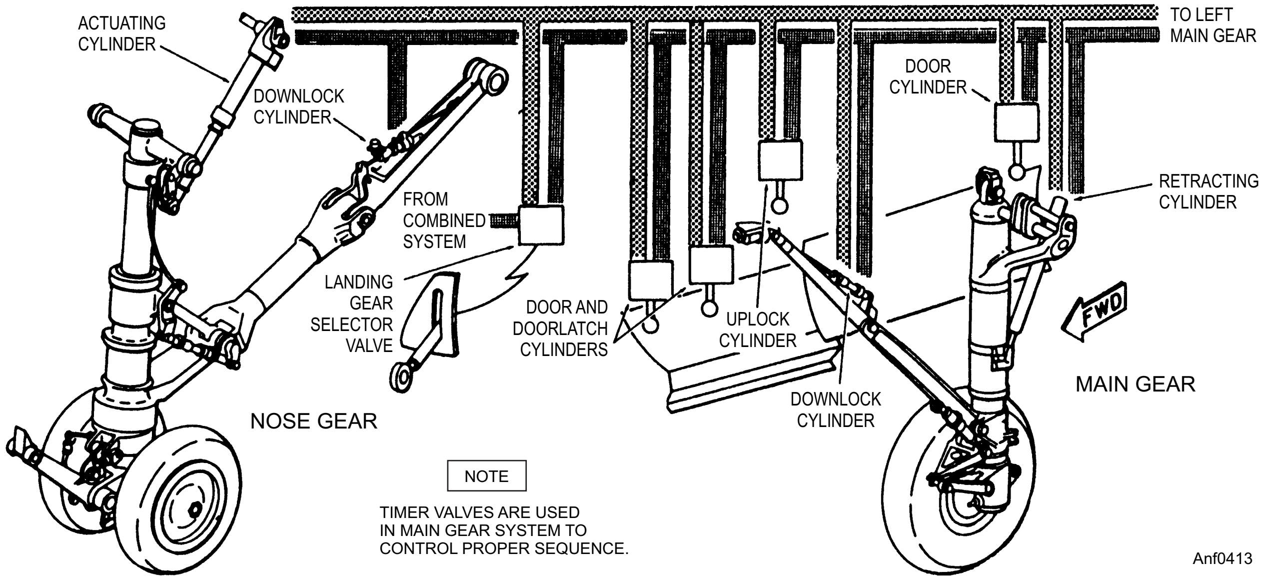


Figure 4-12.—Typical flight control mechanism.



NOTE

TIMER VALVES ARE USED IN MAIN GEAR SYSTEM TO CONTROL PROPER SEQUENCE.

Figure 4-13.—Typical landing gear system.

The landing gear system (fig. 4-13) consists of three retractable landing gear assemblies. Each main landing gear has a conventional air-oil shock strut, a wheel brake assembly, and a wheel and tire assembly. The nose landing gear has a conventional air-oil shock strut, a shimmy damper, and a wheel and tire assembly.

The shock strut is designed to absorb the shock that would otherwise be transmitted to the airframe during landing, taxiing, and takeoff. The air-oil strut is used on all naval aircraft. This type of strut has two telescoping cylinders filled with hydraulic fluid and compressed air or nitrogen. Figure 4-14 shows the internal construction of one type of air-oil shock strut.

The main landing gear is equipped with brakes for stopping the aircraft and assisting the pilot in steering the aircraft on the ground.

The nose gear of most aircraft can be steered from the cockpit. This provides greater ease and safety on the runway when landing and taking off and on the taxiway in taxiing.

ARRESTING GEAR

A carrier-type aircraft is equipped with an arresting hook for stopping the aircraft when it lands on the carrier. The arresting gear has an extendible hook and the mechanical, hydraulic, and pneumatic equipment necessary for hook operation. See figure 4-15. The arresting hook on most aircraft releases mechanically, lowers pneumatically, and raises hydraulically.

The hook hinges from the structure under the rear of the aircraft. A snubber meters hydraulic fluid and works in conjunction with nitrogen pressure. The

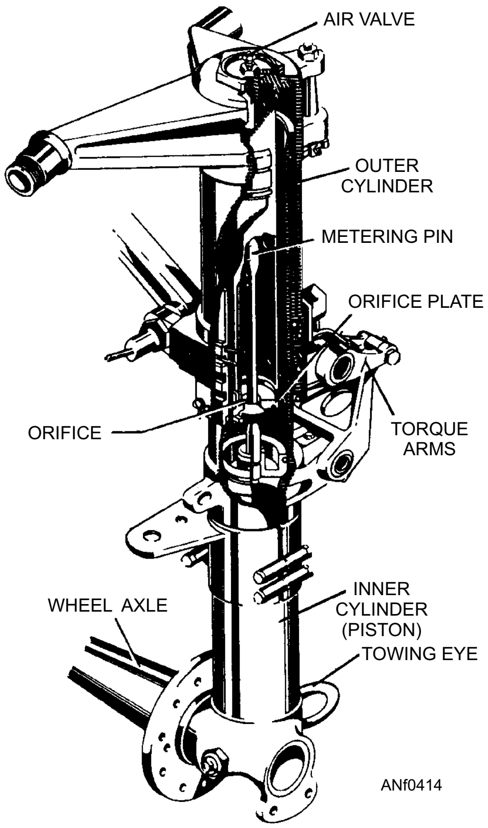


Figure 4-14.—Internal construction of a shock strut.

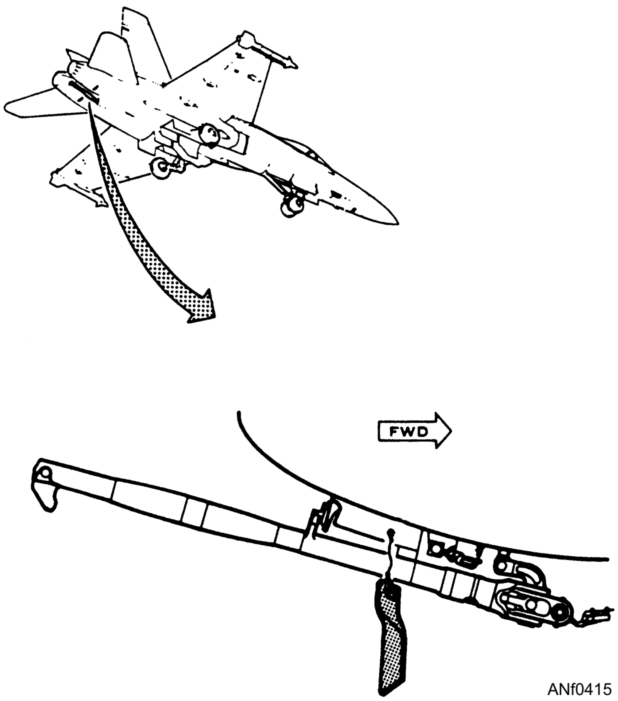


Figure 4-15.—Arresting gear installation.

snubber holds the hook down and prevents it from bouncing when it strikes the carrier deck.

CATAPULT EQUIPMENT

Carrier aircraft have built-in equipment for catapulting off the aircraft carrier. Older aircraft had hooks on the airframe that attached to the cable bridle. The bridle hooks the aircraft to the ship's catapult. Newer aircraft have a launch bar built into the nose landing gear assembly. See figure 4-16. The holdback assembly allows the aircraft to be secured to the carrier deck for full-power turnup of the engine prior to takeoff. For nose gear equipment, a track attaches to the deck to guide the nosewheel into position. The track has provisions for attaching the nose gear to the catapult shuttle and for holdback.

NOTE: The holdback tension bar separates when the catapult is fired, allowing the aircraft to be launched with the engine at full power.

Q4-9. In fuselage construction, what are the three classes of monocoque design?

Q4-10. Points on the fuselage are located by what method?

Q4-11. In an aircraft, what are the main structural members of the wing?

Q4-12. What does the term "wet wing" mean?

Q4-13. The stabilizing surfaces of an aircraft consist of what two airfoils?

Q4-14. What are the three groups of flight control surfaces?

Q4-15. What is the purpose of speed brakes on an aircraft?

Q4-16. Most present-day Navy aircraft are equipped with what type of landing gear?

ROTARY-WING AIRCRAFT

LEARNING OBJECTIVE: Identify the construction features of the rotary-wing aircraft and recognize the fundamental differences between rotary-wing and fixed-wing aircraft.

Within the past 20 years, helicopters have become a reality, and are found throughout the world. They perform countless tasks suited to their unique capabilities.

A helicopter has one or more power-driven horizontal airscrews (rotors) to develop lift and propulsion. If a single main rotor is used, it is necessary to employ a means to counteract torque. If more than one main rotor (or tandem) is used, torque is eliminated by turning each main rotor in opposite directions.

The fundamental advantage the helicopter has over fixed-wing aircraft is that lift and control are independent of forward speed. A helicopter can fly forward, backward, or sideways, or it can remain in stationary flight (hover) above the ground. No runway is required for a helicopter to take off or land. For example, the roof of an office building is an adequate landing area. The helicopter is considered a safe aircraft because the takeoff and landing speed is zero, and it has autorotational capabilities. This allows a controlled descent with rotors turning in case of engine failure in flight.

FUSELAGE

Like the fuselage of a fixed-wing aircraft, the helicopter fuselage may be welded truss or some form of monocoque construction. Many Navy helicopters are of the monocoque design.

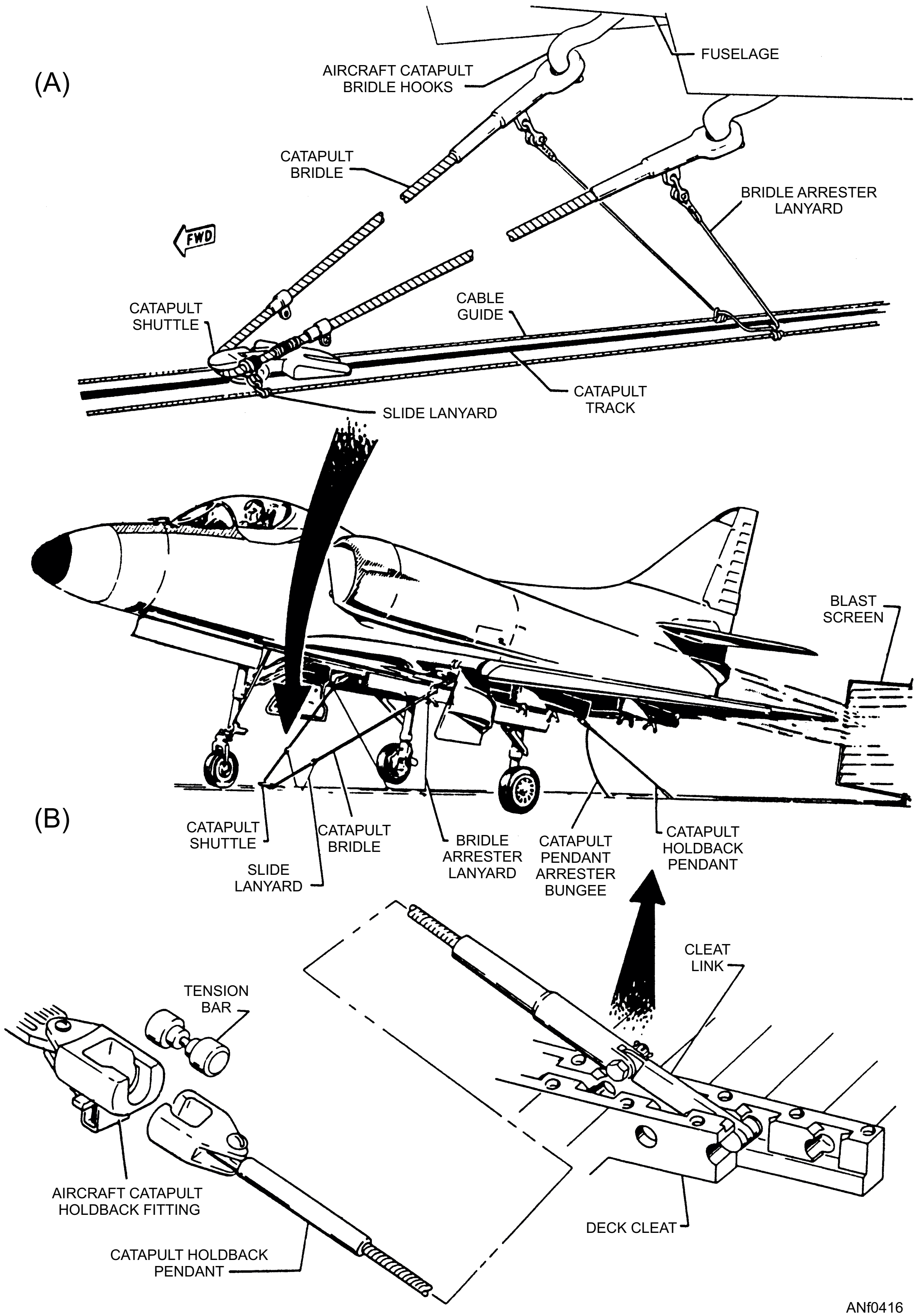


Figure 4-16.—Aircraft catapult equipment.

A typical Navy helicopter, the H-60, is shown in figure 4-17. Some of its features include a single main rotor, twin engine, tractor-type canted tail rotor, controllable stabilizer, fixed landing gear, rescue hoist, external cargo hook, and weapons pylons. The fuselage consists of the entire airframe, sometimes known as the *body group*.

The body group is an all-metal semimonocoque construction. It consists of an aluminum and titanium skin over a reinforced aluminum frame.

LANDING GEAR GROUP

The landing gear group includes all the equipment necessary to support the helicopter when it is not in flight. There are several types of landing gear on helicopters—conventional fixed (skid type), retractable, and nonretractable.

Main Landing Gear

The H-60's nonretracting main landing gear consists of two single axle, air/oil type of shock-strut assemblies that mount to the fuselage. Each is equipped with tubeless tires, hydraulic disc brakes, tie-down rings, drag braces, and safety switches. They are part of the lower end of the shock strut piston.

Tail Landing Gear

The H-60's tail landing gear is a nonretracting, dual wheel, 360-degree swiveling type. It is equipped with tubeless tires, tie-down ring, shimmy damper, tail-wheel lock, and an air/oil shock-strut, which serves as an aft touchdown point for the pilots to cushion the landing shock.

MAIN ROTOR ASSEMBLY

The main rotor (rotor wing) and rotor head (hub assembly) are identical in theory of flight but differ in engineering or design. They are covered here because their functions are closely related. The power plant, transmission, drive-train, hydraulic flight control, and rotor systems all work together. Neither has a function without the other.

Rotary Wing

The main rotor on the H-60 (fig. 4-17) has four identical wing blades. Other types of helicopters may

Figure 4-17.—H-60 helicopter.

have two, four, five, six, or seven blades. Figure 4-18 shows some typical rotor blades.

Rotary-wing blades are made of titanium, aluminum alloys, fiber glass, graphite, honeycomb core, nickel, and steel. Each has a nitrogen-filled, pressurized, hollow internal spar, which runs the length of the blade. The cuff provides the attachment of the blade to the rotor hub. A titanium abrasion strip covers the entire leading edge of the spar from the cuff end to the removable blade tip faring. This extends the life of the rotor blade.

The examples shown in figure 4-18 show other features—trim tabs, deicing protection, balance markings, and construction.

Main Rotor Head/Hub Assembly

The rotor head is fully articulating and is rotated by torque from the engines through the drive train and main gearbox or transmission. The flight controls and hydraulic servos transmit movements to the rotor blades. The principal components of the rotor head are the hub and swashplate assemblies (fig. 4-19). The **hub** is one piece, made of titanium and sits on top of the rotor mast. Attaching components are the sleeve and spindles, blade fold components, vibration absorber, bearings, blade dampers, pitch change horns, adjustable pitch control rods, blade fold hinges, balance weights, antiflapping and droop stops, and faring.

The **swashplate** consists of a rotating disc (upper), stationary (lower) portion with a scissors and sleeve assembly separated by a bearing. The swashplate is permitted to slide on the main rotor vertical driveshaft and mounts on top the main transmission. The entire assembly can tilt in any direction following the motion of the flight controls.

The hydraulic servo cylinders, swashplate, and adjustable pitch control rods permit movement of the

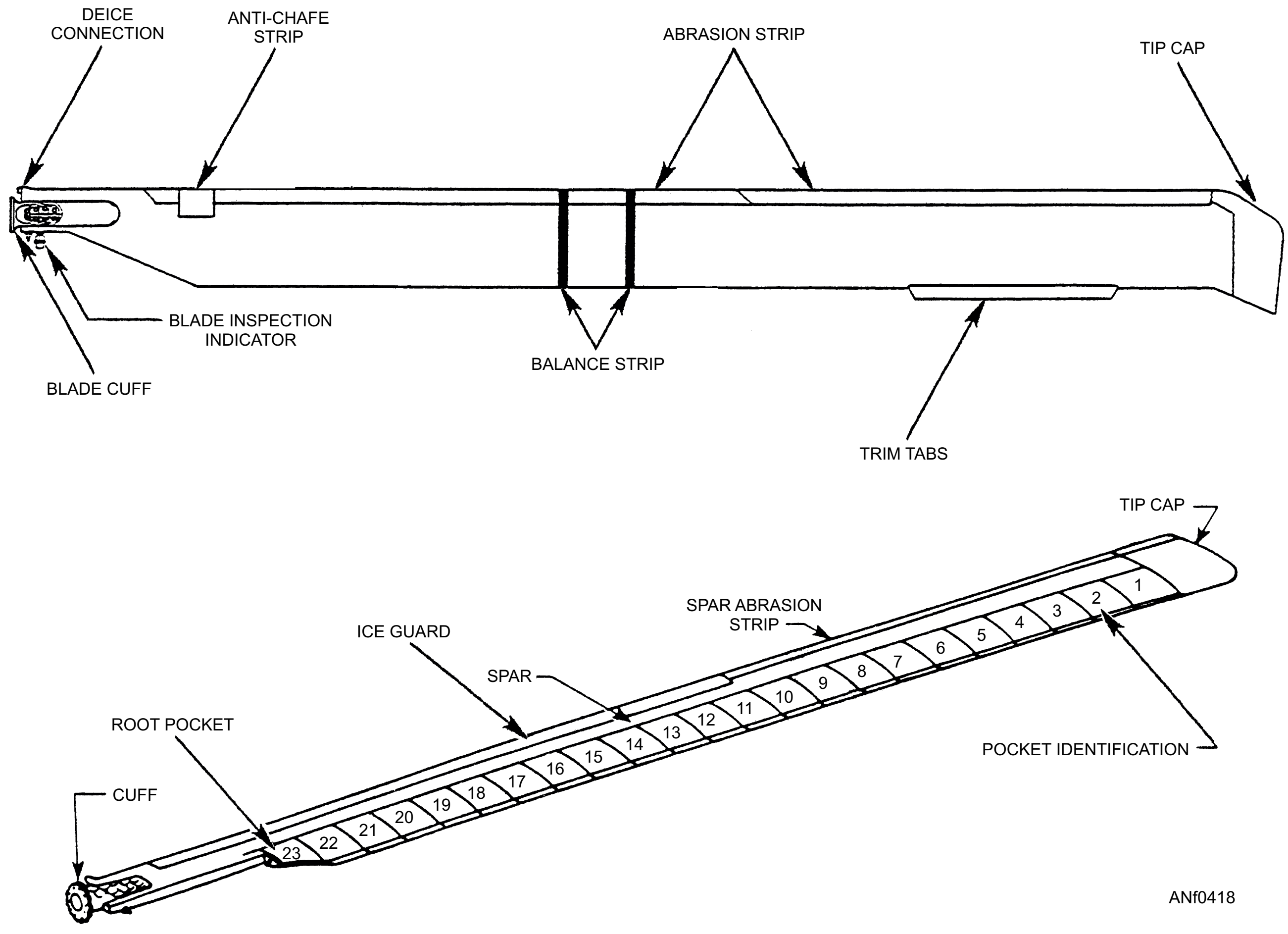


Figure 4-18.—Types of main rotor blades.

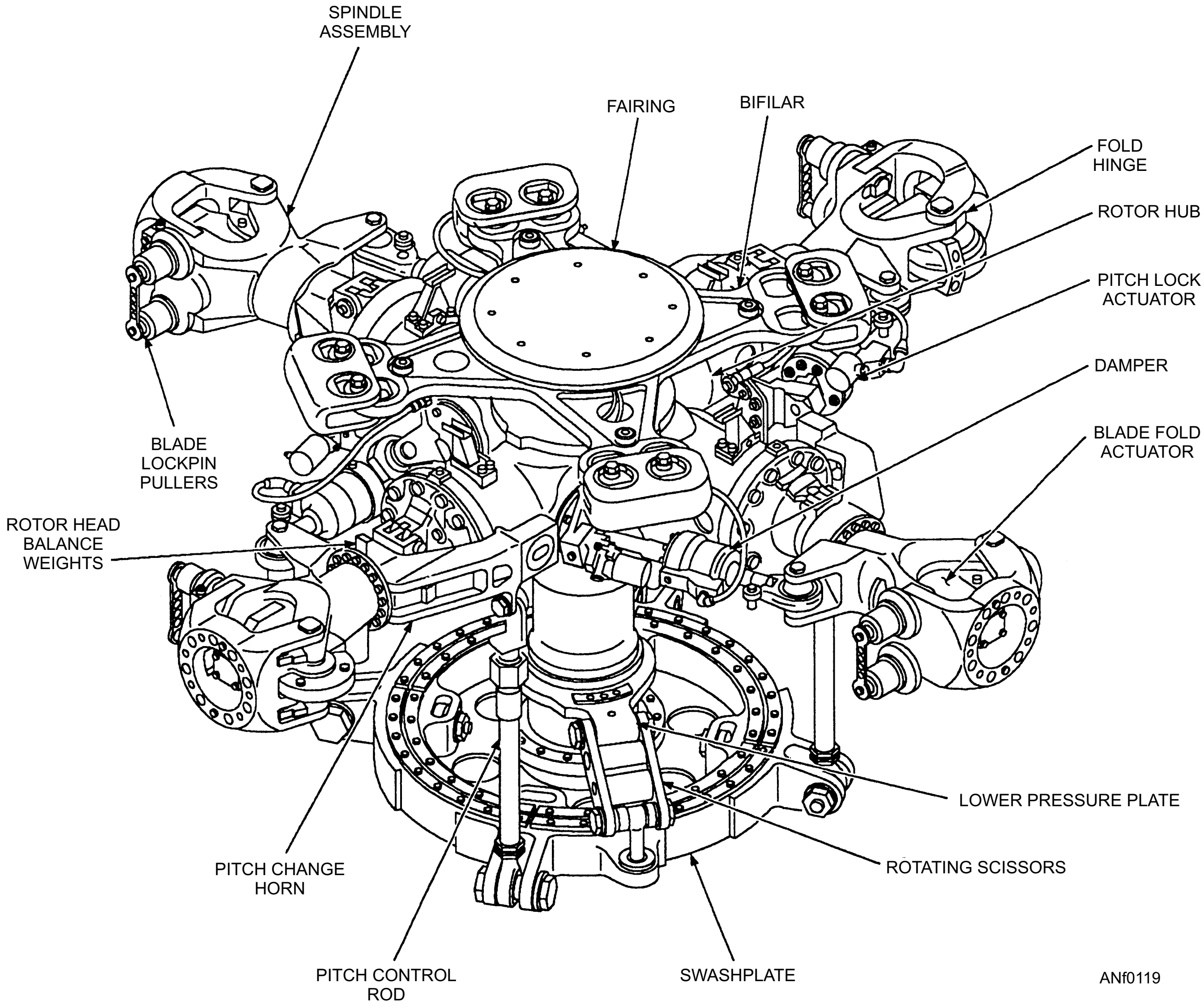


Figure 4-19.—Main rotor head/hub assembly.

flight controls to be transmitted to the rotary-wing blades. The sleeve and spindle and blade dampers allow limited movement of the blades in relation to the hub. These movements are known as *lead*, *lag*, and *flap*.

- Lead occurs during slowing of the drive mechanism when the blades have a tendency to remain in motion.
- Lag is the opposite of lead and occurs during acceleration when the blade has been at rest and tends to remain at rest.
- Flap is the tendency of the blade to rise with high-lift demands as it tries to screw itself upward into the air.

Antiflapping stops and droop stops restrict flapping and conning motion of the rotary-wing head and blades at low rotor rpm when slowing or stopping.

TAIL ROTOR GROUP

The directional control and antitorque action of the helicopter is provided by the tail rotor group. See figure 4-20. These components are similar in function to the main rotor.

Pylon

The pylon, shown in figure 4-20, attaches on the aircraft to the main fuselage by hinge fittings. These hinge fittings serve as the pivot point for the pylon to fold along the fuselage. Folding the pylon reduces the overall length of the helicopter, which helps for confined shipboard handling.

The pylon houses the intermediate and tail rotor gearboxes, tail rotor drive shaft, cover, tail bumper, position/anticollision lights, hydraulic servos, flight control push-pull tubes/cables/bell cranks, stabilizer/elevator flight control surface, some antennas, and rotary rudder assembly.

Rotary Rudder Head

The rudder head can be located on either side of the pylon, depending on the type of aircraft, and includes such items as the hub, spindle, pitch control beam, pitch change links, bearings, and tail rotor blades.

Change in blade pitch is accomplished through the pitch change shaft that moves through the horizontal shaft of the tail gearbox, which drives the rotary rudder assembly. As the shaft moves inward toward the tail gearbox, pitch of the blade is decreased. As the shaft moves outward from the tail gearbox, pitch of the blade is increased. The pitch control beam is connected by links to the forked brackets on the blade sleeves.

Rotary Rudder Blades

Like the blades on a main rotor head, the blades found on a rotary rudder head may differ, depending on the type of aircraft. Tail rotor blades may consist of the following components:

- Aluminum alloy, graphite composite, or titanium spar
- Aluminum pocket and skin with honeycomb core or cross-ply fiber glass exterior
- Aluminum or graphite composite tip cap

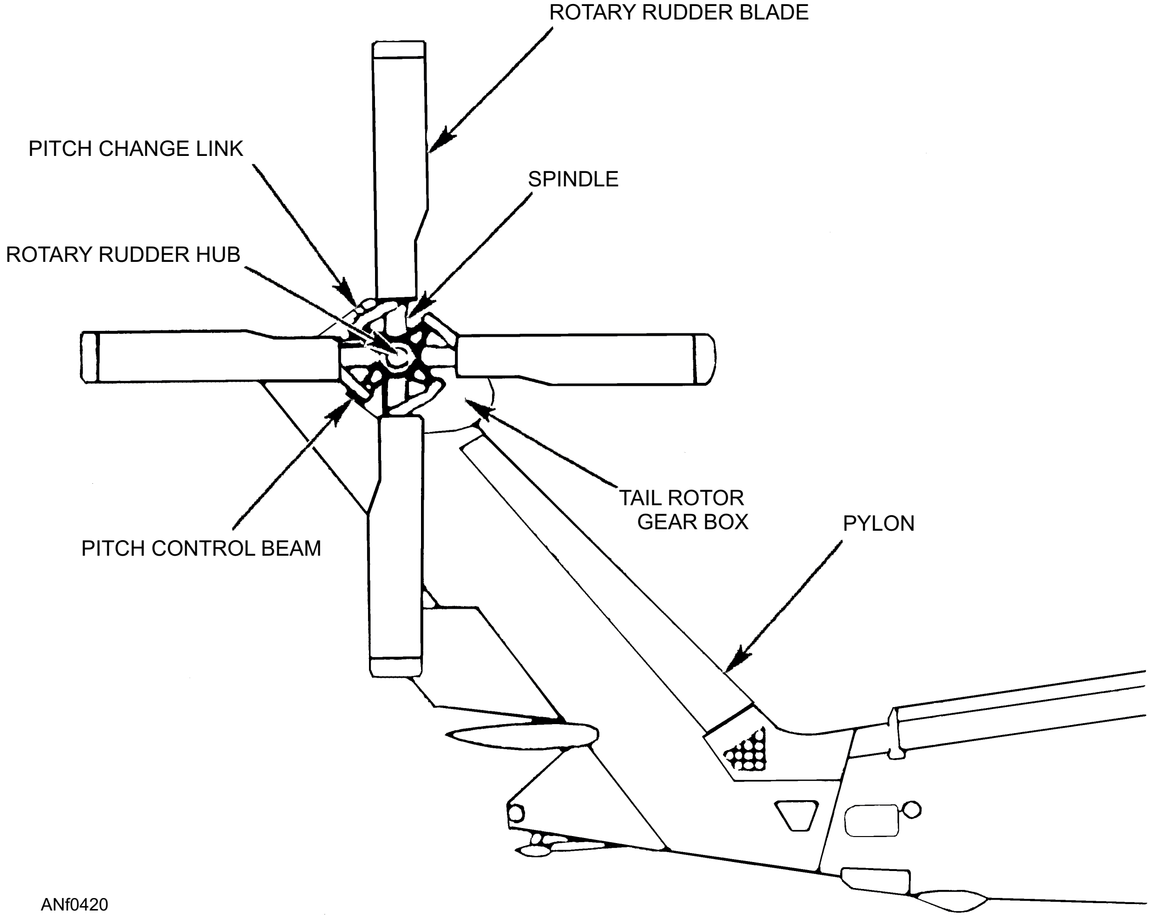


Figure 4-20.—Tail rotor group.

- Aluminum trailing edge cap
- Aluminum or polyurethane and nickel abrasion leading edge strip

Additionally, rotary rudder blades may have deicing provisions, such as electrothermal blankets that are bonded into the blade's leading edge. or a neoprene anti-icing guard embedded with electrical heating elements.

Q4-17. What is the main advantage of rotary-wing aircraft over fixed-wing aircraft?

Q4-18. What are the three types of landing gear used on helicopters?

Q4-19. The directional control and antitorque action of the helicopter is provided by what group?

AIRCRAFT HYDRAULIC SYSTEMS

LEARNING OBJECTIVE: Identify the components of aircraft hydraulic systems and recognize their functions.

The aircraft hydraulic systems found on most naval aircraft perform many functions. Some systems operated by hydraulics are flight controls, landing gear, speed brakes, fixed-wing and rotary-wing folding mechanisms, auxiliary systems, and wheel brakes.

Hydraulics has many advantages as a power source for operating these units on aircraft.

- Hydraulics combine the advantages of lightweight, ease of installation, simplification of inspection, and minimum maintenance requirements.
- Hydraulics operation is almost 100-percent efficient, with only a negligible loss due to fluid friction.

However, there are some disadvantages to using hydraulics.

- The possibility of leakage, both internal and external, may cause the complete system to become inoperative.
- Contamination by foreign matter in the system can cause malfunction of any unit. Cleanliness in hydraulics cannot be overemphasized.

COMPONENTS OF A BASIC HYDRAULIC SYSTEM

Basically, any hydraulic system contains the following units:

- A **reservoir** to hold a supply of hydraulic fluid
- A **pump** to provide a flow of fluid
- **Tubing** to transmit the fluid
- A **selector valve** to direct the flow of fluid
- An **actuating unit** to convert the fluid pressure into useful work

A simple system using these essential units is shown in figure 4-21.

You can trace the flow of fluid from the reservoir through the pump to the selector valve. In figure 4-21, the flow of fluid created by the pump flows through the valve to the right end of the actuating cylinder. Fluid pressure forces the piston to the left. At the same time, the fluid that is on the left of the piston is forced out. It goes up through the selector valve and back to the reservoir through the return line.

When the selector valve is moved to the position indicated by the dotted lines, the fluid from the pump flows to the left side of the actuating cylinder. Movement of the piston can be stopped at any time simply by moving the selector valve to neutral. When the selector valve is in this position, all four ports are closed, and pressure is trapped in both working lines.

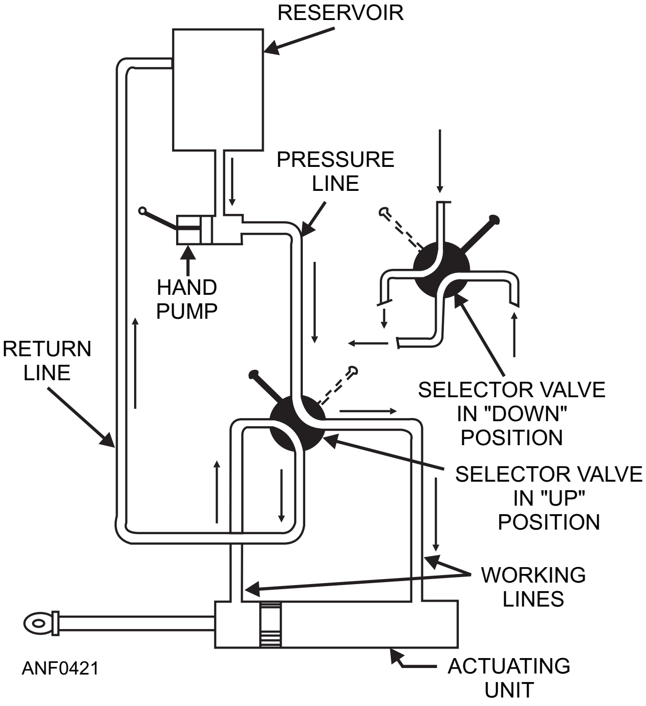


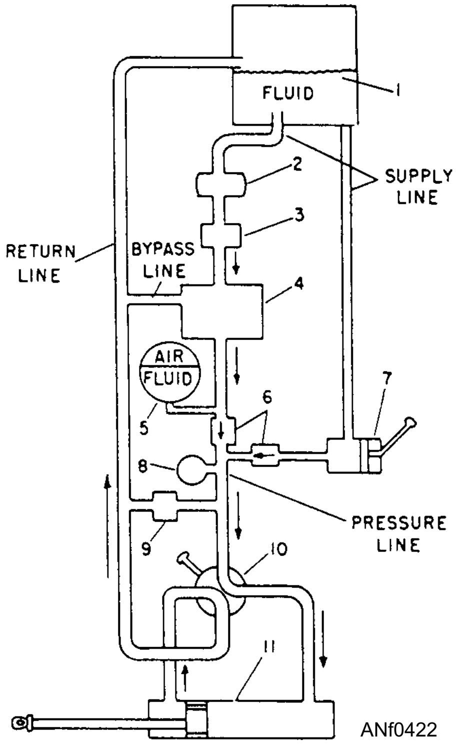
Figure 4-21.—Basic hydraulic system, hand pump operated.

Figure 4-22 shows a basic system with the addition of a power-driven pump and other essential components. These components are the filter, pressure regulator, accumulator, pressure gauge, relief valve, and two check valves. The function of these components is described below.

The **filter** (fig. 4-22) removes foreign particles from the fluid, preventing moisture, dust, grit, and other undesirable matter from entering the system.

The **pressure regulator** (fig. 4-22) unloads or relieves the power-driven pump when the desired pressure in the system is reached. Therefore, it is often referred to as an *unloading valve*. With none of the actuating units operating, the pressure in the line between the pump and selector valve builds up to the desired point. A valve in the pressure regulator automatically opens and fluid is bypassed back to the reservoir. (The bypass line is shown in figure 4-22, leading from the pressure regulator to the return line.)

NOTE: Many aircraft hydraulic systems do not use a pressure regulator. These systems use a pump that automatically adjusts to supply the proper volume of fluid as needed.



1. Reservoir
2. Power pump
3. Filter
4. Pressure regulator
5. Accumulator
6. Check valves
7. Hand pump
8. Pressure gauge
9. Relief valve
10. Selector valve
11. Actuating unit

Figure 4-22.—Basic hydraulic system with addition of power pump.

The **accumulator** serves a twofold purpose.

1. It serves as a cushion or shock absorber by maintaining an even pressure in the system.
2. It stores enough fluid under pressure to provide for emergency operation of certain actuating units.

The accumulator is designed with a compressed-air chamber separated from the fluid by a flexible diaphragm, or a removable piston.

The **pressure gauge** indicates the amount of pressure in the system.

The **relief valve** is a safety valve installed in the system. When fluid is bypassed through the valve to the return line, it returns to the reservoir. This action prevents excessive pressure in the system.

Check valves allow the flow of fluid in one direction only. There are numerous check valves installed at various points in the lines of all aircraft hydraulic systems. A careful study of figure 4-22 shows why the two check valves are necessary in this system. One check valve prevents power pump pressure from entering the hand-pump line. The other valve prevents hand-pump pressure from being directed to the accumulator.

HYDRAULIC CONTAMINATION

Hydraulic contamination is defined as *foreign material in the hydraulic system of an aircraft*. Foreign material might be grit, sand, dirt, dust, rust, water, or any other substance that is not soluble in the hydraulic fluid.

There are two basic ways to contaminate a hydraulic system. One is to inject particles, and the other is to intermix fluids, including water.

Particle contamination in a system may be self-generated through normal wear of system components. It is the injection of contaminants from outside that usually causes the most trouble. Regardless of its origin, any form of contamination in the hydraulic system will slow performance. In extreme cases, it seriously affects safety.

A single grain of sand or grit can cause internal failure of a hydraulic component. Usually, this type of contamination comes from poor servicing and fluid-handling procedures. For this reason, the highest level of cleanliness must be maintained when working on hydraulic components.

Only approved fill stand units are used to service naval aircraft hydraulic systems. By following a few basic rules, you can service hydraulic systems safely and keep contamination to a minimum.

- Never use fluid that has been left open for an undetermined period of time. Hydraulic fluid that is exposed to air will absorb dust and dirt.
- Never pour fluid from one container into another.
- Use only approved servicing units for the specific aircraft.
- Maintain hydraulic fluid-handling equipment in a high state of cleanliness.
- Always make sure you use the correct hydraulic fluid.

Contamination of the hydraulic system may be caused by wear or failure of hydraulic components and seals. This type of contamination is usually found through filter inspection and fluid analysis. Continued operation of a contaminated system may cause malfunctioning or early failure of hydraulic components.

Q4-20. What are two disadvantages of a hydraulic system?

Q4-21. On a basic hydraulic system, what is the purpose of the selector valve?

Q4-22. On a basic hydraulic system, what is the purpose of the actuating unit?

Q4-23. Define hydraulic contamination.

PNEUMATIC SYSTEMS

LEARNING OBJECTIVE: Identify the components of aircraft pneumatic systems and recognize their functions.

There are two types of pneumatic systems currently used in naval aircraft. One type uses storage bottles for an air source, and the other has its own air compressor.

Generally, the storage bottle system is used only for emergency operation. See figure 4-23. This system has an air bottle, a control valve in the cockpit for releasing the contents of the cylinders, and a ground charge (filler) valve. The storage bottle must be filled with compressed air or nitrogen prior to flight. Air storage cylinder pneumatic systems are in use for emergency brakes, emergency landing gear extension, emergency flap extension, and for canopy release mechanisms.

When the control valve is properly positioned, the compressed air in the storage bottle is routed through the shuttle valve to the actuating cylinder.

NOTE: The shuttle valve is a pressure-operated valve that separates the normal hydraulic system from the emergency pneumatic system. When the control handle is returned to the normal position, the air pressure in the lines is vented overboard through the vent port of the control valve.

The other type of pneumatic system in use has its own air compressor. It also has other equipment necessary to maintain an adequate supply of compressed air during flight. Most systems of this type must be serviced on the ground prior to flight. The air

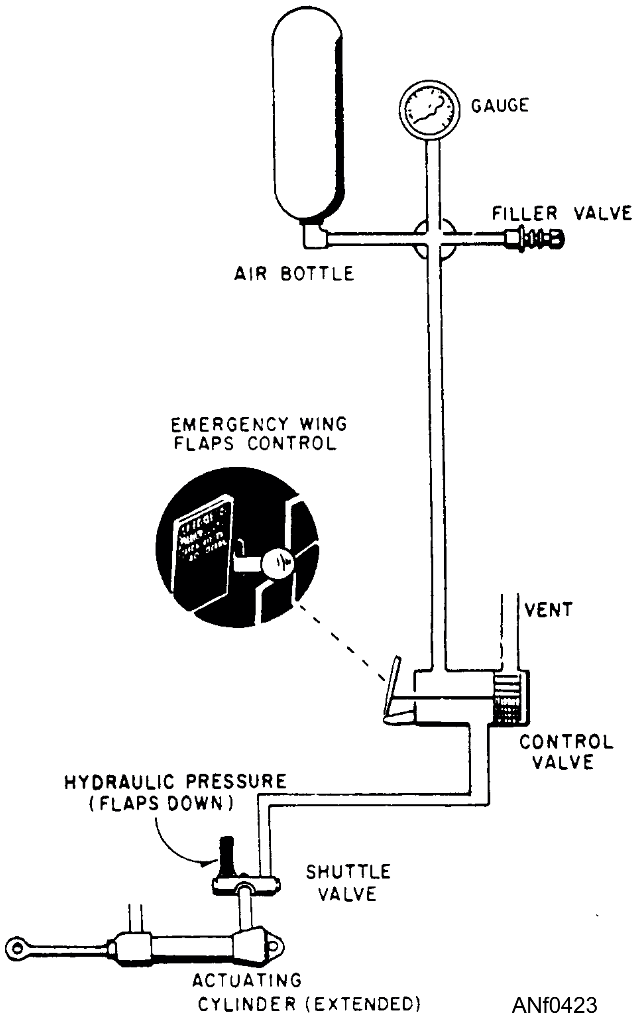


Figure 4-23.—Emergency pneumatic system.

compressor used in most aircraft is driven by a hydraulic motor. Aircraft that have an air compressor use the compressed air for normal and emergency system operation.

Q4-24. What are the two types of pneumatic systems currently used in naval aircraft?

SUMMARY

In this chapter, you have learned about aircraft construction and the materials used in construction. You have also learned about the features and materials used to absorb stress on both fixed-wing and rotary-wing aircraft.