CHAPTER 1
AIRCRAFT STRUCTURES

GENERAL

The airframe of a fixed-wing aircraft is generally considered to consist of five principal units, the fuselage, wings, stabilizers, flight control surfaces, and landing gear. Helicopter airframes consist of the fuselage, main rotor and related gearbox, tail rotor (on helicopters with a single main rotor), and the landing gear.

The airframe components are constructed from a wide variety of materials and are joined by rivets, bolts, screws, and welding or adhesives. The aircraft components are composed of various parts called structural members (*i.e.*, stringers, longerons, ribs, bulkheads, etc.). Aircraft structural members are designed to carry a load or to resist stress. A single member of the structure may be subjected to a combination of stresses. In most cases the structural members are designed to carry end loads rather than side loads: that is, to be subjected to tension or compression rather than bending.

Strength may be the principal requirement in certain structures, while others need entirely different qualities. For example, cowling, fairing, and similar parts usually are not required to carry the stresses imposed by flight or the landing loads. However, these parts must have such properties as neat appearance and streamlined shapes.

MAJOR STRUCTURAL STRESSES

In designing an aircraft, every square inch of wing and fuselage, every rib, spar, and even each metal fitting must be considered in relation to the physical characteristics of the metal of which it is made. Every part of the aircraft must be planned to carry the load to be imposed upon it. The determination of such loads is called stress analysis. Although planning the design is not the function of the aviation mechanic, it is, nevertheless, important that he understand and appreciate the stresses involved in order to avoid changes in the original design through improper repairs.

There are five major stresses to which all aircraft are subjected (figure 1–1):

(1) Tension.
(2) Compression.
(3) Torsion.
(4) Shear.
(5) Bending.

The term "stress" is often used interchangeably with the word "strain." Stress is an internal force of a substance which opposes or resists deformation. Strain is the deformation of a material or substance. Stress, the internal force, can cause strain.

Tension (figure 1–1a) is the stress that resists a force that tends to pull apart. The engine pulls the aircraft forward, but air resistance tries to hold it back. The result is tension, which tries to stretch the aircraft. The tensile strength of a material is measured in p.s.i. (pounds per square inch) and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

Compression (figure 1–1b) is the stress that resists a crushing force. The compressive strength of a material is also measured in p.s.i. Compression is the stress that tends to shorten or squeeze aircraft parts.

Torsion is the stress that produces twisting (figure 1–1c). While moving the aircraft forward, the engine also tends to twist it to one side, but other aircraft components hold it on course. Thus, torsion is created. The torsional strength of a material is its resistance to twisting or torque.

Shear is the stress that resists the force tending to cause one layer of a material to slide over an adjacent layer. Two riveted plates in tension (figure 1–1d) subject the rivets to a shearing force. Usually, the shearing strength of a material is either equal to or less than its tensile or compressive strength. Aircraft parts, especially screws, bolts, and rivets, are often subject to a shearing force.

Bending stress is a combination of compression and tension. The rod in figure 1–1e has been shortened (compressed) on the inside of the bend and stretched on the outside of the bend.

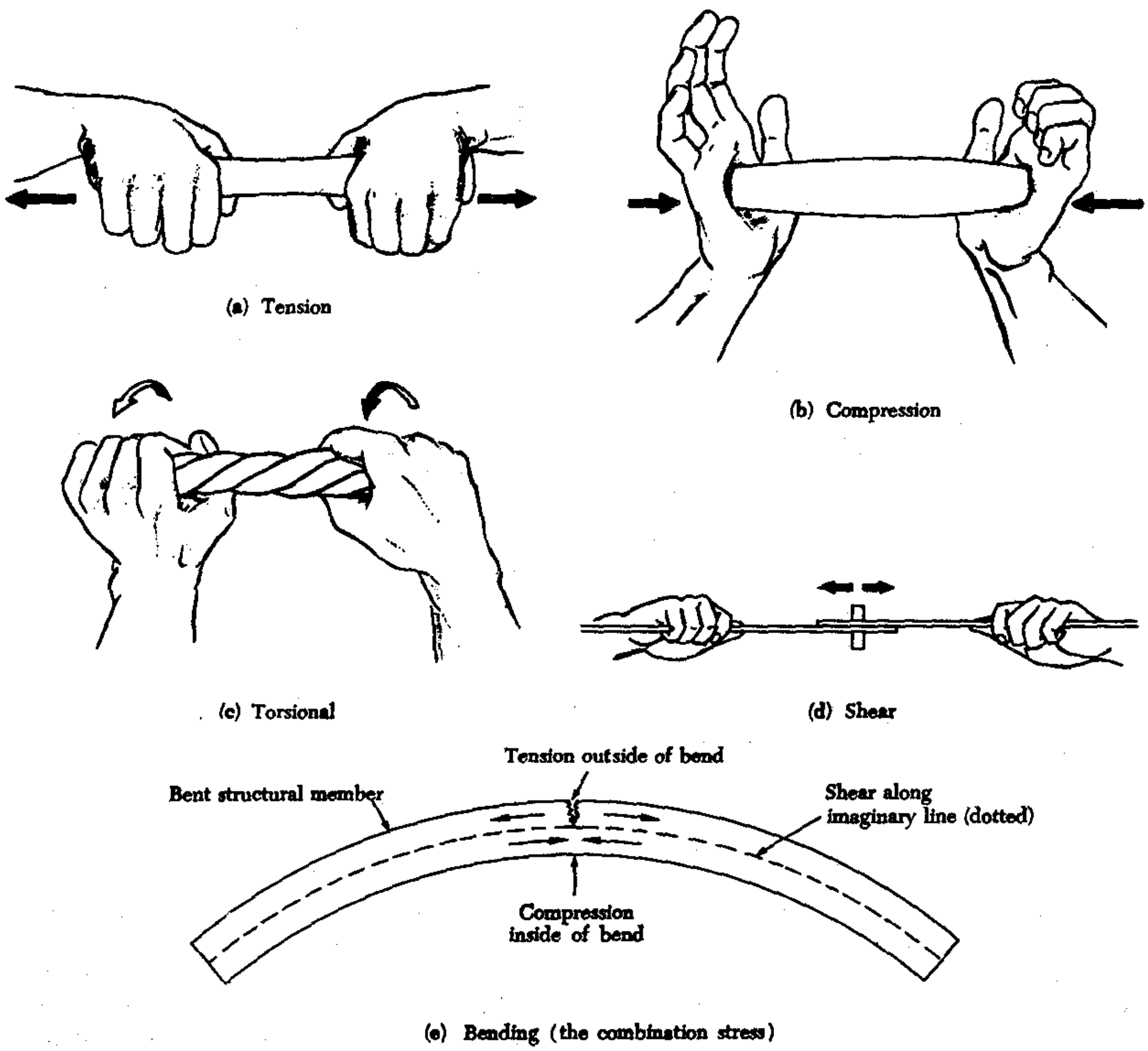


FIGURE 1–1. Five stresses acting on an aircraft.

FIXED-WING AIRCRAFT

The principal components of a single-engine, propeller-driven aircraft are shown in figure 1–2.

Figure 1–3 illustrates the structural components of a typical turbine powered aircraft. One wing and the empennage assemblies are shown exploded into the many components which, when assembled, form major structural units.

FUSELAGE

The fuselage is the main structure or body of the aircraft. It provides space for cargo, controls, accessories, passengers, and other equipment. In single-engine aircraft, it also houses the powerplant. In multi-engine aircraft the engines may either be in the fuselage, attached to the fuselage, or suspended from the wing structure. They vary principally in size and arrangement of the different compartments.

There are two general types of fuselage construction, the truss type, and the monocoque type. A truss is a rigid framework made up of members such as beams, struts, and bars to resist deformation by applied loads. The truss-framed fuselage is generally covered with fabric.

Truss Type

The truss type fuselage frame (figure 1–4) is usually constructed of steel tubing welded together in such a manner that all members of the truss can carry both tension and compression loads. In some

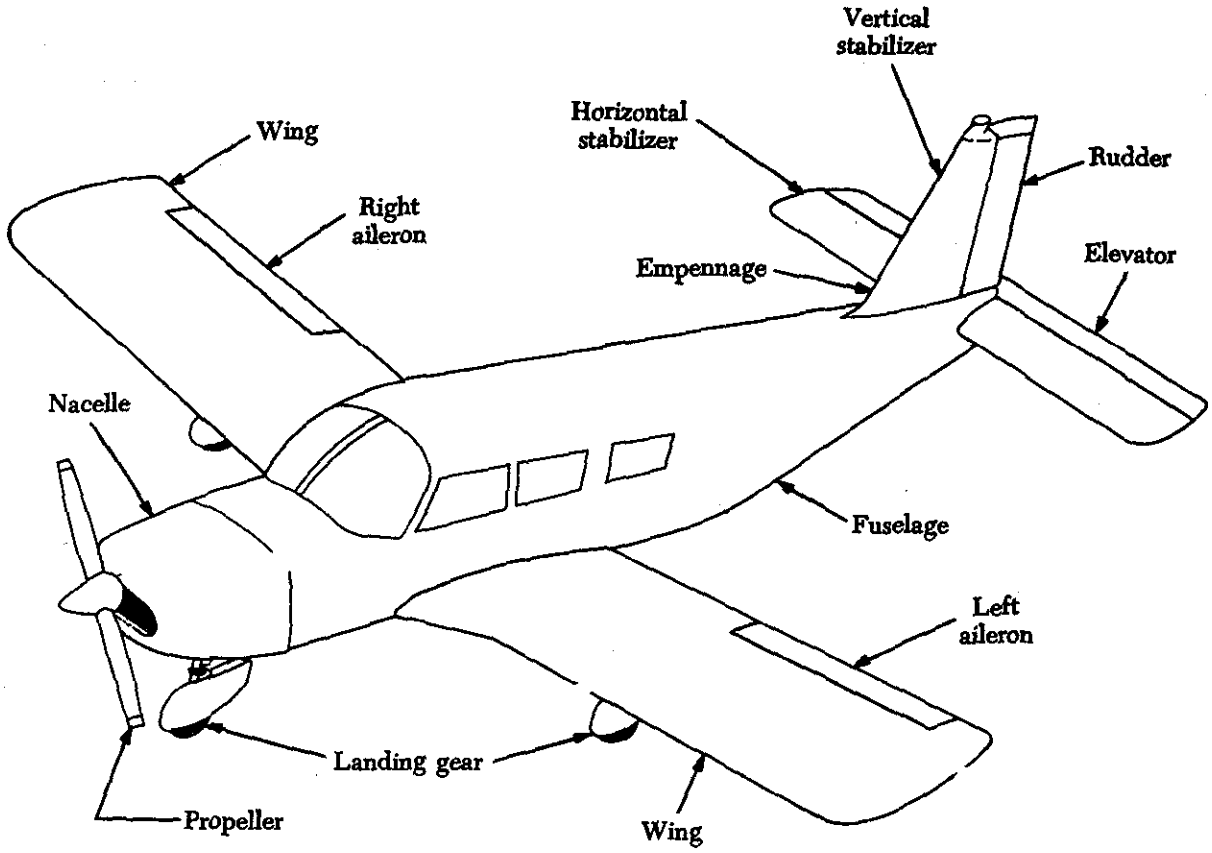


FIGURE 1-2. Aircraft structural components.

aircraft, principally the light, single-engine models, truss fuselage frames are constructed of aluminum alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes.

Monocoque Type

The monocoque (single shell) fuselage relies largely on the strength of the skin or covering to carry the primary stresses. The design may be divided into three classes: (1) Monocoque, (2) semimonocoque, or (3) reinforced shell. The true monocoque construction (figure 1-5) uses formers, frame assemblies, and bulkheads to give shape to the fuselage, but the skin carries the primary stresses. Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits.

To overcome the strength/weight problem of monocoque construction, a modification called semimonocoque construction (figure 1-6) was developed.

In addition to 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, but most aircraft are considered to be of semimonocoque type construction.

Semimonocoque Type

The semimonocoque fuselage is constructed primarily of the alloys of aluminum and magnesium, although steel and titanium are found in areas of high temperatures. Primary bending loads are taken by the *longerons*, which usually extend across several points of support. The longerons are supplemented by other longitudinal members, called *stringers*. Stringers are more numerous and lighter in weight than longerons. The vertical structural members are referred to as *bulkheads, frames, and formers*. The heaviest of these vertical members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units, such as the wings, powerplants, and stabiliz-

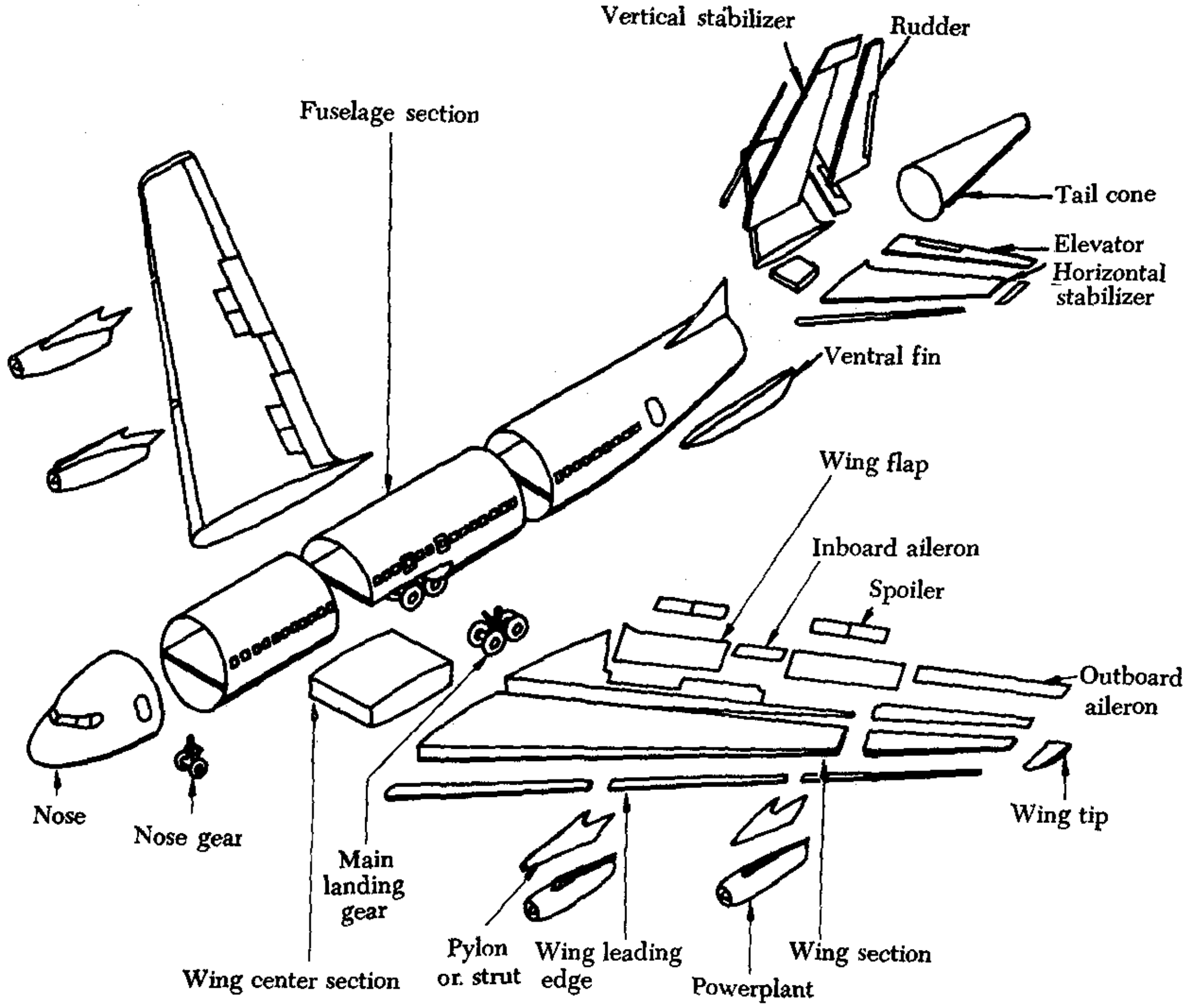


FIGURE 1–3. Typical structural components of a turbine powered aircraft.

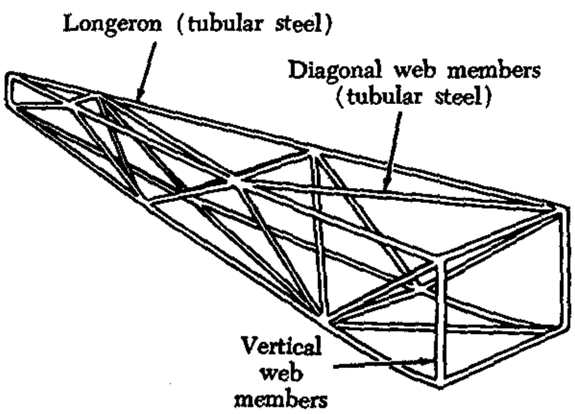


FIGURE 1–4. Warren truss of welded tubular steel.

ers. Figure 1–7 shows one form of the semi-monocoque design now in use.

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 the skin. The strong, heavy longerons hold the bulkheads and formers, and these, in turn, hold the stringers. All of these joined together form a rigid fuselage framework.

There is often little difference between some rings, frames, and formers. One manufacturer may call a brace a former, whereas another may call the same type of brace a ring or frame. Manufacturers' instructions and specifications for a specific aircraft are the best guides.

Stringers and longerons prevent tension and compression from bending the fuselage. Stringers are usually of a one-piece aluminum alloy construction, and are manufactured in a variety of shapes by casting, extrusion, or forming. Longerons, like stringers, are usually made of aluminum alloy; how-

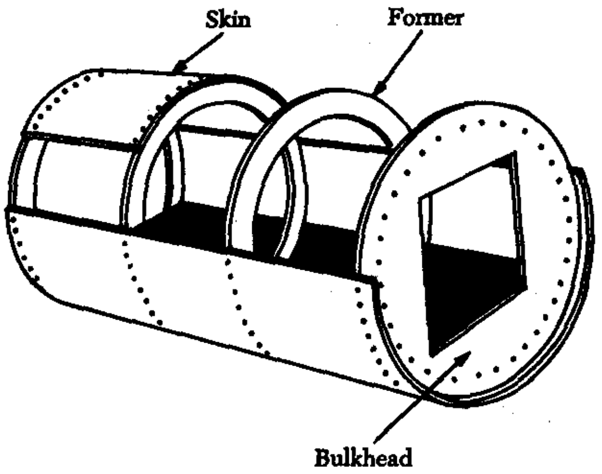


FIGURE 1–5. Monocoque construction.

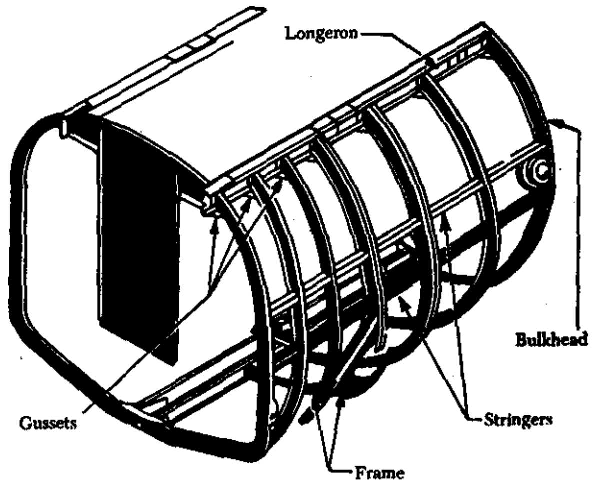


FIGURE 1–7. Fuselage structural members.

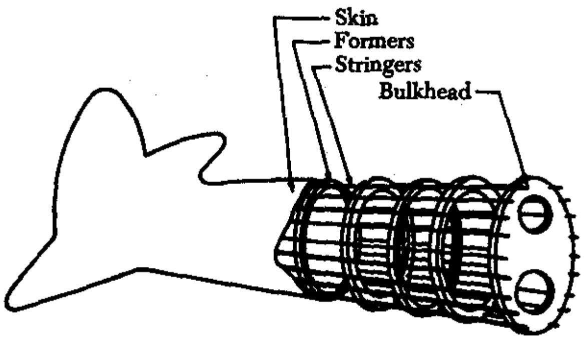


FIGURE 1–6. Semimonocoque construction.

ever, they may be of either a one-piece or a built-up construction.

By themselves, the structural members discussed do not give strength to a fuselage. They must first be joined together by such connective devices as gussets, rivets, nuts and bolts, or metal screws. A gusset (figure 1–7) is a type of connecting bracket. The bracing between longerons is often referred to as web members. They may be installed vertically or diagonally.

The metal skin or covering is riveted to the longerons, bulkheads, and other structural members and carries part of the load. The fuselage skin thickness will vary with the load carried and the stresses sustained at a particular location.

There are a number of advantages in the use of the semimonocoque fuselage. The bulkheads, frames, stringers, and longerons facilitate the design and construction of a streamlined fuselage, and add to the strength and rigidity of the structure. The main advantage, however, lies in the fact that it does not depend on a few members for strength and rigidity. This means that a semimonocoque fuselage, because of its stressed-skin construction, may withstand considerable damage and still be strong enough to hold together.

Fuselages are generally constructed in two or more sections. On small aircraft, they are generally made in two or three sections, while larger aircraft may be made up of as many as six sections.

Quick access to the accessories and other equipment carried in the fuselage is provided for by numerous access doors, inspection plates, landing wheel wells, and other openings. Servicing diagrams showing the arrangement of equipment and location of access doors are supplied by the manufacturer in the aircraft maintenance manual.

Location Numbering Systems

There are various numbering systems in use to facilitate location of specific wing frames, fuselage bulkheads, or any other structural members on an aircraft. Most manufacturers use some system of station marking; for example, the nose of the aircraft may be designated zero station, and all other stations are located at measured distances in inches behind the zero station. Thus, when a blueprint reads "fuselage frame station 137," that particular frame station can be located 137 in. behind the nose of the aircraft. A typical station diagram is shown in figure 1–8.

To locate structures to the right or left of the center line of an aircraft, many manufacturers consider the center line as a zero station for structural member location to its right or left. With such a

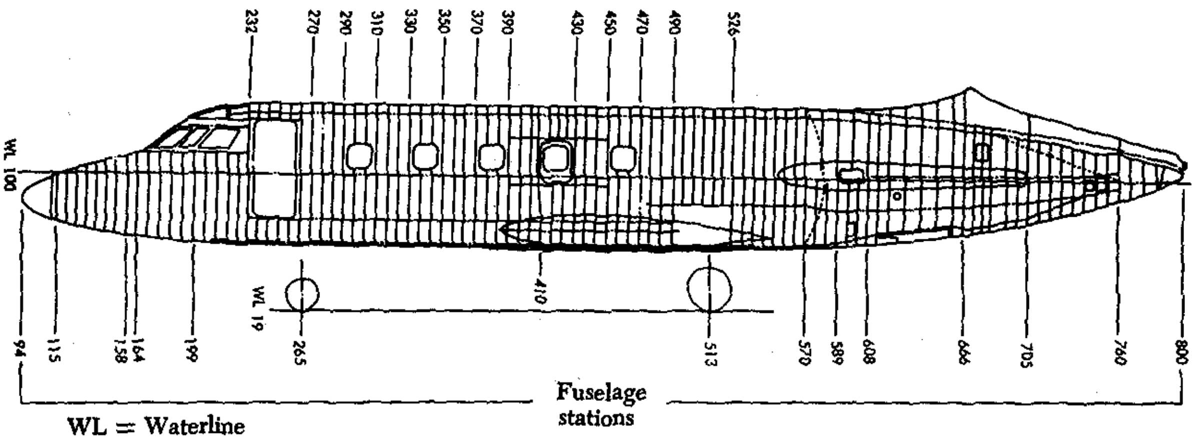


FIGURE 1–8. Fuselage stations.

system the stabilizer frames can be designated as being so many inches right or left of the aircraft center line.

The applicable manufacturer's numbering system and abbreviated designations or symbols should always be reviewed before attempting to locate a structural member. The following list includes location designations typical of those used by many manufacturers.

(1) ***Fuselage stations*** (Fus. Sta. or F.S.) are numbered in inches from a reference or zero point known as the reference datum. The reference datum is an imaginary vertical plane at or near the nose of the aircraft from which all horizontal distances are measured. The distance to a given point is measured in inches parallel to a center line extending through the aircraft from the nose through the center of the tail cone. Some manufacturers may call the fuselage station a body station, abbreviated B.S.

(2) ***Buttock line or butt line*** (B.L.) is a width measurement left or right of, and parallel to, the vertical center line.

(3) ***Water line*** (W.L.) is the measurement of height in inches perpendicular from a horizontal plane located a fixed number of inches below the bottom of the aircraft fuselage.

(4) ***Aileron station*** (A.S.) is measured outboard from, and parallel to, the inboard edge of the aileron, perpendicular to the rear beam of the wing.

(5) ***Flap station*** (F.S.) is measured perpendicular to the rear beam of the wing and parallel to, and outboard from, the inboard edge of the flap.

(6) ***Nacelle station*** (N.C. or Nac. Sta.) is measured either forward of or behind the front spar of the wing and perpendicular to a designated water line.

In addition to the location stations listed above, other measurements are used, especially on large aircraft. Thus, there may be horizontal stabilizer stations (H.S.S.), vertical stabilizer stations (V.S.S.) or powerplant stations (P.P.S.). In every case the manufacturer's terminology and station location system should be consulted before locating a point on a particular aircraft.

WING STRUCTURE

The wings of an aircraft are surfaces which are designed to produce lift when moved rapidly through the air. The particular design for any given aircraft depends on a number of factors, such as size, weight, use of the aircraft, desired speed in flight and at landing, and desired rate of climb. The wings of a fixed-wing aircraft are designated left and right, corresponding to the left and right sides of the operator when seated in the cockpit.

The wings of some aircraft are of cantilever design; that is, they are built so that no external bracing is needed. The skin is part of the wing structure and carries part of the wing stresses. Other aircraft wings use external bracings (struts, wires, etc.) to assist in supporting the wing and carrying the aerodynamic and landing loads. Both aluminum alloy and magnesium alloy are used in wing construction. The internal structure is made up of spars and stringers running spanwise, and ribs and formers running chordwise (leading edge to trailing edge). The spars are the principal structural members of the wing. The skin is attached to the internal members and may carry part of the wing stresses. During flight, applied loads which are imposed on the wing structure are primarily on the skin. From the skin they are transmitted to the ribs and from the ribs to the spars. The spars support all distributed loads as well as concentrated weights, such as fuselage, landing gear, and, on multi-engine aircraft, the nacelles or pylons.

The wing, like the fuselage, may be constructed in sections. One commonly used type is made up of a center section with outer panels and wing tips. Another arrangement may have wing stubs as an integral part of the fuselage in place of the center section.

Inspection openings and access doors are provided, usually on the lower surfaces of the wing. Drain holes are also placed in the lower surface to provide for drainage of accumulated moisture or fluids. On some aircraft built-in walkways are provided on the areas where it is safe to walk or step. On some aircraft jacking points are provided on the underside of each wing.

Various points on the wing are located by station number. Wing station 0 (zero) is located at the center line of the fuselage, and all wing stations are measured outboard from that point, in inches.

In general, wing construction is based on one of three fundamental designs: (1) Monospar, (2) multi-spar, or (3) box beam. Modifications of these basic designs may be adopted by various manufacturers.

The monospar wing incorporates only one main longitudinal member in its construction. Ribs or bulkheads supply the necessary contour or shape to the airfoil. Although the strict monospar wing is not common, this type of design, modified by the addition of false spars or light shear webs along the trailing edge as support for the control surfaces, is sometimes used.

The multi-spar wing incorporates more than one main longitudinal member in its construction. To give the wing contour, ribs or bulkheads are often included.

The box beam type of wing construction uses two main longitudinal members with connecting bulkheads to furnish additional strength and to give contour to the wing. A corrugated sheet may be

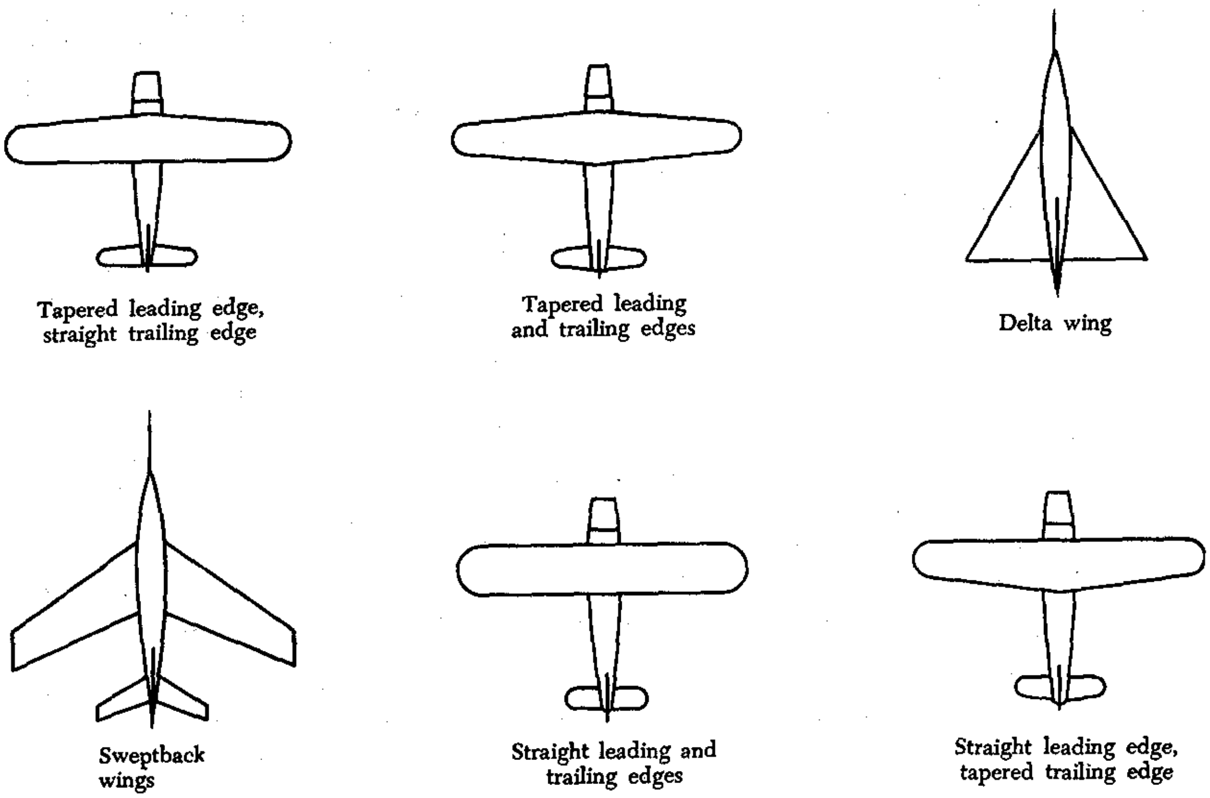


Figure 1–9. Typical wing leading and trailing edge shapes.

placed between the bulkheads and the smooth outer skin so that the wing can better carry tension and compression loads. In some cases, 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 Configurations

Depending on the desired flight characteristics, wings are built in many shapes and sizes. Figure 1-9 shows a number of typical wing leading and trailing edge shapes.

In addition to the particular configuration of the leading and trailing edges, wings are also designed to provide certain desirable flight characteristics, such as greater lift, balance, or stability. Figure 1-10 shows some common wing forms.

Features of the wing will cause other variations in its design. The wing tip may be square, rounded, or even pointed. Both the leading edge and the trailing edge of the wing may be straight or curved, or one edge may be straight and the other curved. In addition, one or both edges may be tapered so that the wing is narrower at the tip than at the root where it joins the fuselage. Many types of modern aircraft employ sweptback wings (figure 1-9).

Wing Spars

The main structural parts of a wing are the spars, the ribs or bulkheads, and the stringers or stiffeners, as shown in figure 1-11.

Spars are the principal structural members of the wing. They correspond to the longerons of the fuselage. They run parallel to the lateral axis, or toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss system.

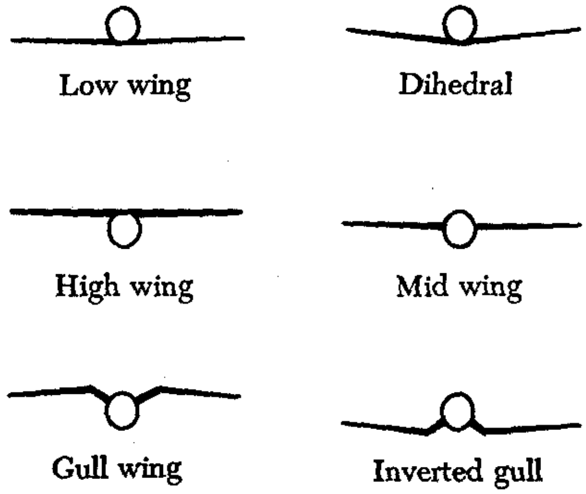


FIGURE 1-10. Common wing forms.

Wooden spars can be generally classified into four different types by their cross sectional configuration. As shown in figure 1-12, they may be partly hollow, in the shape of a box, solid or laminated, rectangular in shape, or in the form of an I-beam.

Spars may be made of metal or wood depending on the design criteria of a specific aircraft. Most aircraft recently manufactured use spars of solid extruded aluminum or short aluminum extrusions riveted together to form a spar.

The shape of most wooden spars is usually similar to one of the shapes shown in figure 1-12. The rectangular form, figure 1-12A, can be either solid or laminated. Figure 1-12B is an I-beam spar that has been externally routed on both sides to reduce weight while retaining adequate strength. A box spar, figure 1-12C, is built up from plywood and solid spruce. The I-beam spar, figure 1-12D, may be built up of wood or manufac-

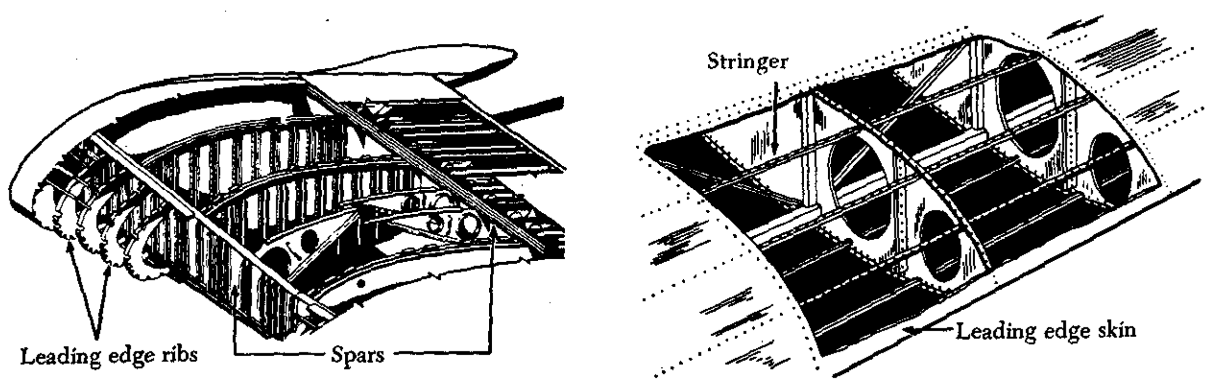


FIGURE 1-11. Internal wing construction.

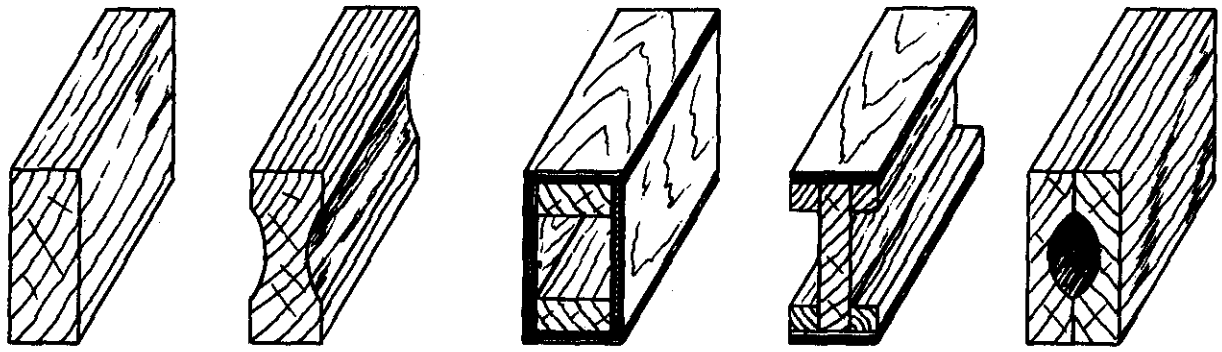


FIGURE 1–12. Typical spar cross sectional configurations.

tured by an aluminum extrusion process. The I-beam construction for a spar usually consists of a web (a deep wall plate) and cap strips, which are extrusions or formed angles. The web forms the principal depth portion of the spar. Cap strips are extrusions, formed angles, or milled sections to which the web is attached. These members carry the loads caused by the wing bending and also provide a foundation for attaching the skin. An example of a hollow or internally routed spar is represented in figure 1–12E.

Figure 1–13 shows the basic configuration of some typical metal spars. Most metal spars are built up from extruded aluminum alloy sections, with riveted aluminum alloy web sections to provide extra strength.

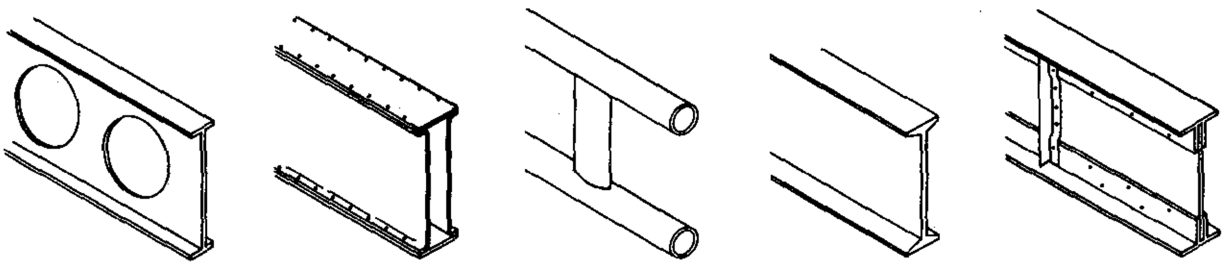


FIGURE 1–13. Metal spar shapes.

Although the spar shapes of figure 1–13 are typical of most basic shapes, the actual spar configuration may assume many forms. For example, a spar may have either a plate or truss type web. The plate web (figure 1–14) consists of a solid plate with vertical stiffeners which increase the strength of the web. Some spar plate webs are constructed differently. Some have no stiffeners; others contain flanged holes for reducing weight. Figure 1–15 shows a truss spar made up of an upper cap, a lower cap, and connecting vertical and diagonal tubes.

A structure may be designed so as to be considered "fail-safe." In other words, should one member of a complex structure fail, some other member would assume the load of the failed member.

A spar with "fail-safe" construction is shown in figure 1–16. This spar is made in two sections. The top section consists of a cap, riveted to the upper web plate. The lower section is a single extrusion, consisting of the lower cap and web plate. These two sections are spliced together to form the spar. If either section of this type of spar breaks, the other section can still carry the load, which is the "fail-safe" feature.

As a rule, a wing has two spars. One spar is usually located near the front of the wing, and the other about two-thirds of the distance toward the wing's trailing edge. Regardless of type, the spar is the most important part of the wing. When other structural members of the wing are placed under load, they pass most of the resulting stress on to the wing spars.

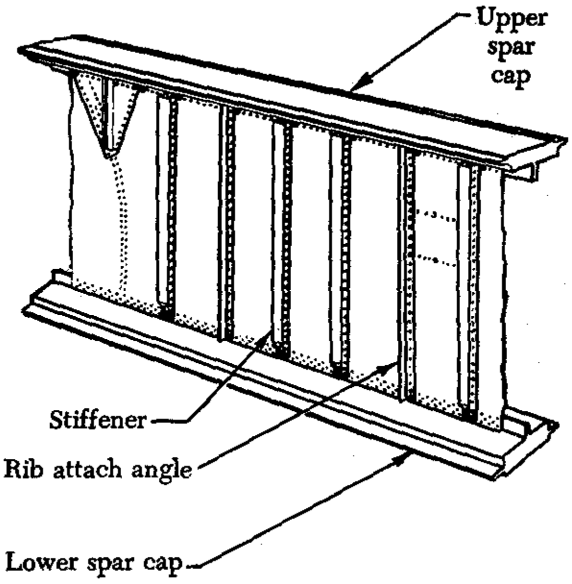


FIGURE 1–14. Plate web wing spar.

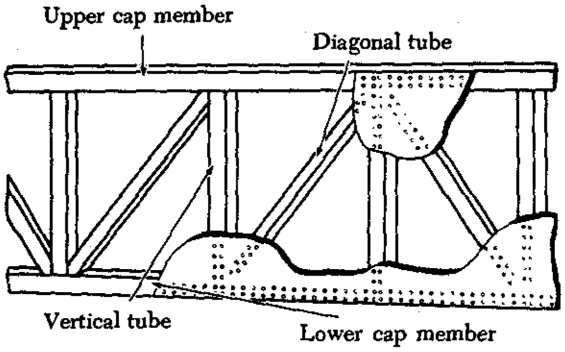


FIGURE 1–15. Truss wing spar.

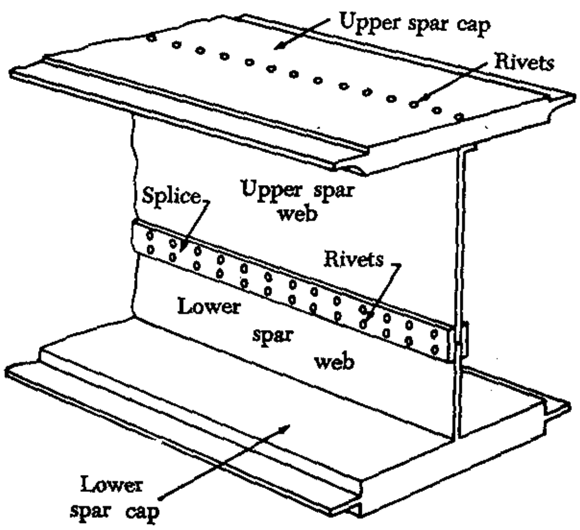


FIGURE 1–16. Wing spar with "fail-safe" construction.

Wing Ribs

Ribs are the structural crosspieces that make up the framework of the wing. They usually extend from the wing leading edge to the rear spar or to the trailing edge of the wing. The ribs give the wing its cambered shape and transmit the load from the skin and stringers to the spars. Ribs are also used in ailerons, elevators, rudders, and stabilizers.

Ribs are manufactured from wood or metal. Either wood or metal ribs are used with wooden spars while metal ribs are usually used with metal spars. Some typical wooden ribs, usually manufactured from spruce, are shown in figure 1–17.

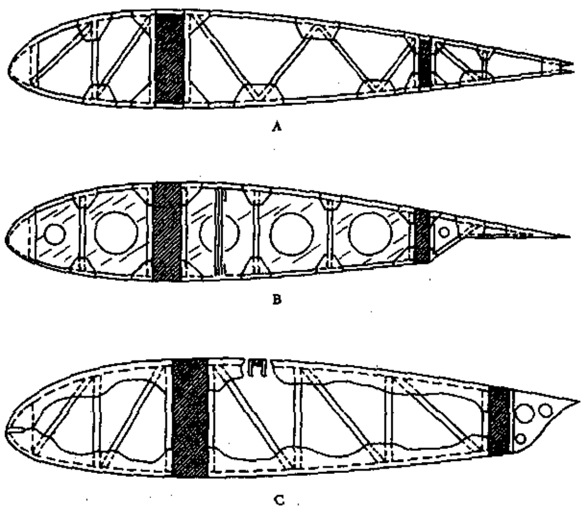


FIGURE 1–17. Typical wooden ribs.

The most common types of wooden ribs are the plywood web, the lightened plywood web, and the truss types. Of these three types, the truss type is the most efficient, but it lacks the simplicity of the other types.

The wing rib shown in Figure 1–17A is a truss type, with plywood gussets on both sides of the rib and a continuous rib cap around the entire rib. Rib caps, often called cap strips, are usually made of the same material as the rib itself, especially when using wooden ribs. They stiffen and strengthen the rib and provide an attaching surface for the rib covering.

A lightened plywood web rib is illustrated in figure 1–17B. On this type the cap strip may be laminated, especially at the leading edge. Figure 1–17C shows a rib using a continuous gusset, which provides extra support throughout the entire rib with very little additional weight.

A continuous gusset stiffens cap strips in the plane of the rib. This aids in preventing buckling and helps to obtain better rib/skin glue joints where nail-gluing is used because such a rib can resist the driving force of nails better than the other types. Continuous gussets are more easily handled than the many small separate gussets otherwise required.

Figure 1–18 shows the basic rib and spar structure of a wooden wing frame, together with some of the other wing structural members. In addition to the front and rear spars, an aileron spar, or false spar, is shown in figure 1–18. This type of spar extends only part of the spanwise length of the wing and provides a hinge attachment point for the aileron.

Various types of ribs are also illustrated in figure 1–18. In addition to the wing rib, sometimes called "plain rib" or even "main rib," nose ribs and the butt rib are shown. A nose rib is also called a false rib, since it usually extends from the wing leading edge to the front spar or slightly beyond. The nose ribs give the wing leading edge area the necessary curvature and support. The wing rib, or plain rib, extends from the leading edge of the wing to the rear spar and in some cases to the trailing edge of the wing. The wing butt rib is normally the heavily stressed rib section at the inboard end of the wing near the attachment point to the fuselage. Depending on its location and method of attachment, a butt rib may be called a bulkhead rib or a compression rib, if it is designed to receive compression loads that tend to force the wing spars together.

Since the ribs are laterally weak, they are strengthened in some wings by tapes that are woven above and below rib sections to prevent sidewise bending of the ribs.

Drag and antidrag wires (figure 1–18) are crisscrossed between the spars to form a truss to resist forces acting on the wing in the direction of the wing chord. These tension wires are also referred to as tie rods. The wire designed to resist the backward forces is called a drag wire; the antidrag wire resists the forward forces in the chord direction.

The wing attachment fittings, shown in figure 1–18, provide a means of attaching the wing to the aircraft fuselage.

The wing tip is often a removable unit, bolted to the outboard end of the wing panel. One reason for this is the vulnerability of the wing tips to damage, especially during ground handling and taxiing.

Figure 1–19 shows a removable wing tip for a large aircraft wing. The wing-tip assembly is of aluminum alloy construction. The wing-tip cap is secured to the tip with countersunk screws and is

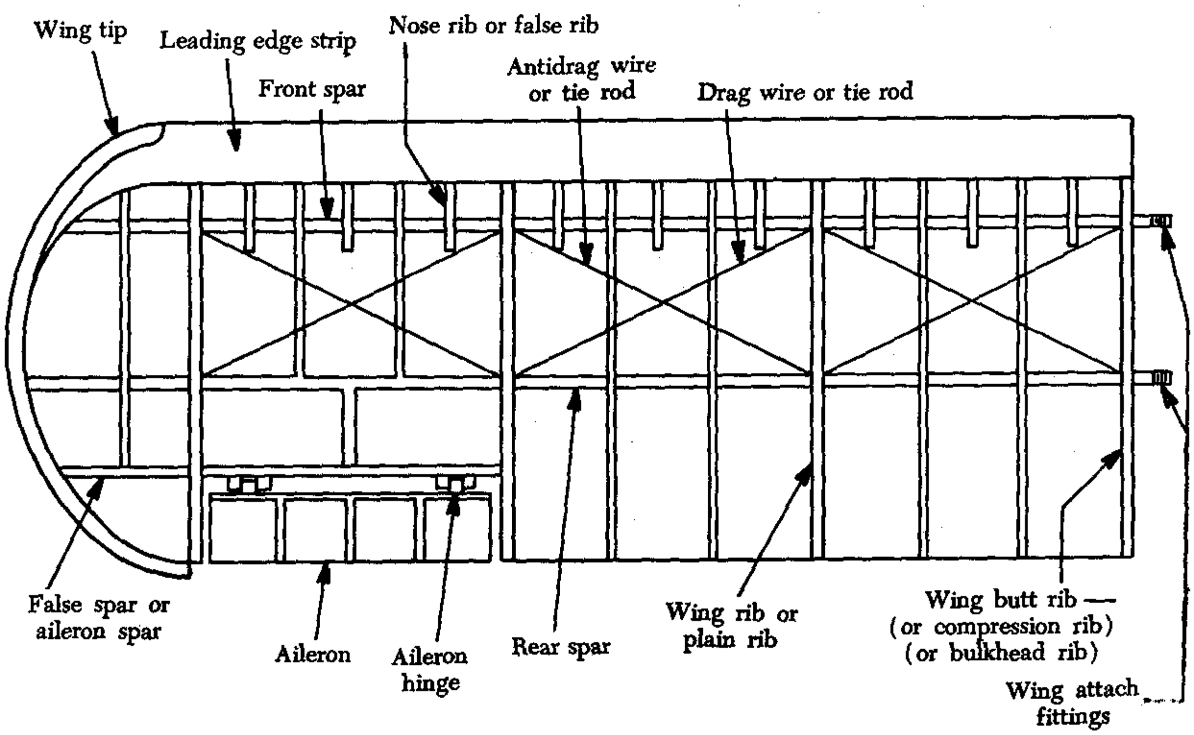


FIGURE 1–18. Basic rib and spar structure.

secured to the interspar structure at four points with 1/4-in. bolts. The tip leading edge contains the heat anti-icing duct. Wing-heated air is exhausted through a louver on the top surface of the tip. Wing position lights are located at the center of the tip and are not directly visible from the cockpit. As an indication that the wing tip light is operating, some wing tips are equipped with a lucite rod to transmit the light to the leading edge.

Figure 1–20 shows a cross sectional view of an

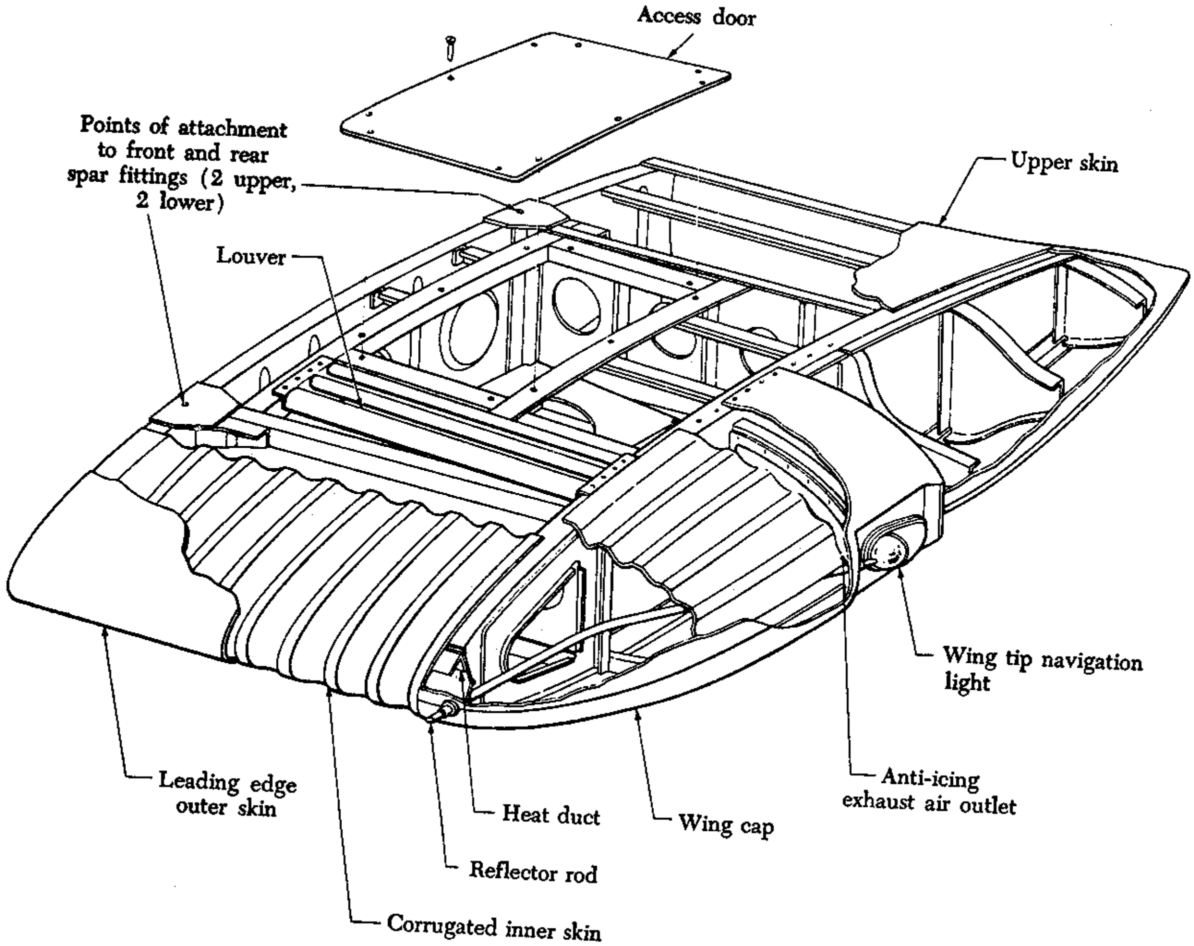


FIGURE 1–19. Removable wing tip.

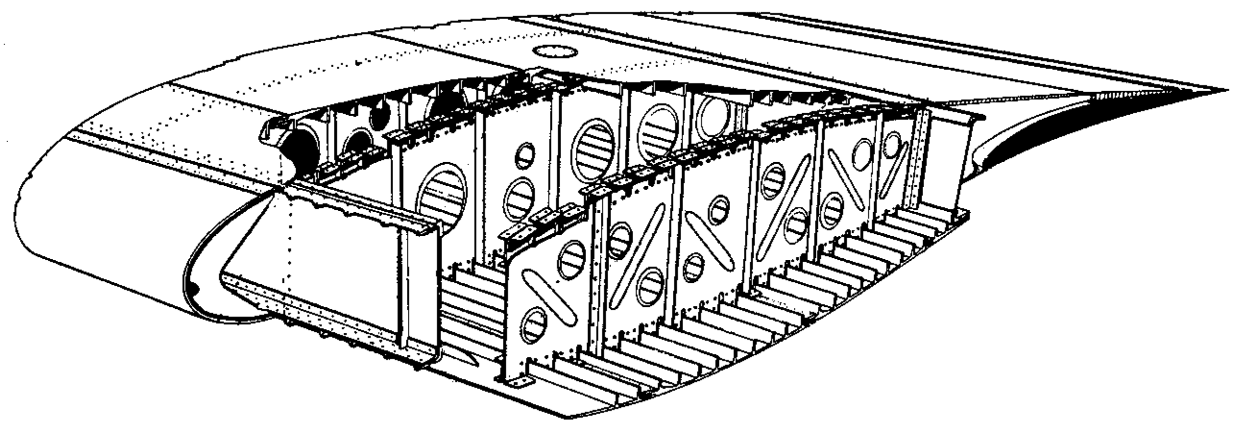


FIGURE 1–20. All-metal wing with chemically milled channels.

all-metal full cantilever (no external bracing) wing section. The wing is made up of spars, ribs, and lower and upper wing skin covering. With few exceptions, wings of this type are of the stressed-skin design (the skin is part of the wing structure and carries part of the wing stresses).

The top and bottom wing skin covers are made up of several integrally stiffened sections. This type of wing construction permits the installation of bladder-type fuel cells in the wings or is sealed to hold fuel without the usual fuel cells or tanks. A wing which is constructed to allow it to be used as a fuel cell or tank is referred to as a "wet-wing."

A wing that uses a box-beam design is shown in figure 1–21. This type of construction not only increases strength and reduces weight, but it also enables the wing to serve as a fuel tank when properly sealed.

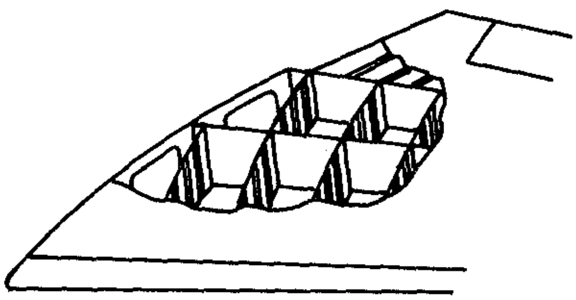


FIGURE 1–21. Box-beam milled wing.

Both aluminum honeycomb and fiber glass honeycomb sandwich material are commonly used in the construction of wing and stabilizer surfaces, bulkheads, floors, control surfaces, and trim tabs. Aluminum honeycomb material is made of aluminum foil honeycomb core, bonded between sheets of aluminum. Fiber glass honeycomb material consists of fiber glass honeycomb core bonded between layers of fiber glass cloth.

In the construction of large aircraft structures, and in some small aircraft as well, the honeycomb sandwich structure employs either aluminum or reinforced plastic materials. Honeycomb panels are usually a lightweight cellular core sandwiched between two thin skins or facing materials such as aluminum, wood, or plastic.

Aircraft honeycomb material is manufactured in various shapes, but is usually of the constant thickness or tapered core types. An example of each is shown in figure 1–22.

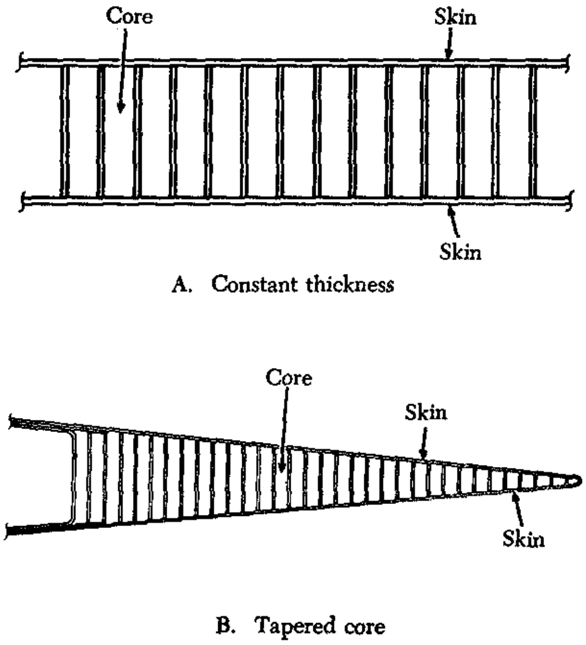


FIGURE 1–22. Constant-thickness and tapered-core honeycomb sections.

Figure 1–23 shows a view of the upper surface of a large jet transport wing. The various panels manufactured from honeycomb material are outlined by diagonal lines and labeled.

Still another type of construction is illustrated in figure 1–24. In this case the sandwich structure of the wing leading edge is bonded to the metal spar. Also shown is the integrally bonded deicer panel.

NACELLES OR PODS

Nacelles or pods are streamlined enclosures used on multi-engine aircraft primarily to house the engines. They are round or spherical in shape and are usually located above, below, or at the leading edge of the wing on multi-engine aircraft. If an aircraft has only one engine, it is usually mounted at the forward end of the fuselage, and the nacelle is the streamlined extension of the fuselage.

An engine nacelle or pod consists of skin, cowling, structural members, a firewall, and engine mounts. Skin and cowling cover the outside of the nacelle. Both are usually made of sheet aluminum alloy, stainless steel, magnesium, or titanium. Regardless of the material used, the skin is usually attached to the framework by rivets.

The framework usually consists of structural members similar to those of the fuselage. The framework includes lengthwise members, such as

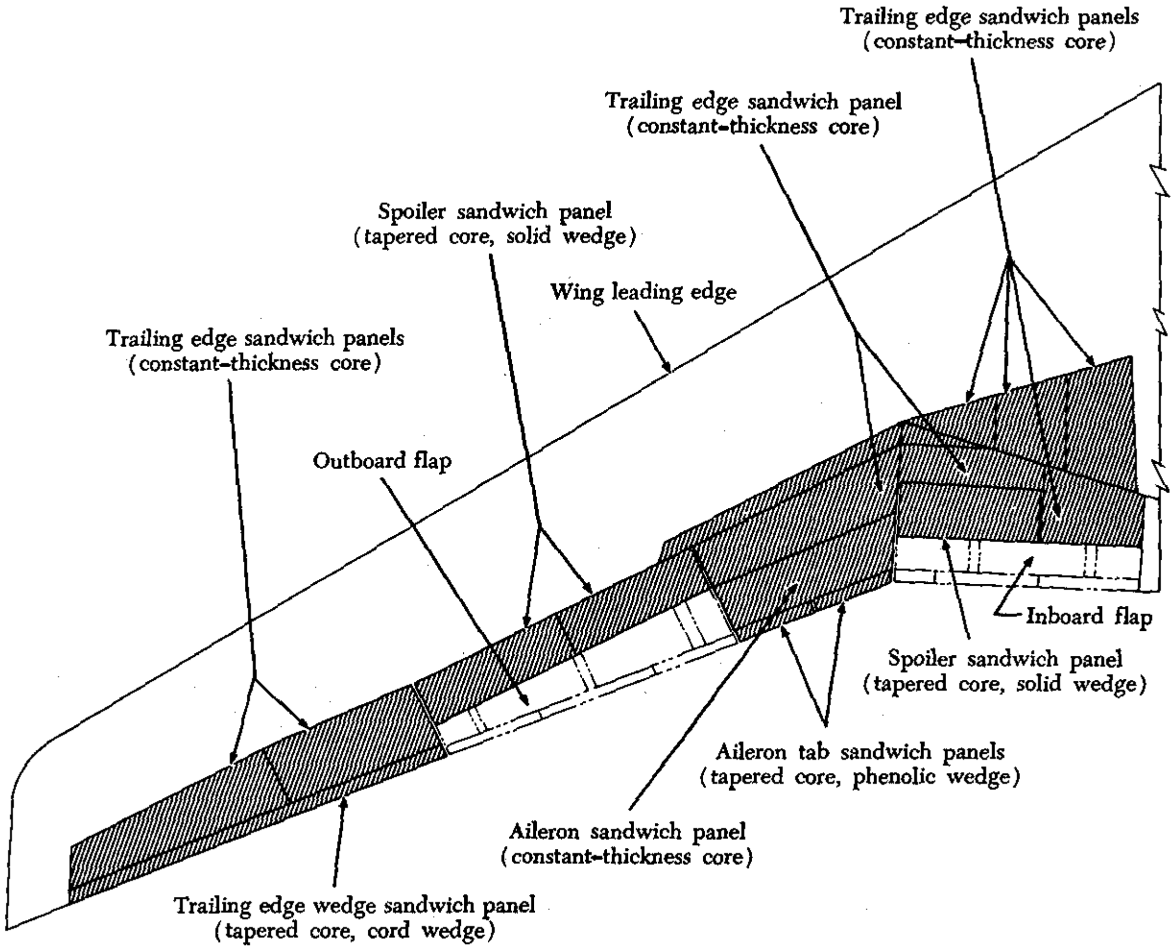


FIGURE 1–23. Honeycomb wing construction on a large jet transport aircraft.

longerons and stringers, and widthwise/vertical members, such as bulkheads, rings, and formers.

A nacelle or pod also contains a firewall which separates the engine compartment from the rest of the aircraft. This bulkhead is usually made of stainless steel sheet metal, or as in some aircraft, of titanium.

Another nacelle or pod member is the engine mount. The mount is usually attached to the firewall, and the engine is attached to the mount by nuts, bolts, and vibration-absorbing rubber cushions or pads. Figure 1–25 shows examples of a semimonocoque and a welded tubular steel engine mount used with reciprocating engines.

Engine mounts are designed to meet particular conditions of installation, such as the location and the method of attachment of the engine mount and the size, type, and characteristics of the engine it is intended to support. An engine mount is usually constructed as a single unit which can be detached quickly and easily from the remaining structure. Engine mounts are commonly made of welded chrome/molybdenum steel tubing, and forgings of chrome/nickel/molybdenum are used for the highly stressed fittings.

To reduce wind resistance during flight, the landing gear of most high-speed or large aircraft is retracted (drawn up into streamlined enclosures). The part of the aircraft which receives or encloses the landing gear as it retracts is called a wheel well. In many instances, the wheel well is part of the nacelle; however, on some aircraft the landing gear retracts into the fuselage or wing.

Cowling

Cowling usually refers to the detachable covering of those areas into which access must be gained regularly, such as engines, accessory sections, and engine mount or firewall areas. Figure 1–26 shows an exploded view of the pieces of cowling for a horizontally opposed engine on a light aircraft.

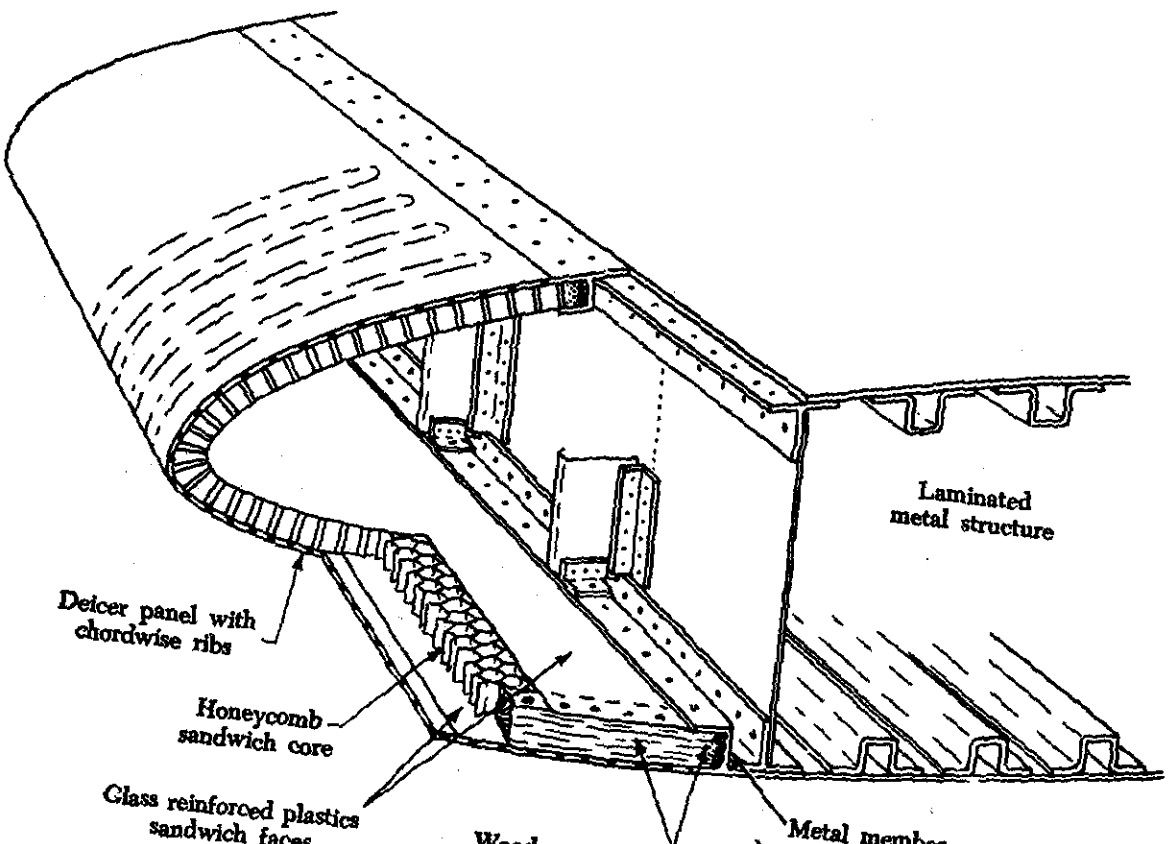


FIGURE 1–24. Leading edge sandwich material bonded to metal wing member.

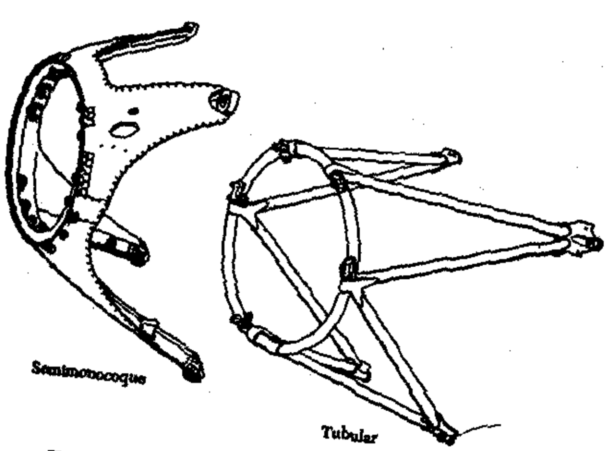


FIGURE 1–25. Semimonocoque and welded tubular steel engine mounts.

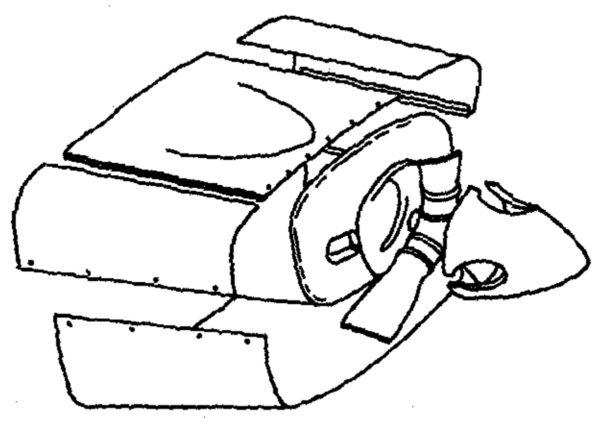


FIGURE 1–26. Cowling for horizontally opposed engine.

Some large reciprocating engines are enclosed by "orange-peel" cowl panels. The cowl panels are attached to the firewall by mounts which also serve as hinges when the cowl is opened (figure 1–27).

The lower cowl mounts are secured to the hinge brackets by pins which automatically lock in place, but can be removed by simply pulling on a ring. The side panels are held open by short rods; the top panel is held open by a longer rod, and the lower panel is restrained in the "open" position by a spring and cable.

All four panels are locked in the "closed" position by over-center steel latches, which are secured

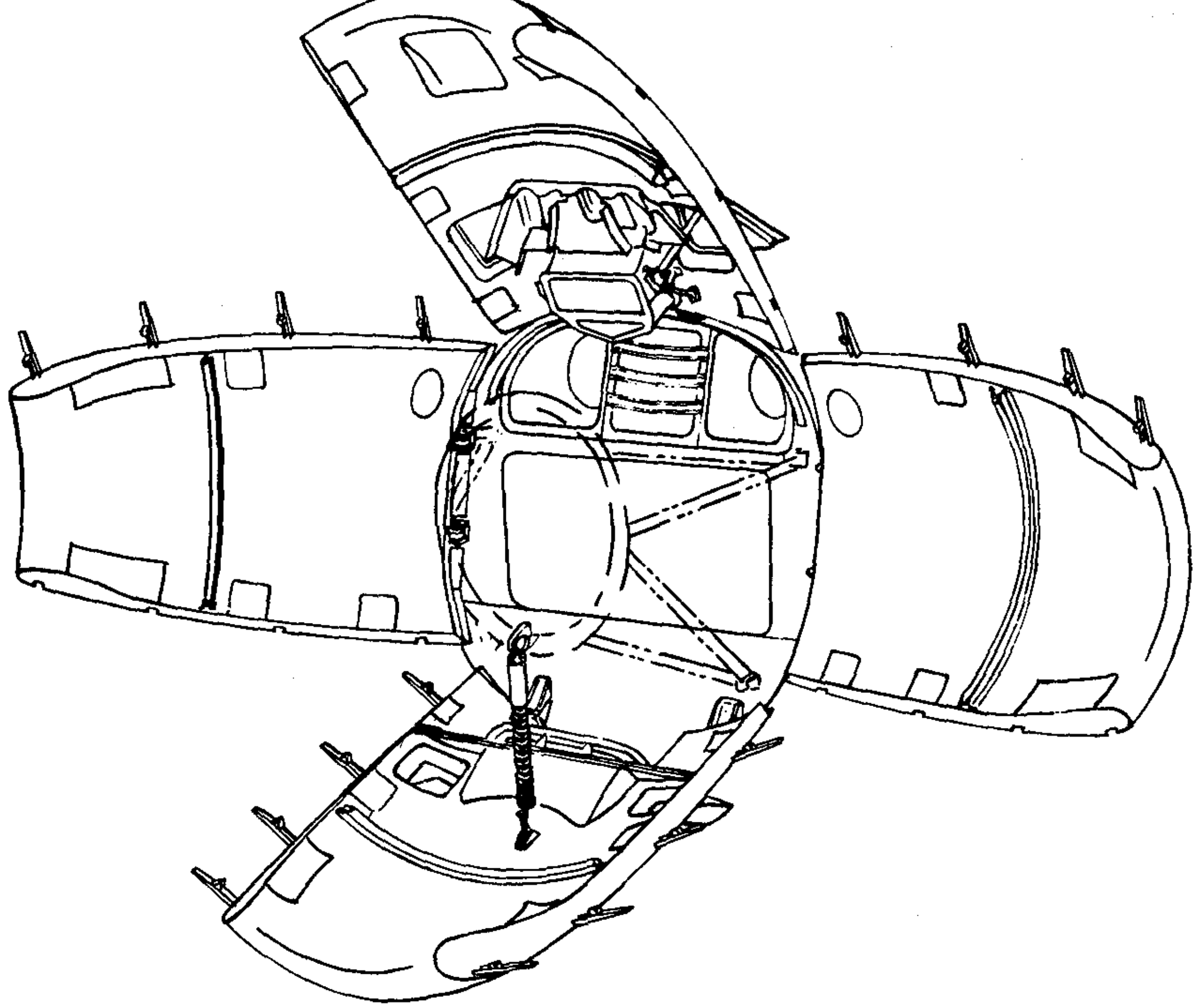


FIGURE 1-27. "Orange-peel" cowling opened.

in the closed position by spring-loaded safety catches. Cowl panels are generally of aluminum alloy construction; however, stainless steel is generally used as the inner skin aft of the power section, for cowl flaps and near the cowl flap openings, and for oil cooler ducts.

On turbojet engine installations, cowl panels are designed to provide a smooth airflow over the engines and to protect the engine from damage. The entire engine cowling system includes a nose cowl, upper and lower hinged removable cowl panels, and fixed cowl panel. Typical upper and lower hinged removable panels are shown in figure 1-28.

EMPENNAGE

The empennage is also called the tail section and most aircraft designs consist of a tail cone, fixed surfaces, and movable surfaces.

The tail cone serves to close and streamline the aft end of most fuselages. The cone is made up of structural members (figure 1-29) like those of the fuselage; however, cones are usually of lighter construction since they receive less stress than the fuselage.

Other components of the typical empennage are of heavier construction than the tail cone. These members include fixed surfaces that help steady the aircraft and movable surfaces that help to direct an aircraft's flight. The fixed surfaces are the horizontal and vertical stabilizers. The movable surfaces are usually a rudder and elevators.

Figure 1-30 shows how the vertical surfaces are braced, using spars, ribs, stringers, and skin in a similar manner to the systems used in a wing.

Stress in an empennage is also carried like stress

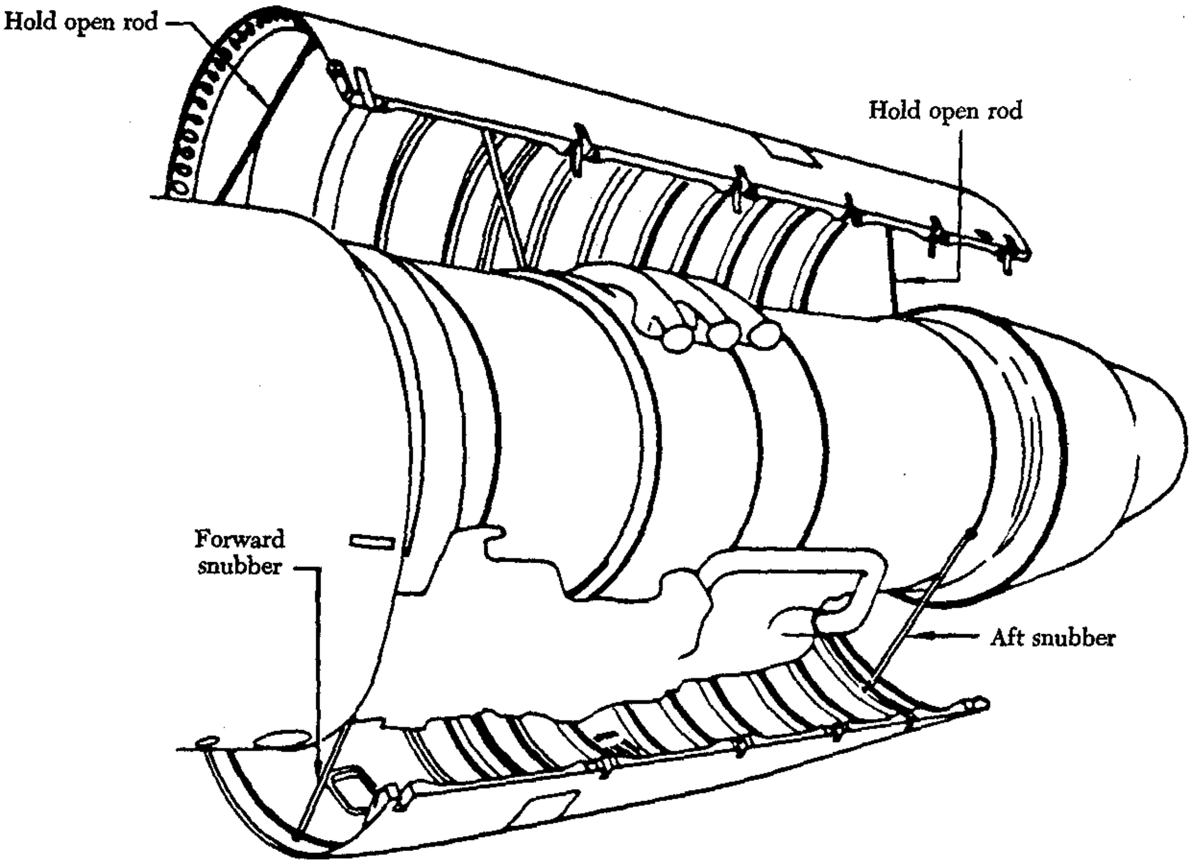


FIGURE 1–28. Side-mounted turbojet engine cowling.

in a wing. Bending, torsion, and shear, created by airloads, pass from one structural member to another. Each member absorbs some of the stress and passes the remainder to other members. The overload of stress eventually reaches the spars, which transmit it to the fuselage structure.

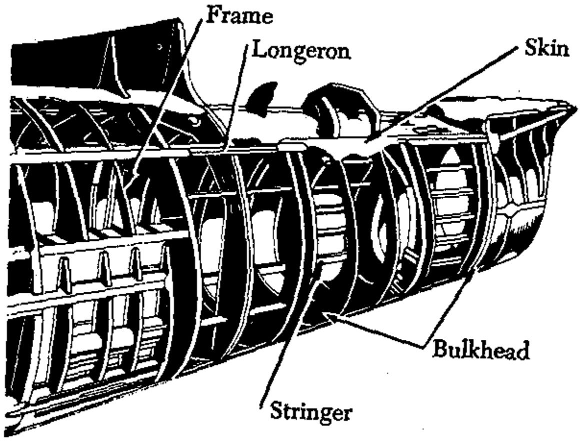


FIGURE 1–29. The fuselage terminates in a tail cone.

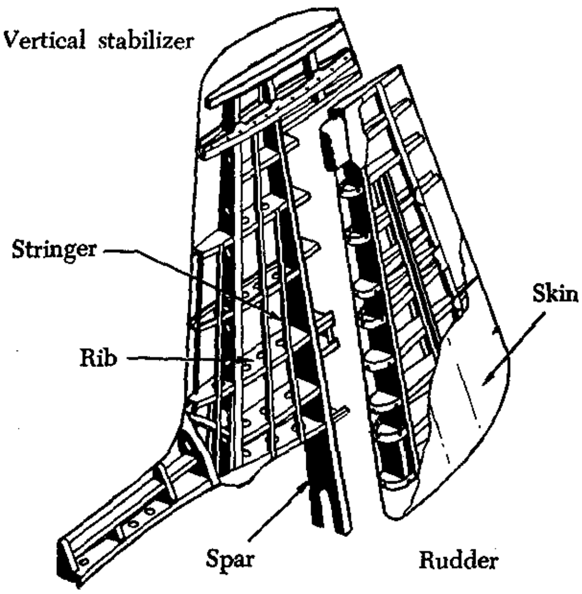


FIGURE 1–30. Construction features of rudder and vertical stabilizer.

FLIGHT CONTROL SURFACES

The directional control of a fixed-wing aircraft takes place around the lateral, longitudinal, and vertical axes by means of flight control surfaces. These control devices are hinged or movable surfaces through which the attitude of an aircraft is controlled during takeoff, flight, and landing. They are usually divided into two major groups, the primary or main, and the auxiliary control surfaces.

The primary group of flight control surfaces consists of ailerons, elevators, and rudders. Ailerons are attached to the trailing edge of both wings of an aircraft. Elevators are attached to the trailing edge of the horizontal stabilizer. The rudder is hinged to the trailing edge of the vertical stabilizer.

Primary control surfaces are similar in construction and vary only in size, shape, and methods of attachment. In construction, control surfaces are similar to the all-metal wing. They are usually made of an aluminum alloy structure built around a single spar member or torque tube. Ribs are fitted to the spar at the leading and trailing edges and are joined together with a metal strip. The ribs, in many cases, are formed from flat sheet stock. They are seldom solid; more often, the formed, stamped-out ribs are reduced in weight by holes which are punched in the metal.

The control surfaces of some aircraft are fabric covered. However, all turbojet powered aircraft have metal-covered surfaces for additional strength.

The control surfaces previously described can be considered conventional, but on some aircraft, a control surface may serve a dual purpose. For example, one set of control surfaces, the elevons, combines the functions of both ailerons and elevators. Flaperons are ailerons which can also act as flaps. A movable horizontal tail section is a control surface which supplies the action of both the horizontal stabilizer and the elevators.

The secondary or auxiliary group of control surfaces consists of such members as trim tabs, balance tabs, servo tabs, flaps, spoilers, and leading edge devices. Their purpose is to reduce the force required to actuate the primary controls, to trim and balance the aircraft in flight, to reduce landing speed or shorten the length of the landing roll, and to change the speed of the aircraft in flight. They are usually attached to, or recessed in, the main control surfaces.

Ailerons

Ailerons are primary control surfaces which make up part of the total wing area. They are movable through a pre-designed arc and are usually hinged to the aileron spar or rear wing spar. The ailerons are operated by a lateral (side-to-side) movement of the aircraft control stick, or a turning motion of the wheel on the yoke.

In a conventional configuration, one aileron is hinged to the outboard trailing edge of each wing. Figure 1–31 shows the shape and location of typical small-aircraft ailerons on various wing-tip designs.

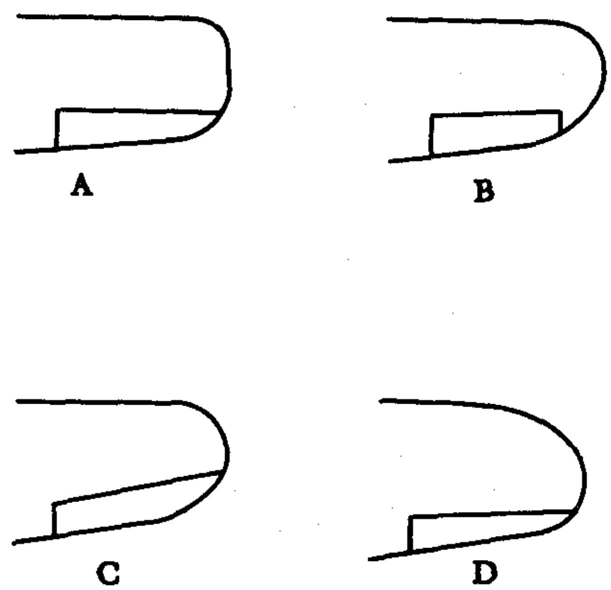


FIGURE 1–31. Aileron location on various wing-tip designs.

The ailerons are interconnected in the control system to operate simultaneously in opposite directions. As one aileron moves downward to increase lift on its side of the fuselage, the aileron on the opposite side of the fuselage moves upward to decrease lift on its side. This opposing action results in more lift being produced by the wing on one side of the fuselage than on the other, resulting in a controlled movement or roll due to unequal aerodynamic forces on the wings.

An end view of a typical metal rib in an aileron is shown in figure 1–32. The hinge point of this type of aileron is behind the leading edge of the aileron to provide a more sensitive response to control movements. The horns attached to the aileron spar are levers to which the aileron control cables are secured.

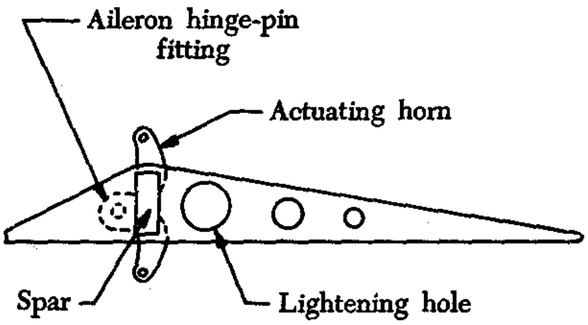


FIGURE 1–32. End view of aileron rib.

Large aircraft may use all-metal ailerons, except for fiber glass trailing edges, hinged to the rear wing spar in at least four places. Figure 1–33 shows several examples of aileron installation.

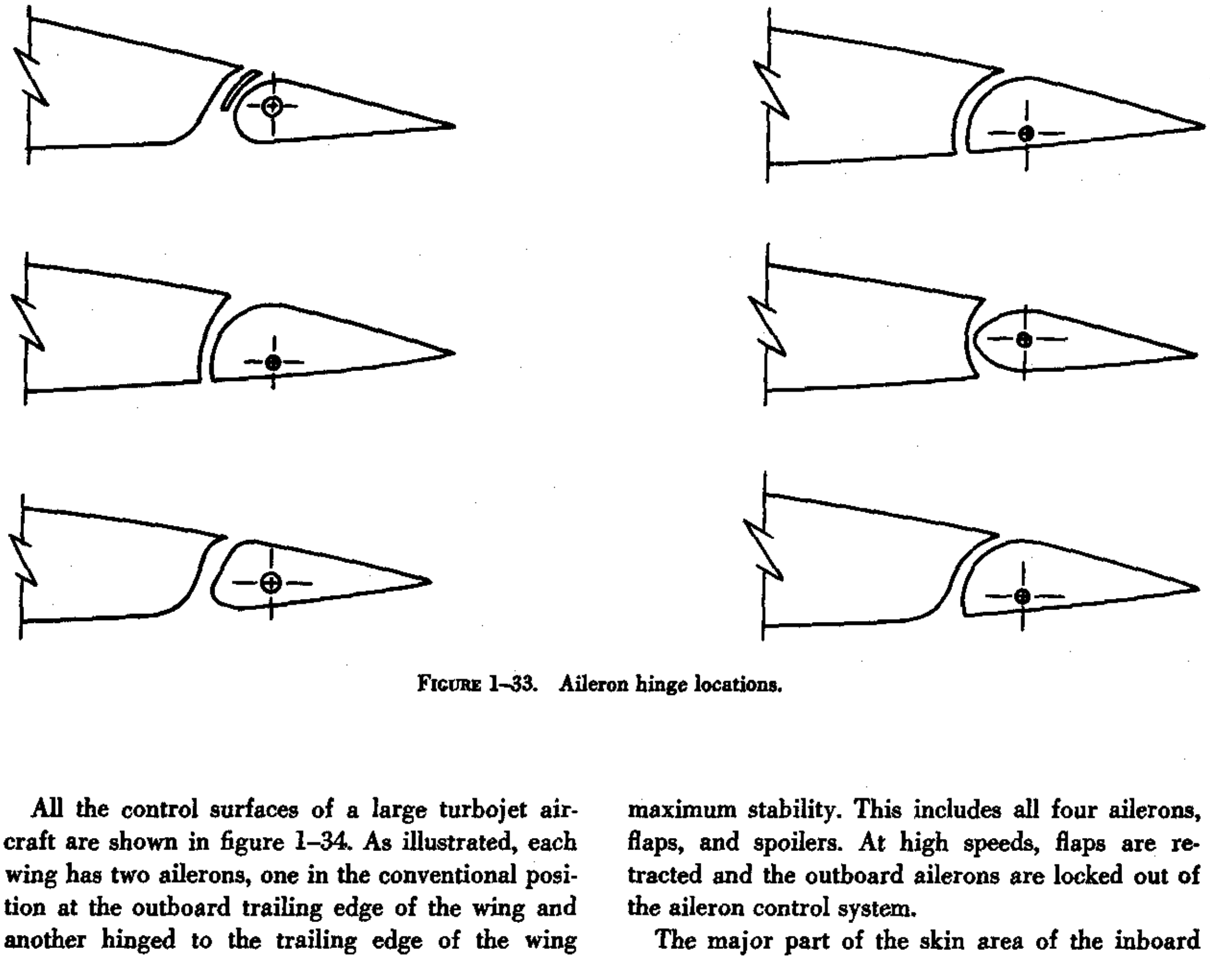


FIGURE 1–33. Aileron hinge locations.

All the control surfaces of a large turbojet aircraft are shown in figure 1–34. As illustrated, each wing has two ailerons, one in the conventional position at the outboard trailing edge of the wing and another hinged to the trailing edge of the wing center section.

The complex lateral control system in large turbojet aircraft is far more sophisticated than the type employed in a light airplane. During low-speed flight all lateral control surfaces operate to provide maximum stability. This includes all four ailerons, flaps, and spoilers. At high speeds, flaps are retracted and the outboard ailerons are locked out of the aileron control system.

The major part of the skin area of the inboard ailerons is aluminum honeycomb panels. Exposed honeycomb edges are covered with sealant and protective finish. The aileron nose tapers and extends forward of the aileron hinge line. Each inboard aileron is positioned between the inboard and out-

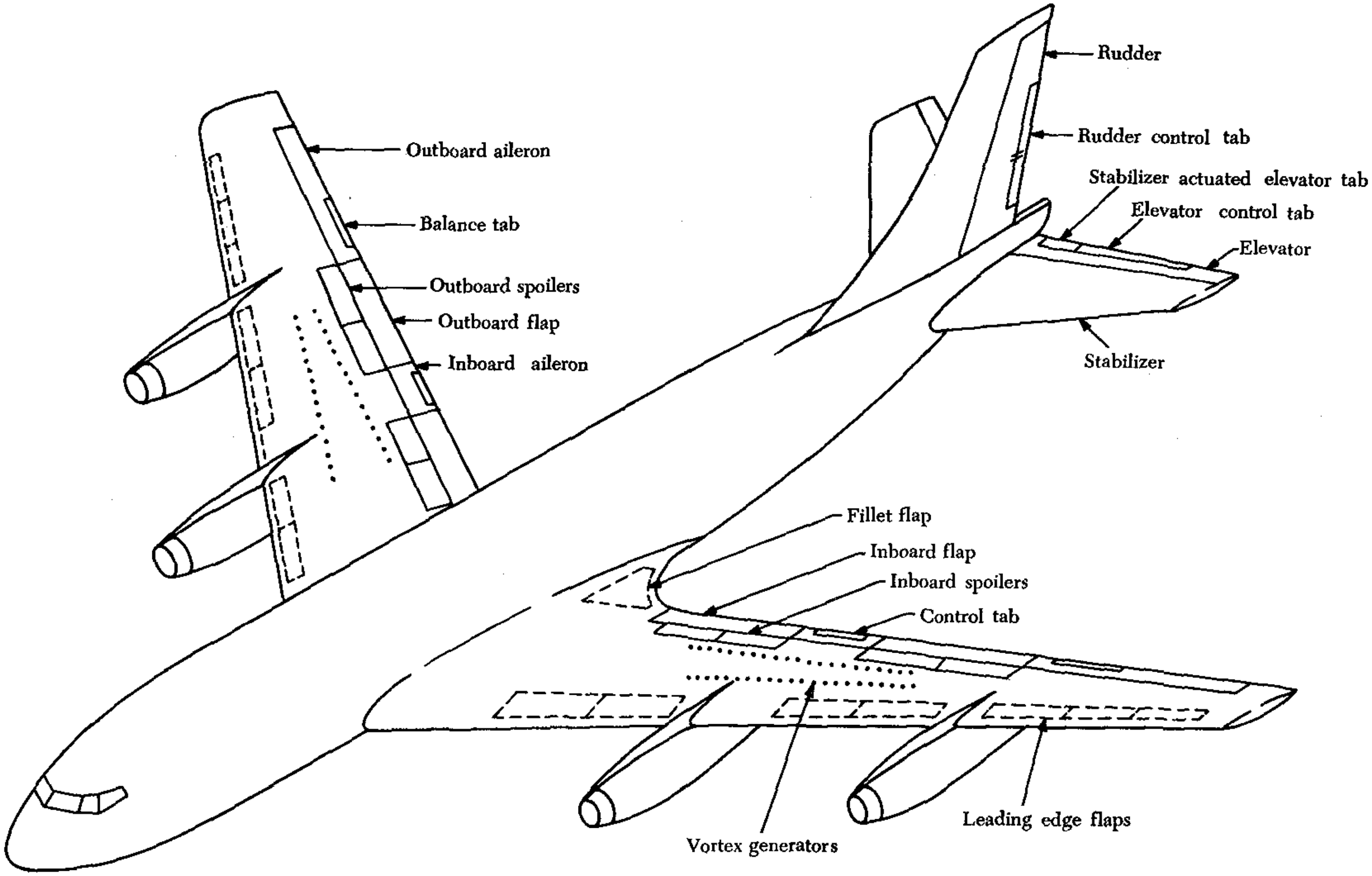


FIGURE 1–34. Control surfaces on a large turbojet aircraft.

board flaps at the trailing edge of the wing. The aileron hinge supports extend aft and are attached to aileron hinge bearings to support the aileron.

The outboard ailerons are made up of a nose spar and ribs covered with aluminum honeycomb panels. A continuous hinge attached to the forward edge of the nose is grooved to mate with the hem of a fabric seal.

The outboard ailerons are located in the trailing edge of each outboard wing section. Hinge supports extend aft from the wing and are attached to the aileron hinge bearing to support the aileron. The nose of the aileron extends into a balance chamber in the wing and is attached to balance panels.

Aileron balance panels (figure 1–35) reduce the force necessary to position and hold the ailerons. The balance panels may be made of aluminum honeycomb skin bonded to an aluminum frame, or of aluminum skin-covered assemblies with hat-section stiffeners. Clearance between the aileron nose and wing structure provides a controlled airflow area necessary for balance panel action. Seals attached to the panels control air leakage.

Air loads on the balance panels (figure 1–35) depend on aileron position. When the ailerons are moved during flight to either side of the streamline position, differential pressure is created across the balance panels. This differential pressure acts on the balance panels in a direction that assists aileron movement. Full balance panel force is not required for small angles of aileron displacement because the manual force necessary to rotate the control tab through small angles is slight. A controlled air bleed is progressively decreased as the aileron displacement angle is increased. This action increases the differential air pressure on the balance panels as

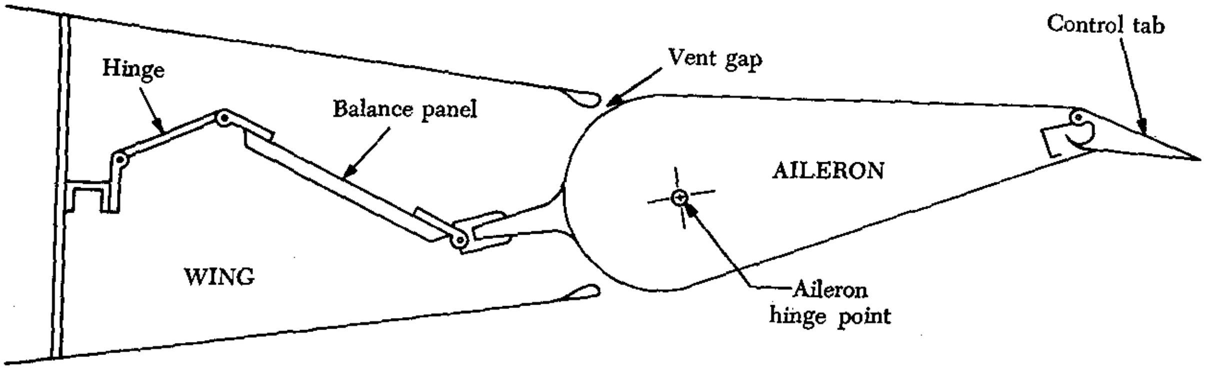


FIGURE 1–35. Aileron balance panel.

the ailerons rotate from the streamline position. The increasing load on the balance panel counteracts the increasing load on the ailerons.

Auxiliary Wing Flight Surfaces

The ailerons are the primary wing flight surfaces. Auxiliary wing flight surfaces include trailing edge flaps, leading edge flaps, speed brakes, spoilers, and leading edge slats. The number and type of auxiliary wing flap surfaces on an aircraft vary widely, depending on the type and size of aircraft.

Wing flaps are used to give the aircraft extra lift. They reduce the landing speed, thereby shortening the length of the landing rollout to facilitate landing in small or obstructed areas by permitting the gliding angle to be increased without greatly increasing the approach speed. In addition, the use of flaps during takeoff reduces the length of the takeoff run.

Most flaps are hinged to the lower trailing edges of the wings, inboard of the ailerons. Leading edge flaps are also used, principally on large high-speed aircraft. When they are in the "up" (or retracted) position, they fair in with the wings and serve as part of the wing trailing edge. When in the "down" (or extended) position, the flaps pivot on the hinge points and drop to about a 45° or 50° angle with the wing chord line. This increases the wing camber and changes the airflow, providing greater lift.

Some common types of flaps are shown in figure 1–36. The plain flap (figure 1–36A) forms the trailing edge of the wing when the flap is in the up (or

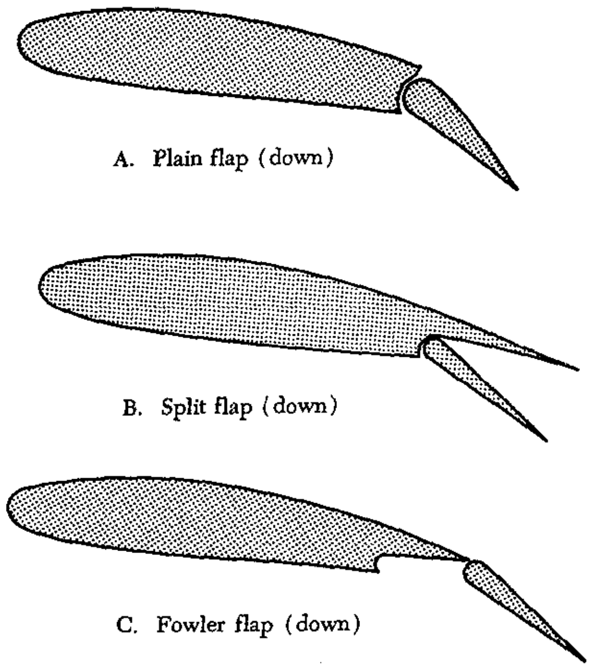


FIGURE 1–36. Wing flaps.

retracted) position. It contains both the upper and lower surface of the wing trailing edge.

The plain split flap (figure 1–36B) is normally housed flush with the undersurface of the wing. It is similar to a plain flap except that the upper surface of the wing extends to the flap trailing edge and does not droop with the flap. This flap is also called the split-edge flap. It is usually just a braced, flat metal plate hinged at several points along its leading edge.

Aircraft requiring extra wing area to aid lift often use Fowler flaps (figure 1–36C). This system houses the flaps flush under the wings much as does the plain split flap system. But, instead of the flaps hinging straight down from a stationary hinge line, worm-gear drives move the flaps leading edge rearward as the flaps droop. This action provides normal flap effect, and, at the same time, wing area is increased when the flaps are extended.

An example of a triple-slotted segmented flap used on some large turbine aircraft is shown in figure 1–37. This type of trailing edge flap system provides high lift for both takeoff and landing. Each flap consists of a foreflap, a mid-flap, and an aft-flap. The chord length of each flap expands as the flap is extended, providing greatly increased

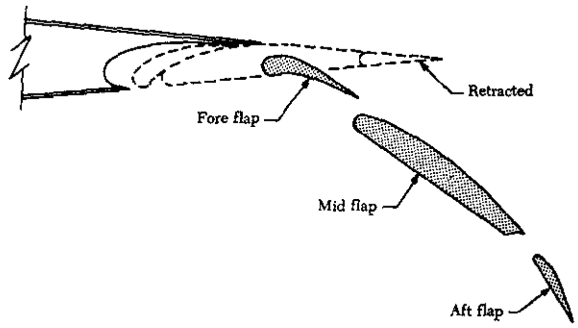


FIGURE 1–37. Triple-slotted trailing edge flaps.

flap area. The resulting slots between flaps prevents separation of the airflow over the flap area.

The leading edge flap (figure 1–38) is similar in operation to the plain flap; that is, it is hinged on the bottom side, and, when actuated, the leading edge of the wing extends in a downward direction to increase the camber of the wing. Leading edge flaps are used in conjunction with other types of flaps.

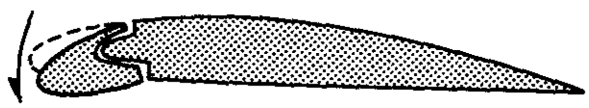


FIGURE 1–38. Cross section of a leading edge flap.

Figure 1–34 shows the location of the leading edge flaps on a large multi-engine turbine aircraft. Three Kruger-type flaps are installed on each wing. The flaps are machined magnesium castings with integral ribs and stiffeners. The magnesium casting of each flap is the principal structural component and consists of a straight section with a hollow core called the torque tube extending from the straight section at the forward end.

Each leading edge flap has three gooseneck hinges attached to fittings in the fixed wing leading edge, and a hinged fairing is installed on the trailing edge of each flap. Figure 1–39 shows a typical leading edge flap in retracted position, with an outline of the extended position.

Speed brakes, sometimes called dive flaps or dive brakes, serve to slow an aircraft in flight. These brakes are used when descending at a steep angle or when approaching the runway for a landing. The brakes themselves are manufactured in many

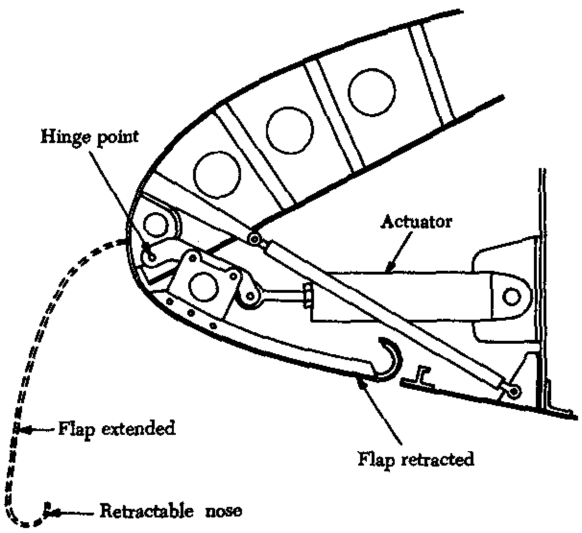


Figure 1-39. Leading edge flap.

shapes, and their location depends on the design of the aircraft and the purpose of the brakes.

The brake panels may be located on certain parts of the fuselage or on the wing surfaces. Brakes on the fuselage are small panels that can be extended into the smooth airflow to create turbulence and drag. Wing-type brakes may be multiple-finger channels extending above and below the wing surfaces to break up smooth airflow. Usually speed brakes are controlled by electrical switches and actuated by hydraulic pressure.

Another type of air brake is a combination of spoilers and speed brakes. A typical combination consists of spoiler flaps located in the upper wing surfaces ahead of the ailerons. When the operator wishes to use both air brakes and spoilers, he can slow the flight speed and maintain lateral control as well.

Spoilers are auxiliary wing flight control surfaces, mounted on the upper surface of each wing, which operate in conjunction with the ailerons to provide lateral control.

Most spoiler systems can also be extended symmetrically to serve a secondary function as speed brakes. Other systems are equipped with separate ground and flight spoilers. Most spoiler panels are bonded honeycomb structures with aluminum skin. They are attached to the wing structure by machined hinge fittings which are bonded into the spoiler panel.

Tabs

One of the simplest yet most important devices to aid the pilot of an aircraft is the tab attached to a control surface. Although a tab does not take the place of a control surface, it is mounted on or attached to a movable control surface and causes easier movement or better balance of the control surface.

All aircraft, except a few of the very lightest types, are equipped with tabs that can be controlled from the cockpit. Tabs on some of these aircraft are usually adjustable only when the aircraft is on the ground. Figure 1-40 shows the location of a typical rudder tab.

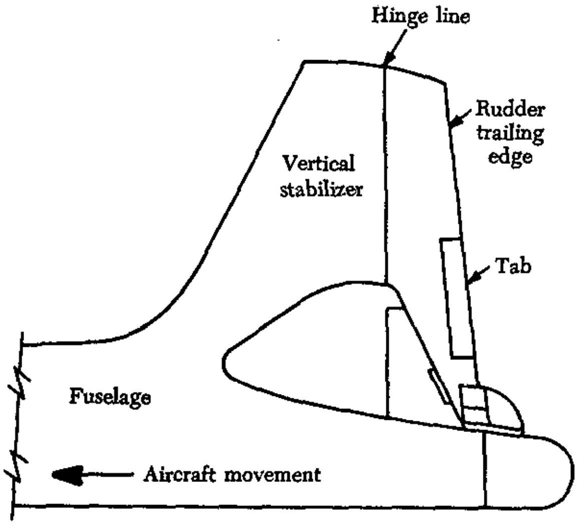


Figure 1-40. Typical location of rudder control tab.

LANDING GEAR

The landing gear is the assembly that supports the aircraft during landing or while it is resting or moving about on the ground. The landing gear has shock struts to absorb the shock of landing and taxiing. By means of a gear-retraction mechanism, the landing gear attaches to the aircraft structure and enables the gear to extend and retract. The landing gear arrangement either has a tailwheel or a nosewheel. Landing gear arrangements having a nosewheel are usually equipped for nosewheel steering. Nosewheel aircraft are protected at the fuselage tail section with a tail skid or bumper. By means of wheels and tires (or skis), the landing gear forms a stabilizing contact with the ground during landing and taxiing. Brakes installed in the wheels enable the aircraft to be slowed or stopped during movement on the ground.

SKIN AND FAIRING

The smooth outer cover of the aircraft is referred to as skin. The skin covers the fuselage, wings, empennage, nacelles, and pods. The material used for the skin covering is usually sheet aluminum alloy, treated so that it will not corrode. Magnesium and stainless steel may also be used to a limited extent. The thickness of the skin materials covering a structural unit may differ, depending on the load and stresses imposed within and throughout the structure. To smooth out the airflow over the angles formed by the wings and other structural units with the fuselage, shaped and rounded panels or metal skin are attached. This paneling or skin is called fairing. Fairing is sometimes referred to as a fillet. Some fairing is removable to provide access to aircraft components, whereas other fairing is riveted to the aircraft structure.

ACCESS AND INSPECTION DOORS

Access doors permit normal or emergency entrance into or exit from the aircraft. Also, they provide access to servicing points and manually operated drains. Inspection doors provide access to a particular part of the aircraft being inspected or maintained. Access or inspection doors are either hinged or removable. They are fastened in the closed position with catch and locking mechanisms, screws, quick-release devices, or cowling type fasteners. Access and inspection doors that are removable often have a stenciled identification number that is identical to a number stenciled near the opening that they cover. Other access and inspection doors have a stenciled nomenclature to identify the opening that they cover.

HELICOPTER STRUCTURES

Like the fuselages in fixed-wing aircraft, helicopter fuselages may be welded truss or some form of monocoque construction. Although their fuselage configurations may vary a great deal, most helicopter fuselages employ structural members similar to those used in fixed-wing aircraft. For example, most helicopters have such vertical/widthwise braces as bulkheads, formers, rings, and frames. They are also provided with such lengthwise braces as stringers and longerons. In addition, the gussets, joiners, and skin hold the other structural members together.

The basic body and tail boom sections of a typical helicopter are of conventional, all-metal, riveted structures incorporating formed aluminum alloy bulkheads, beams, channels, and stiffeners. Stressed skin panels may be either smooth or beaded. The firewall and engine deck are usually stainless steel. The tail boom is normally of semimonocoque construction, made up of formed aluminum bulkheads, extruded longerons, and skin panels or of welded tubular steel.

The major structural components of one type of helicopter are shown in figure 1–41. The members of a helicopter's tail group vary widely, depending on the individual type and design. In this case, a stabilizer is mounted on a pylon to make up the group. In other cases, the stabilizer may be mounted on the helicopter tail cone or fuselage. In either case, both the pylon and stabilizer usually contain aluminum alloy structural members covered with magnesium alloy skin. The types of structural members used, however, usually vary. A pylon usually has bulkheads, formers, frames, stringers, and beams, making it somewhat of a blend of aircraft wing and fuselage structural members. The stabilizer is usually built more like an aircraft wing, with ribs and spars.

In a typical helicopter, the tail, body, and tail boom are constructed of all-metal stressed skin and metal reinforcing members. The helicopter cabin is normally a plexiglass enclosure which is supported by aluminum tubing in some models.

A large single-rotor helicopter is shown in figure 1–42. It is all-metal and is basically composed of two major sections, the cabin and the tail cone. The cabin section is further divided into passenger or cargo compartments, which provide space for the crew, passengers, cargo, fuel and oil tanks, controls, and powerplant. In multi-engine helicopters, the powerplants are usually mounted in separate engine nacelles.

As shown in figure 1–42, the aft section of a typical single-rotor helicopter consists of the tail cone, the fin, the tail-cone housing, the tail-rotor pylon, and the tail-end fairing. The tail cone is bolted to the rear of the forward section and supports the tail rotor, tail-rotor drive shafts, stabilizers, tail-cone housing, and tail-rotor pylon. The tail cone is of magnesium alloy and aluminum alloy construction. The tail-cone housing is bolted to the aft end of the tail cone. Trim stabilizers extend out

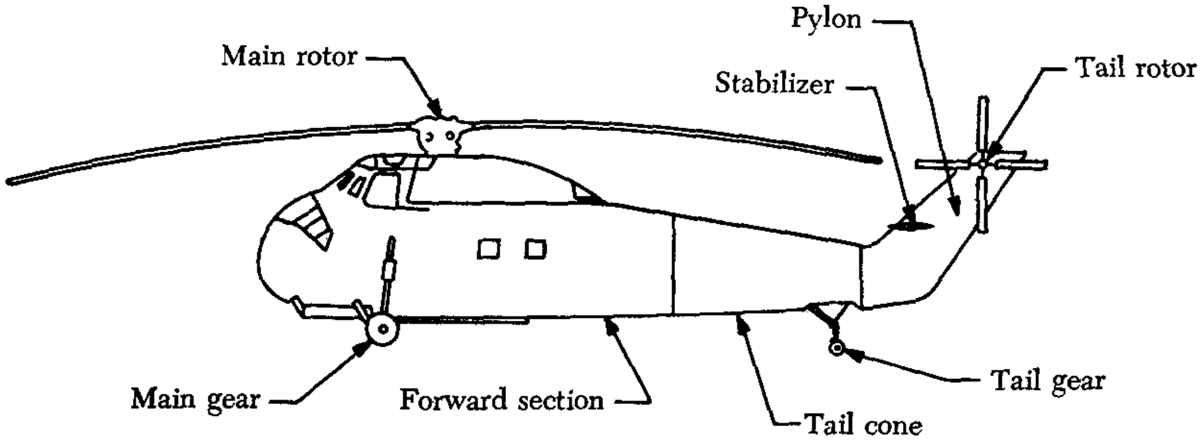
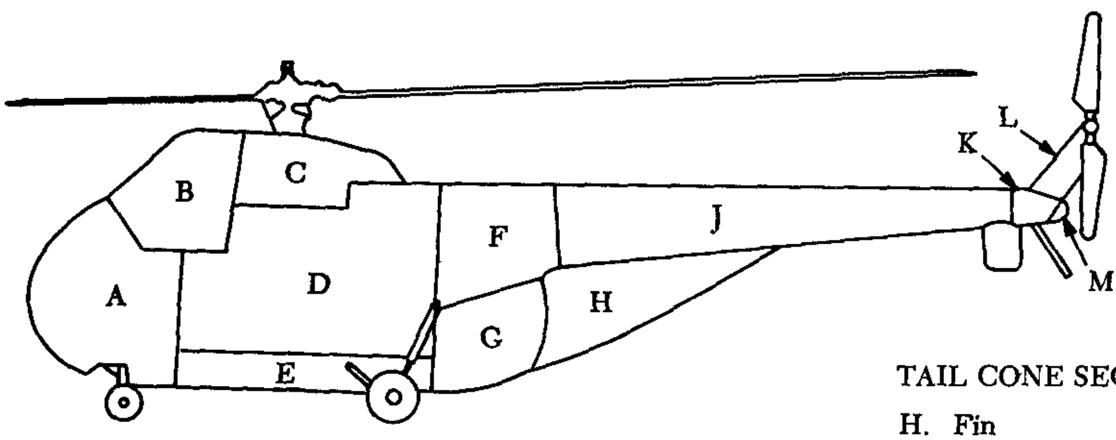


Figure 1–41. Typical helicopter structural components.



TAIL CONE SECTION

H. Fin
J. Tail cone
K. Tail-cone housing
L. Pylon
M. Tail-end fairing

CABIN SECTION

A. Engine compartment
B. Cockpit
C. Transmission compartment
D. Cabin
E. Fuel tank compartment
F. Baggage compartment
G. Electrical and radio compartment

Figure 1–42. Location of major helicopter components.

on both sides of the tail cone forward of the housing.

Helicopter structural members are designed to carry a load or, stated differently, to resist stress. A single member of the helicopter structure may be subjected to a combination of stresses. In most cases it is desirable for structural members to carry end loads rather than side loads; that is, to be subjected to tension or compression rather than bending. Structural members are usually combined into a truss to carry end loads. In a typical Pratt truss, the longitudinal and vertical members are tubes or rods capable of carrying compression loads.

Nonstructural members that are not removable from the helicopter are usually attached by riveting or spot welding. Riveting is the most common method of attaching aluminum alloy sheets together. Parts that can be removed from the helicopter structure are usually bolted together.

Transparent materials are used for windshields and windows and sometimes to cover parts requiring frequent visual inspection. Transparent plastic sheet and laminated glass are the materials most commonly used.

Some helicopter manufacturers use impregnated glass cloth laminate (fiber glass) as a lightweight substitute for certain metal parts, since fiber glass is simple to manufacture, has a high strength-weight ratio, and resists mildew, corrosion, and rot.