Airframe & Aircraft Components

(According to the Syllabus Prescribed by Director General of Civil Aviation, Govt. of India)

FIRST EDITION

AIRFRAME & AIRCRAFT COMPONENTS

Prepared by

L.N.V.M. Society Group of Institutes
* School of Aeronautics
  (Approved by Director General of Civil Aviation, Govt. of India)

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Dedicated To

Shri Laxmi Narain Verma
[Who Lived An Honest Life]

Preface

This book is intended as an introductory text on "Airframe and Aircraft Components" which is an essential part of General Engineering and Maintenance Practices of DGCA license examination, BAMEL, Paper-II.

It is intended that this book will provide basic information on principle, fundamentals and technical procedures in the subject matter areas relating to the "Airframe and Aircraft Components".

The written text is supplemented with large number of suitable diagrams for reinforcing the key aspects.

I acknowledge with thanks the contribution of the faculty and staff of L.N.V.M. Society Group of Institutions for their dedicated efforts to make this book a success.

I am also thankfull to our Director Mr. C.C. Ashoka for having faith on me in publishing this book.

I would very much appreciate criticism, suggestions for improvement and detection of errors from the readers, which will be gratefully acknowledged.

Sheo Singh

(Senior Instructor, School of Aeronautics)

L.N.V.M. Society Group of Institutes   Dated : March, 2007

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Knowledge of the functions of the major Aircraft Components and Systems

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 airframe consist of fuselage, main rotor and related gearbox, tail 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 loads rather than side; 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 to understand and appreciate the stresses involved in order to avoid changes in the original design through improper repairs.
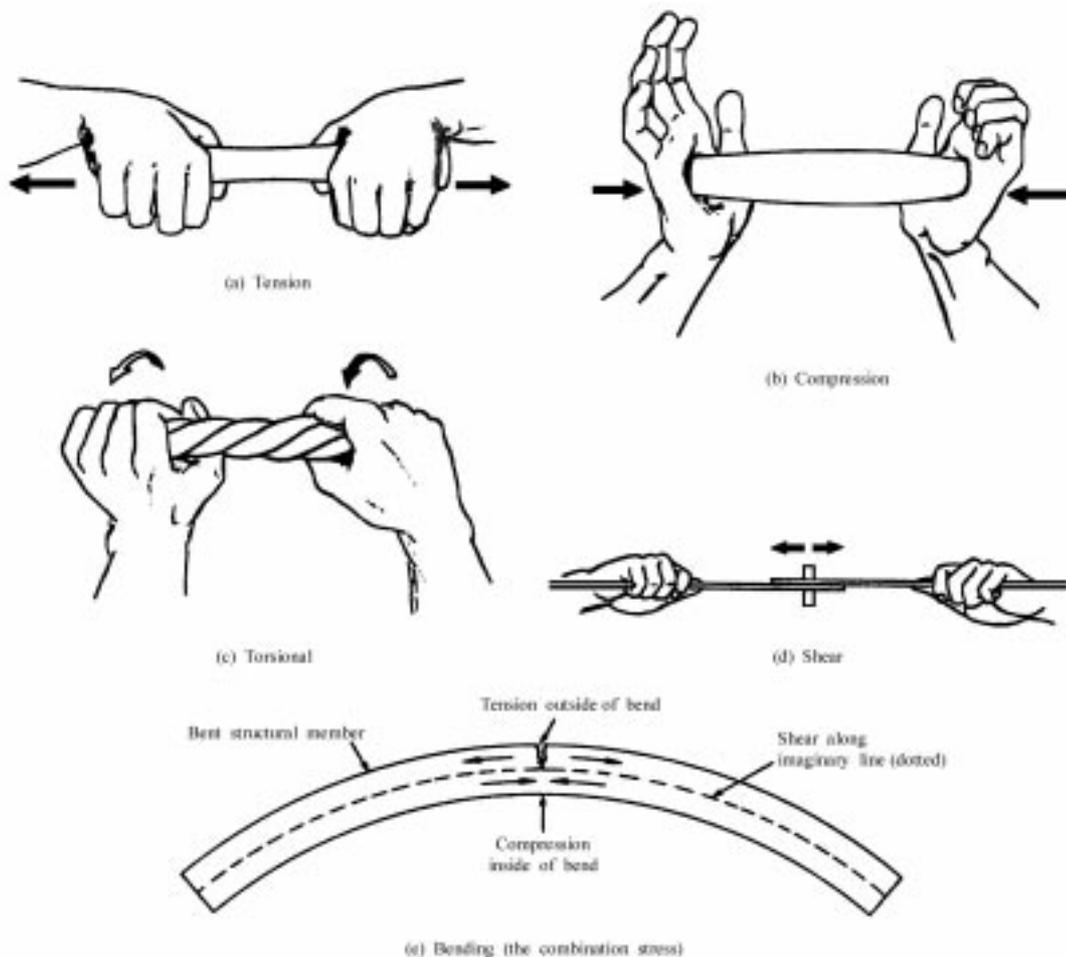

Fig.1. Five stresses acting on an aircraft.

There are five major stresses to which all aircraft are subjected .

(i) Tension (ii) Compression (iii) Torsion (iv) Shear (v) 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 in Fig. (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 (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. 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. (Fig.1c)

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 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. (Fig.1d).

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

FIXED-WING AIRCRAFT

The principal components of a single-engine, propeller-driven aircraft are shown in below Fig.2.
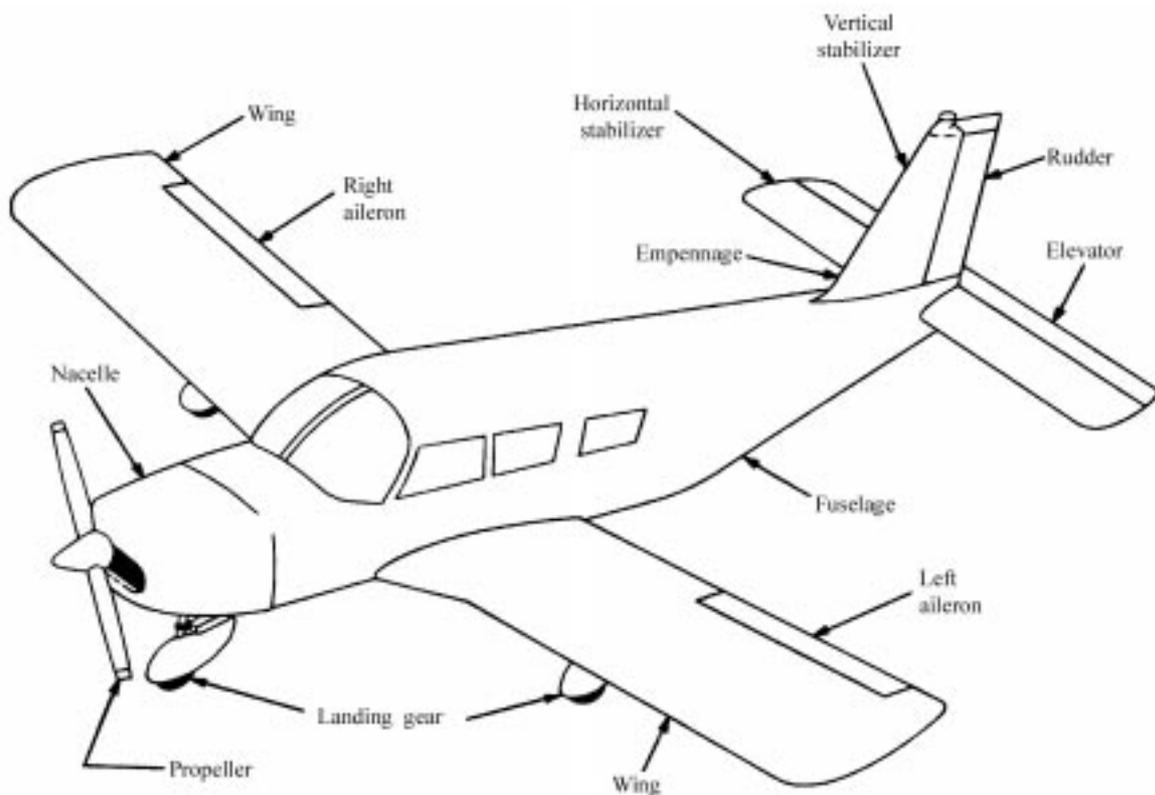
Fig.2. Aircraft structural component.

Fig. 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.
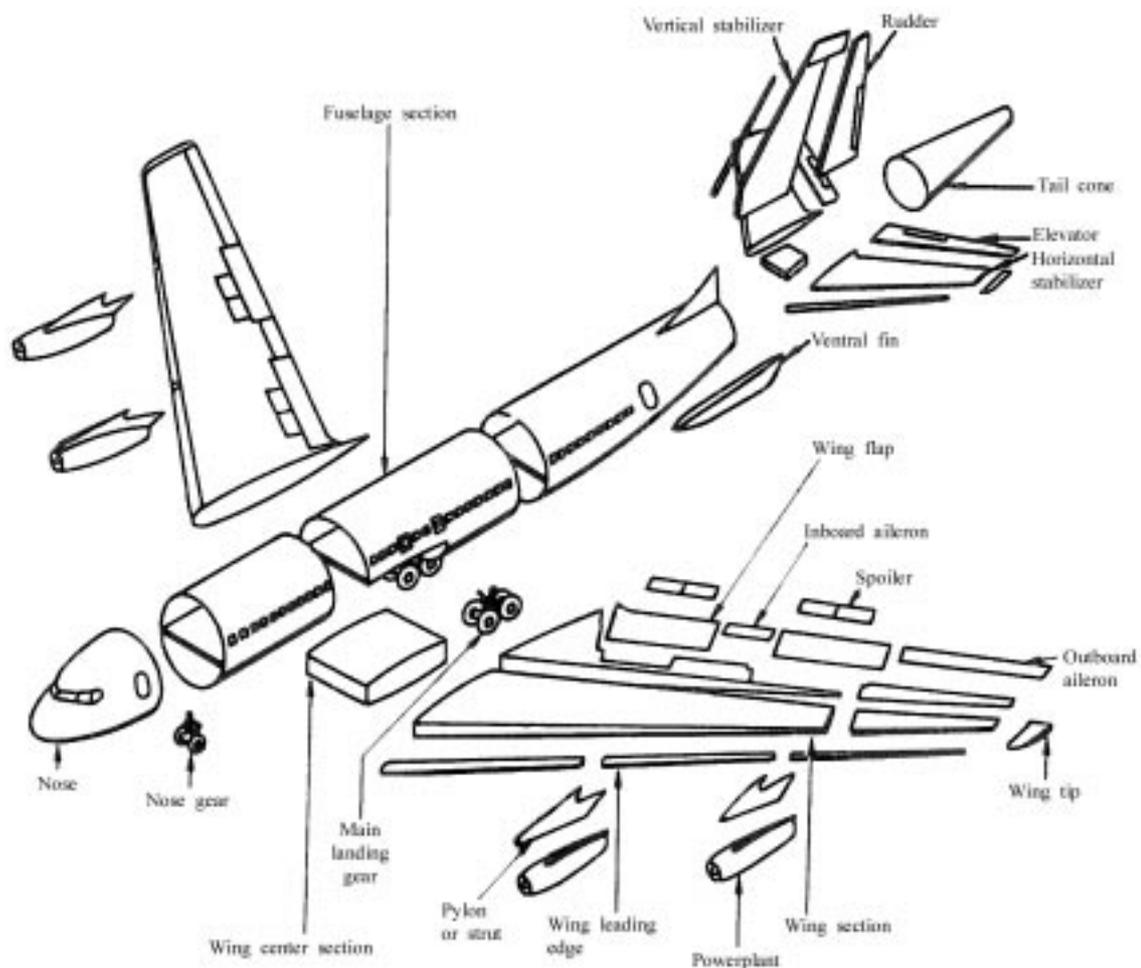
Fig.3. Typical structural components of a turbine powered aircraft.

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 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 aircraft, principally the light, single-engine models, truss fuselage frames are constructed of aluminium alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes. (Fig.4).

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 : (i) Monocoque, (ii) semimonocoque, or (iii) reinforced shell. The true monocoque construction 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. (Fig.5).

To overcome the strength / weight problem of monocoque

Fig.4. Warren truss of welded tubular steel.
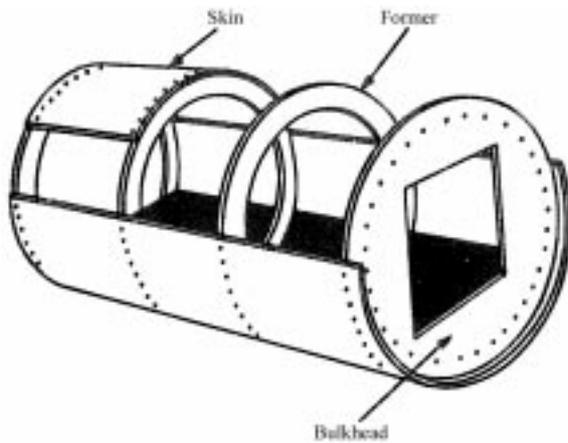
Fig.5. Monocoque construction.
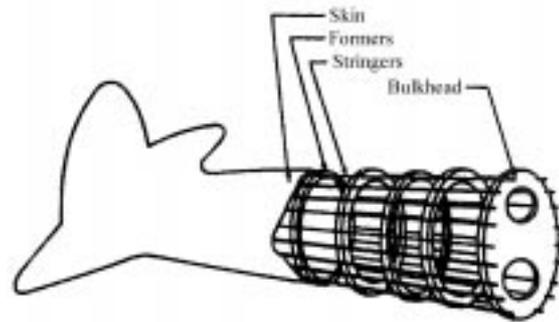
Fig. 6. Semimonocoque construction.

construction, a modification called semimonocoque construction (Fig.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 aluminium 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, power plants, and stabilizers. Below Fig.7 shows one form of the semimonocoque 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 aluminium alloy construction, and are manufactured in a variety of shapes by casting, extrusion, or forming. Longerons, like stringers, are usually made of aluminium alloy; however, 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 is a type of connecting bracket. The bracing between longerons is often referred to as web members. They may be installed vertically or diagonally.
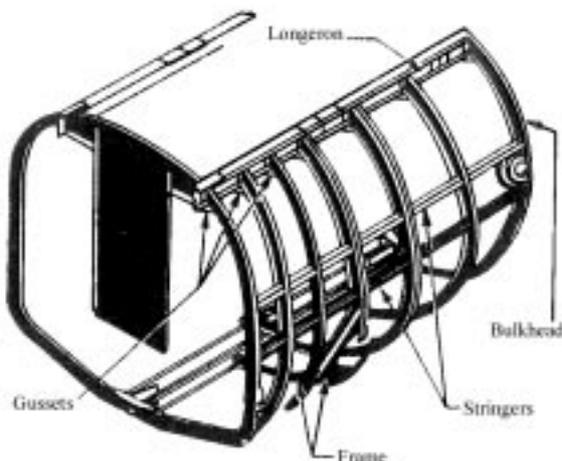
Fig. 7. Fuselage structural member.

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 with stand 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 Fig 8.
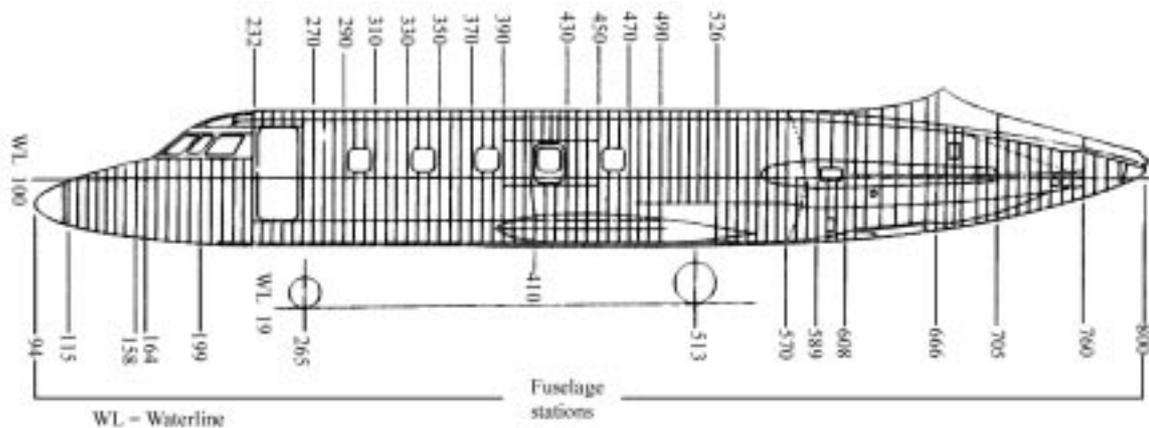

Fig. 8. Fuselage stations.

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 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.

i)   *Fuselage stations* 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.

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

iii) *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.

iv) *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.

v)   *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.

vi) *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 bracing (struts, wires, etc.) to assist in supporting the wing and carrying the aerodynamic and landing loads. Both aluminium alloy and magnesium alloy are used in wing construction. The internal structure is made up of spars and stringers running span wise, and ribs and formers running chord wise (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. One 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 design : (1) Monospar, (2) multi-spar, (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 aerofoil. 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 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. Fig. 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. Fig.10 shows below some common 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 swept back wings.(Fig.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 Fig.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 towards the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss system.

Wooden spars can be generally classified into four different types by their cross sectional configuration. As shown in Fig.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 aluminium or short aluminium extrusions riveted together to form a spar.

The shape of most wooden spars is usually similar to one of the shapes shown in Fig.12. The rectangular form, Fig. 12A , can be either solid or laminated. Fig.12B is an I-beam spar that has been externally routed on both sides to reduce weight while retaining adequate strength. A box spar, Fig. 12C, is built up from plywood and solid spruce. The I-beam spar, Fig.12D , may be built up of wood or manufactured by an aluminium 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 Fig.12 shows the basic configuration of some typical metal spars. Most metal spars are built up from extruded aluminium alloy sections, with riveted aluminium alloy web sections to provide extra strength.

Although the spar shapes of Fig. 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 (Fig.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. Fig.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 Fig.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
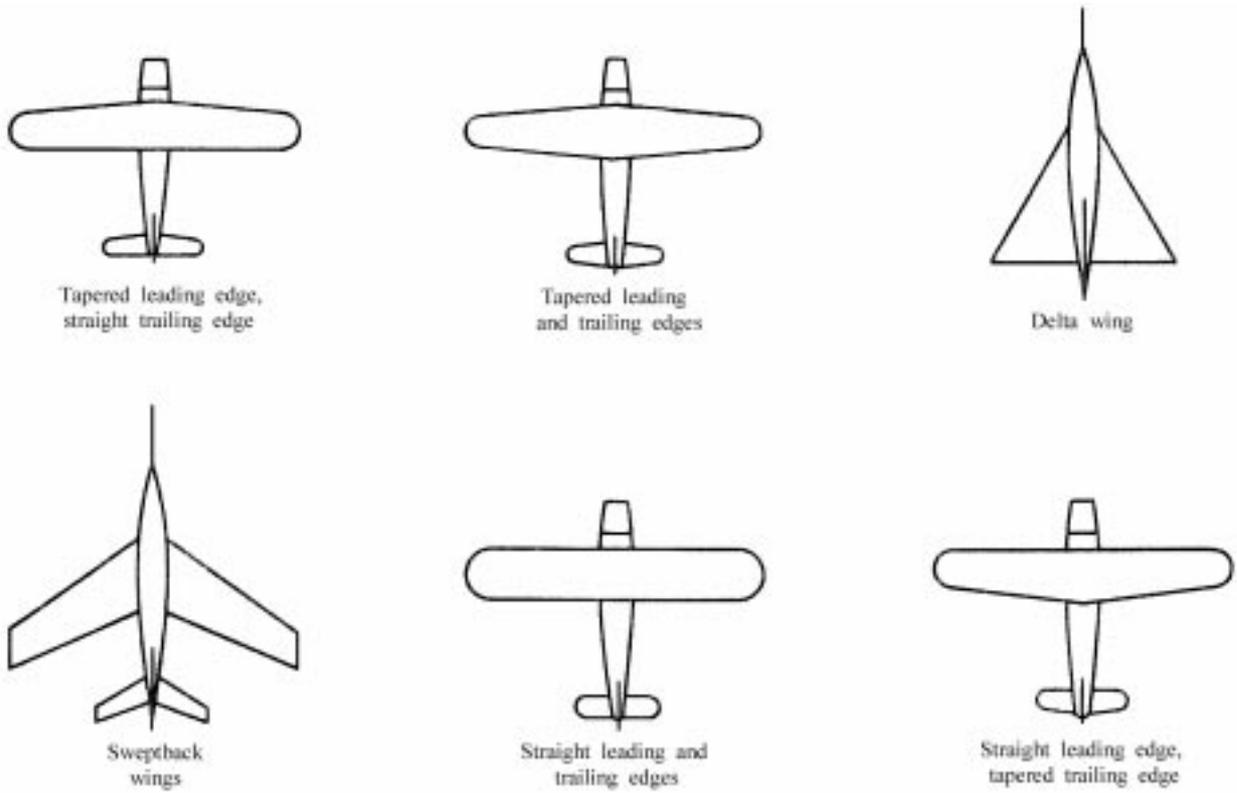
Tapered leading edge, straight trailing edge

Tapered leading and trailing edges

Delta wing

Sweptback wings

Straight leading and trailing edges

Straight leading edge, tapered trailing edge

Fig.9. Typical wing leading and trailing edge shapes.

Low wing

Dihedral

High wing

Mid wing

Gull wing

Inverted gull

Fig. 10.Comman wing forms.

Leading edge ribs

Spars

Stringer

Leading edge skin
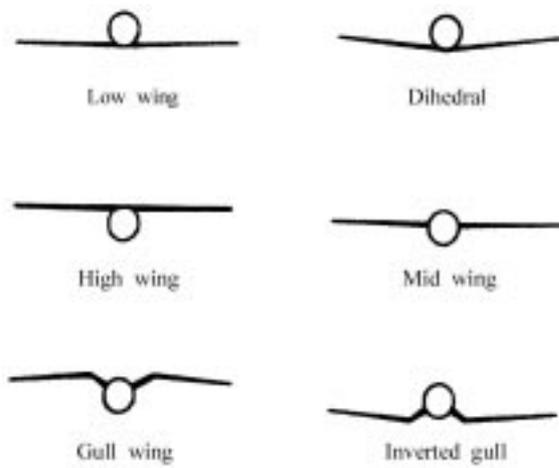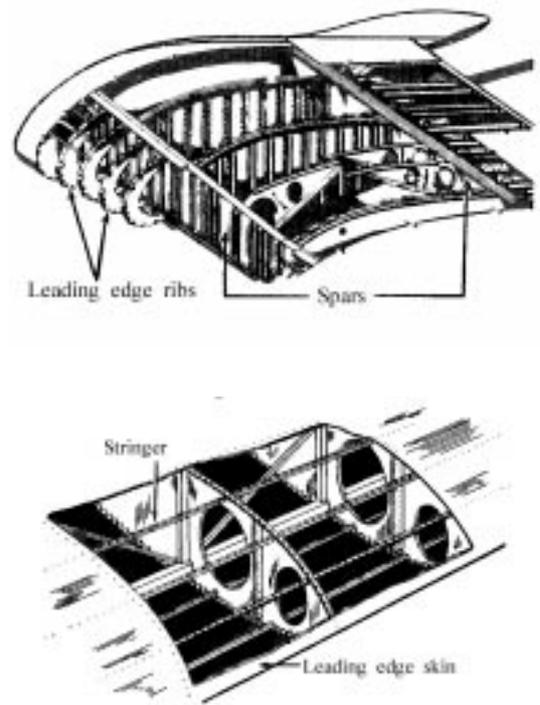
*Fig. 11.Internal wing construction.*
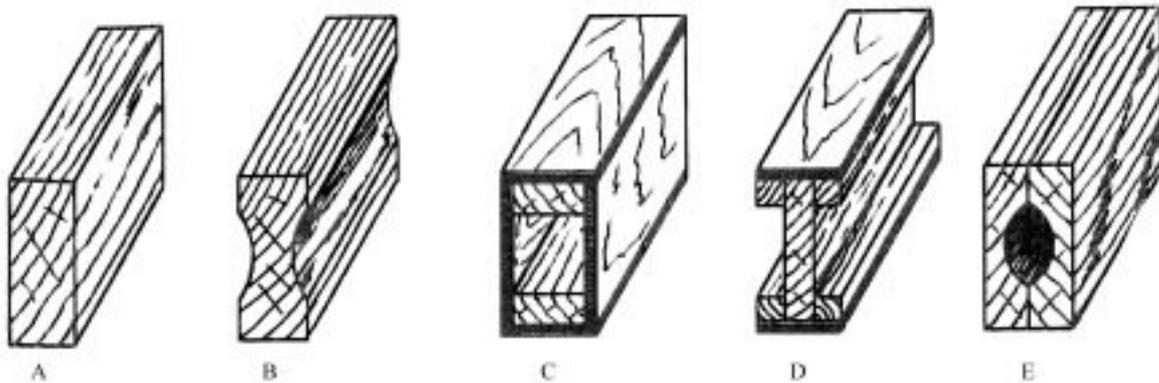
*Fig. 12.Typical spar cross sectional configurations.*
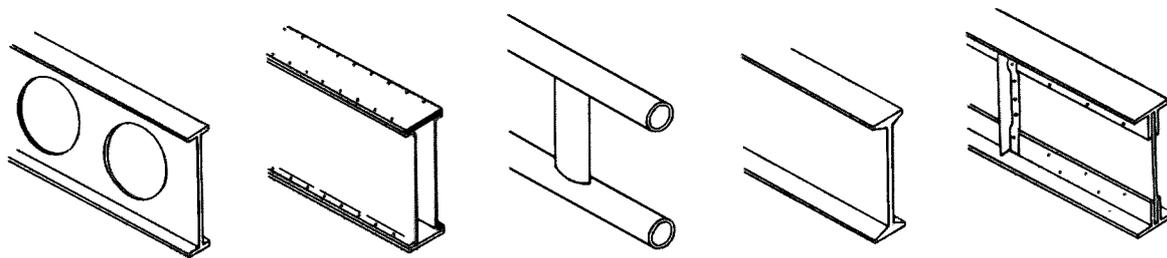
Fig. 13.Metal spar shapes.

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.

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 are used with metal spars. Some typical wooden ribs, usually manufactured from spruce, are shown in Fig.17.

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 Fig. 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 Fig. 17B. On this type the cap strip may be laminated, especially at the leading edge. Fig. 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.

Fig. 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 Fig. below. This type of spar extends only part of the span wise length of the wing and provides a hinge attachment point for the aileron.

Various types of ribs are also illustrated in Fig. 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 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
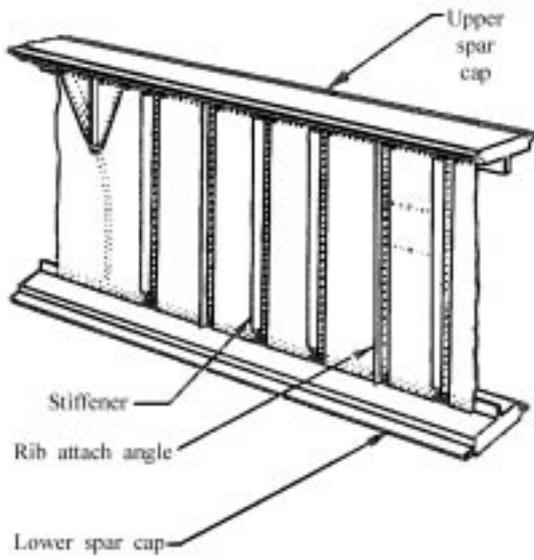
Fig.14. Plate web wing spar.
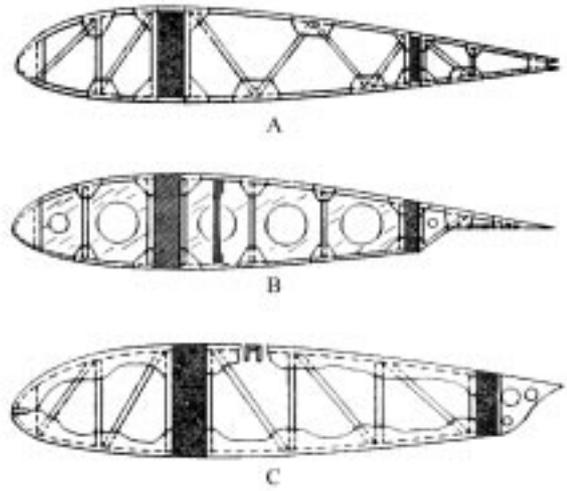

Fig.17. Typical wooden ribs.
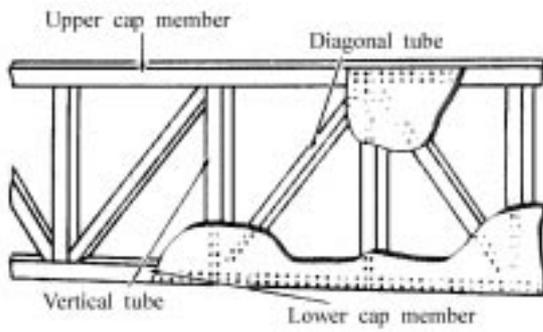

Fig. 15.Truss wing spar.
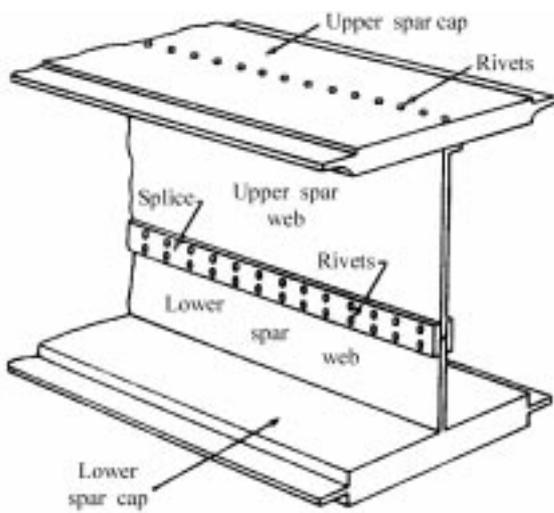
Fig.16. Wing spar with 'fail safe' construction.
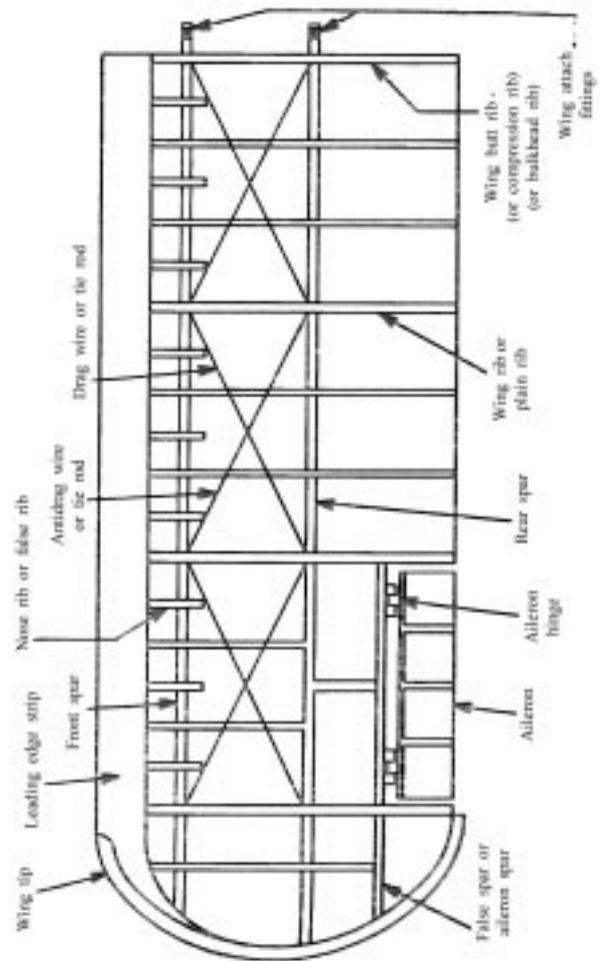

Fig.18. Basic rib and spar structure.
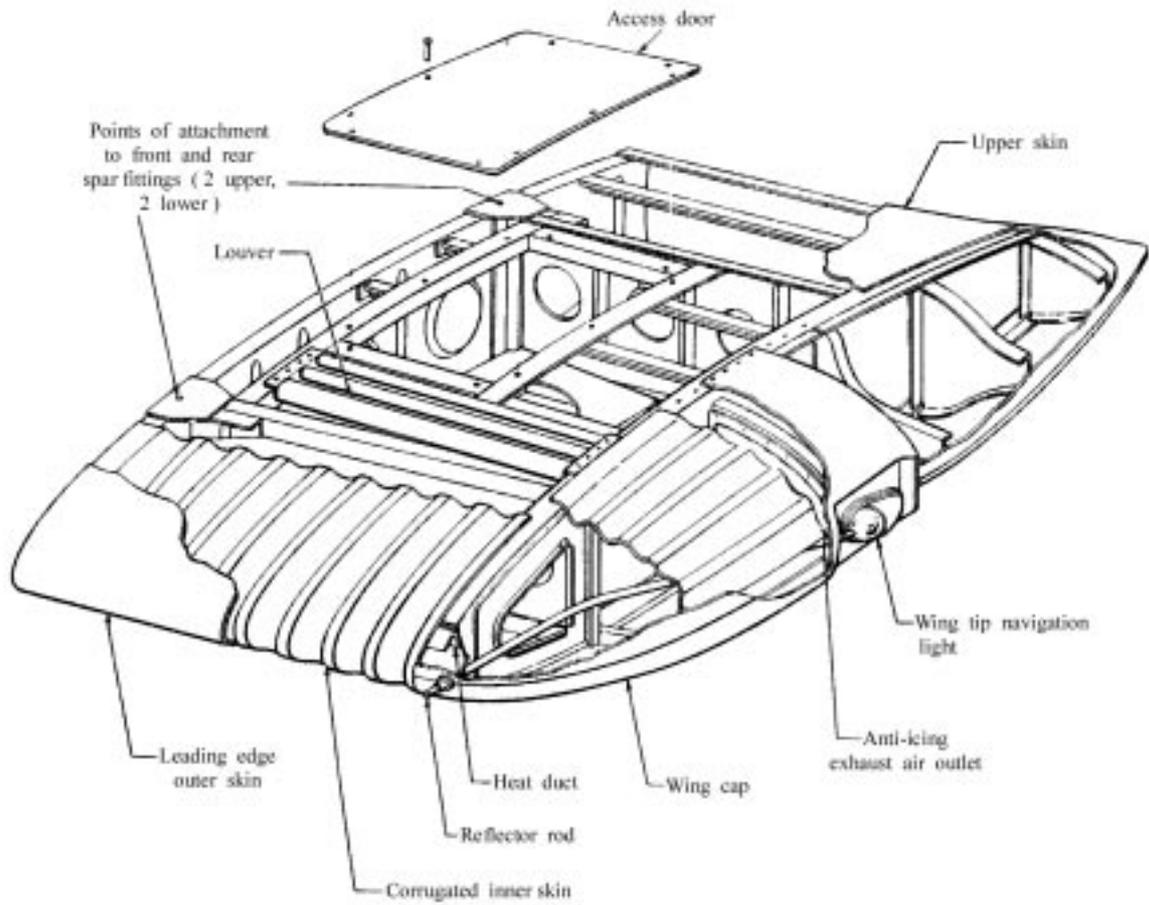
Fig.19. Removable wing tips.
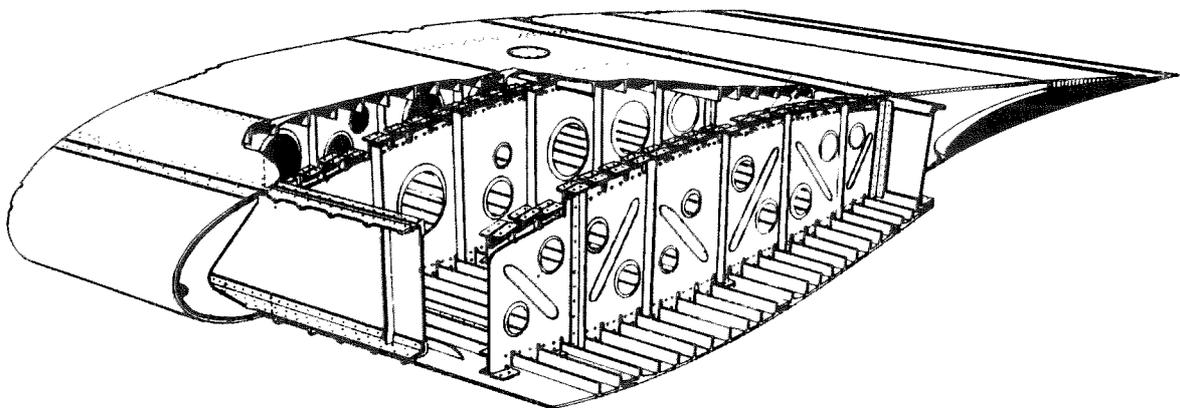
Fig.20. All metal wing with chemically milled channels.

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 woven above and below rib sections to prevent side wise bending of the ribs.

Drag and anti drag wires (Fig. 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 back as tie rods. The wire designed to resist the backward forces is called a drag wire; the anti drag wire resists the forward forces in the chord direction.

The wing attachment fittings, shown in Fig. 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.

Fig. 19 shows a removable wing tip for a large aircraft wing. The wing-tip assembly is of aluminium alloy construction. The wing-tip cap is secured to the tip with countersunk screws and is secured to the inter spar structure at four points with 1/4 in bolts. The tip leading edge contains the best 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 lucid rod to transit the light to the leading edge.

Fig. 20 shows a cross sectional view of an 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 Fig. 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.

Both aluminium 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. Aluminium honeycomb material is made of aluminium foil honeycomb core, bonded between sheets of aluminium. Fibre glass honeycomb material consists of fibre glass honeycomb core bonded between layers of fibre glass cloth.

In the construction of large aircraft structures, and in some small aircraft as well, the honeycomb sandwich structure employes either aluminium or reinforced plastic materials. Honeycomb panels are usually a lightweight cellular core sandwiched between two thin skins or facing materials such as aluminium, 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 Fig. 22.
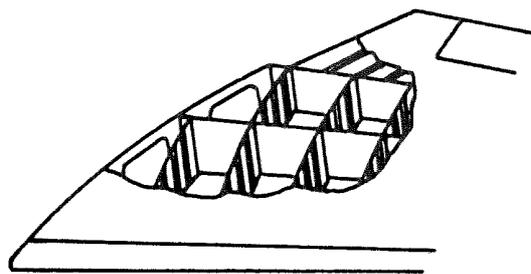
Fig.21. Box beam milled wing.   *Fig.22.Constant thickness and tapered core honey comb sections.*
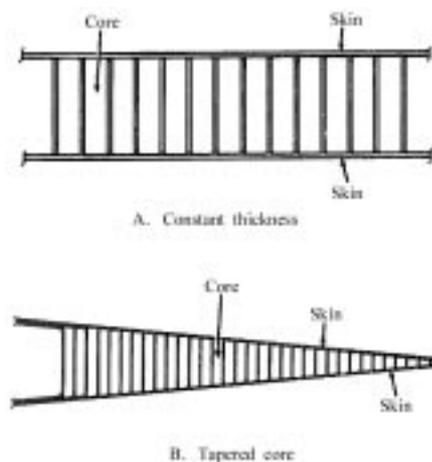
Fig.23 shows a view of the upper surface of a large jet transport wing. The various panels manufactured from honeycomb material are outlined by diagonal lines and labelled.

Still another type of construction is illustrated in Fig.24. In this case the sandwich structure of the wing leading edge is bonded to the metal spar. Also shown is the integrally bonded de-icer 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.
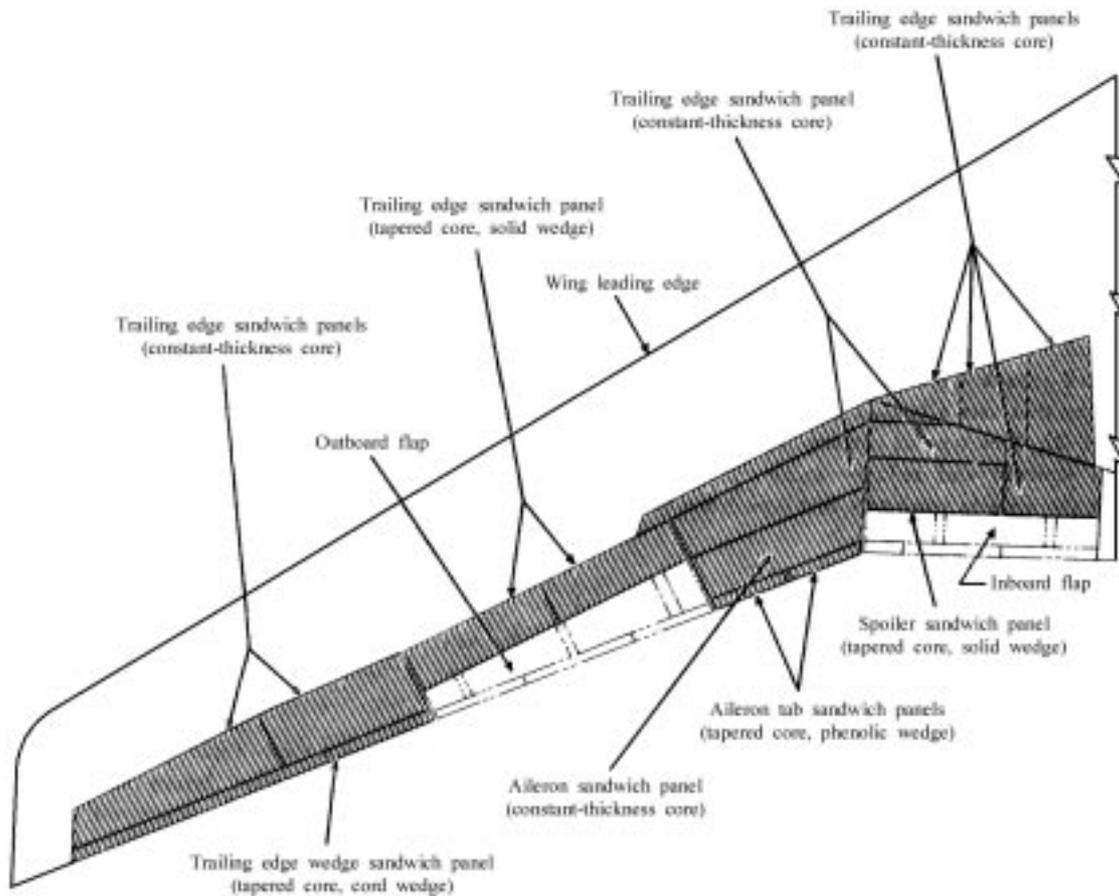
Fig. 23.Honeycomb wing construction on a large jet transport aircraft.

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 aluminium 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 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. Fig. 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 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. Fig. 26 shows an exploded view of the pieces of cowling for a horizontally opposed engine on a light aircraft.

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 (Fig.27).
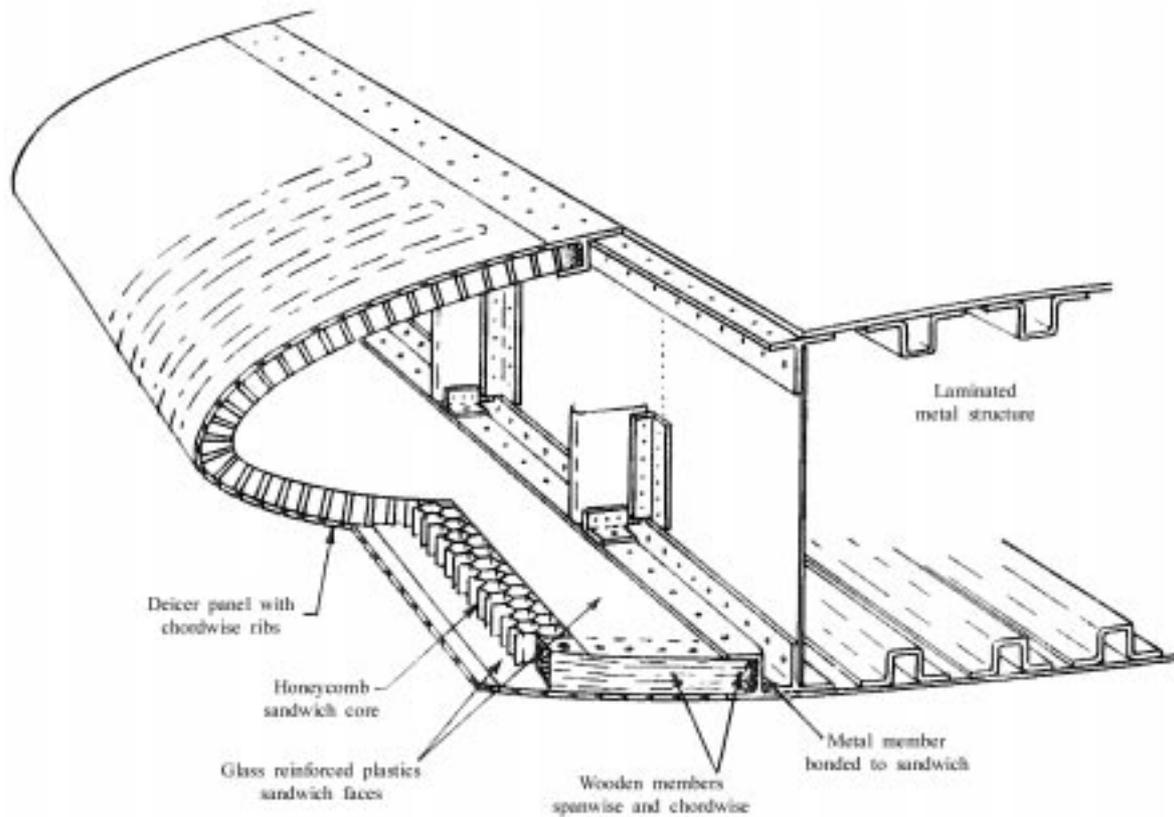
Fig. 24 . Leading edge sandwich material bounded to metal wing members.
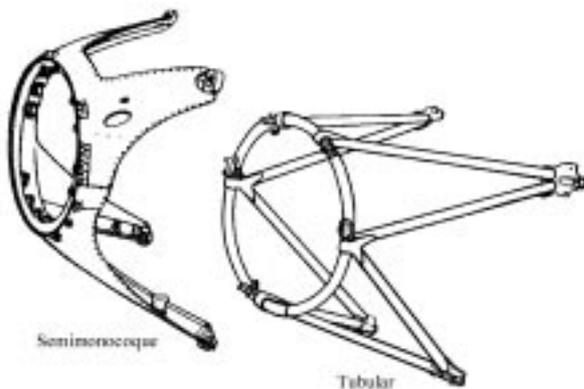
Fig.25. Semimonocoque and welded tubular steel engine mounts.
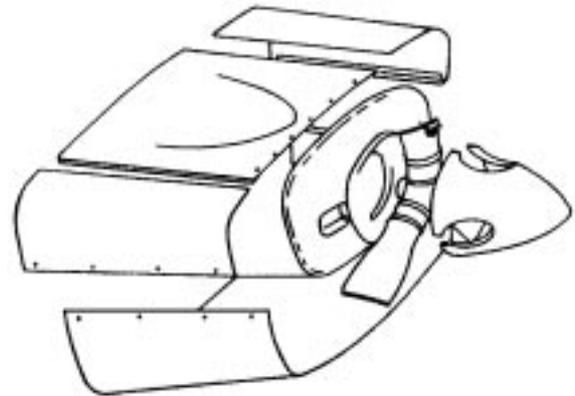
Fig. 26.Cowling for horizontally opposed engine.

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 in the closed position by spring-loaded safety catches. Cowl panels are generally of aluminium 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 Fig 28.

EMPENNAGE

The empennage is also called the tail section and most aircraft designs consist of a tail cone, fixed surfaces, and movable surfaces.
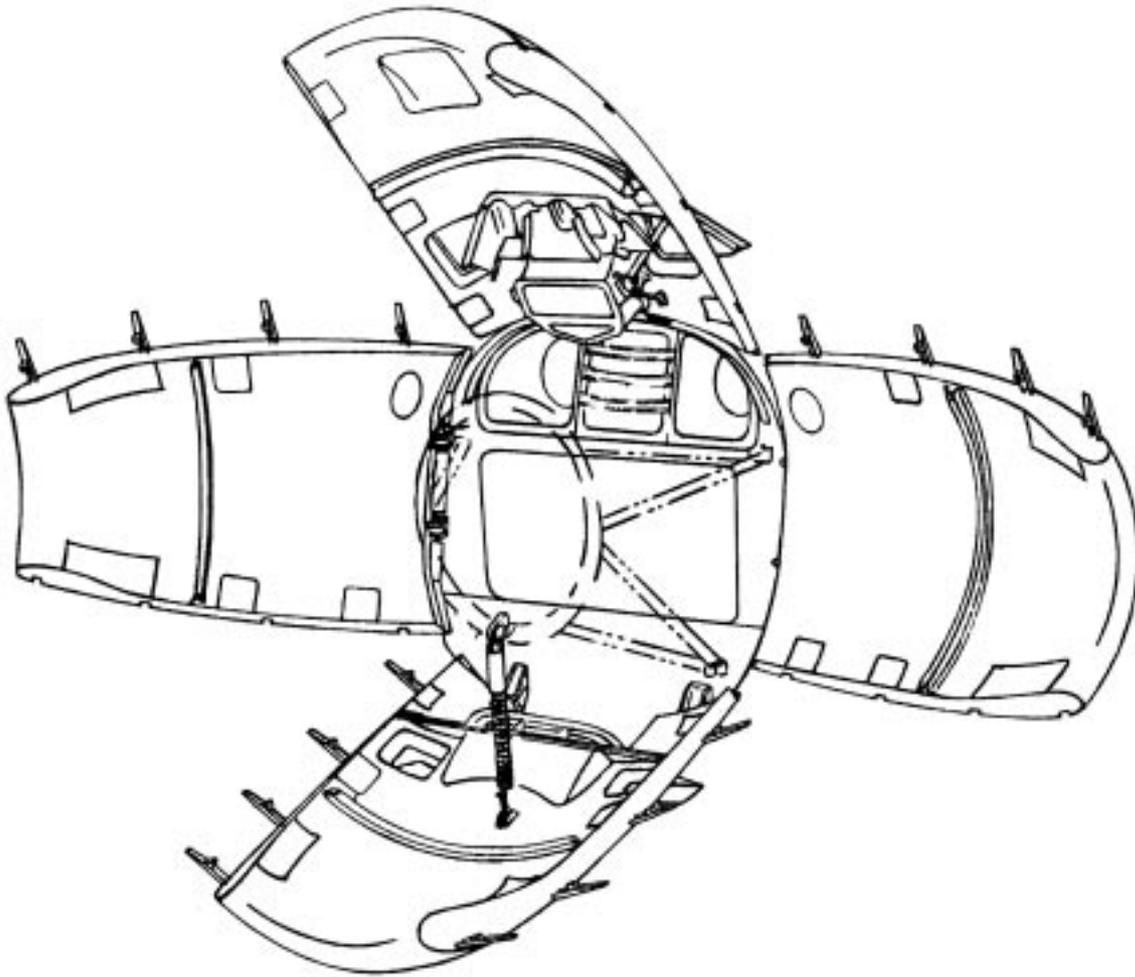
Fig. 27. Orange peel cowling opened.

The tail cone serves to close and streamline the aft end of most fuselages. The cone is made up of structural members (Fig. 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.

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

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 altitude 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 aluminium 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.
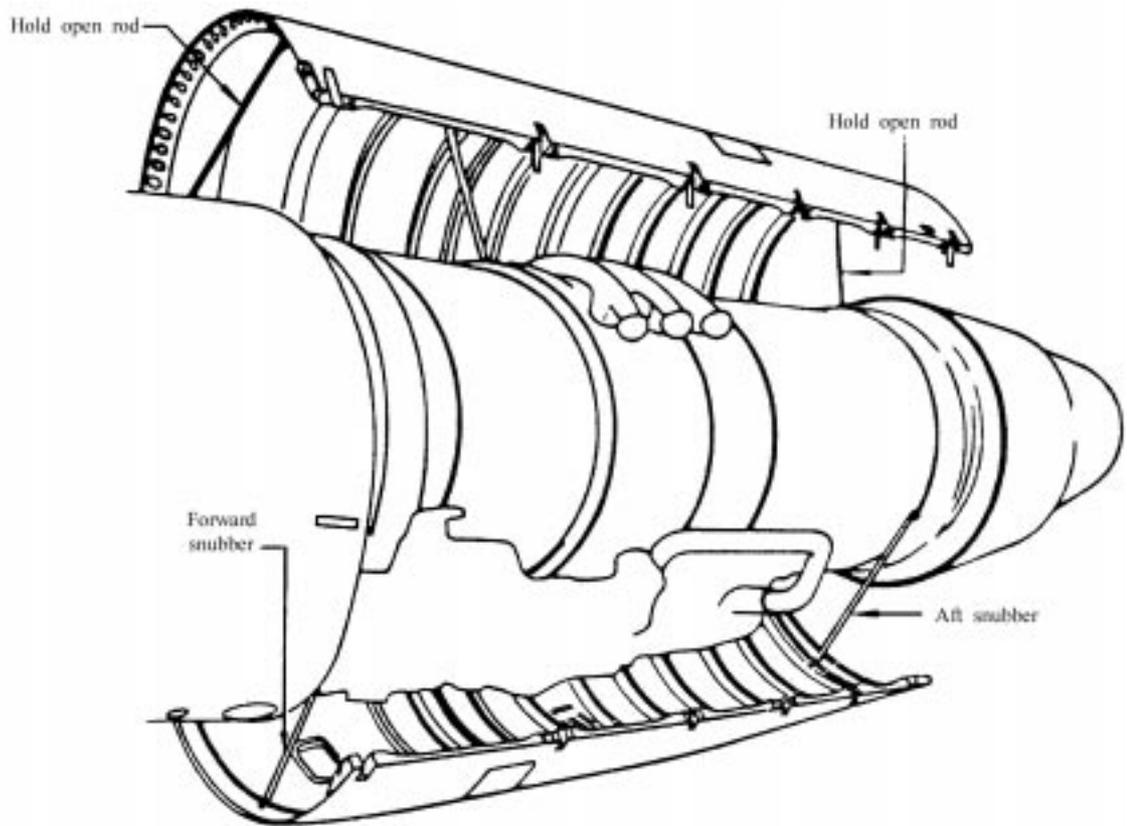
Fig. 28. Side mounted turbojet engine cowling.
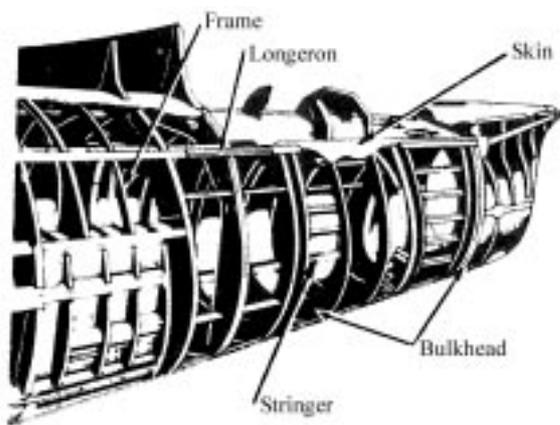
Fig.29. The fuselage terminates in a tail cone.
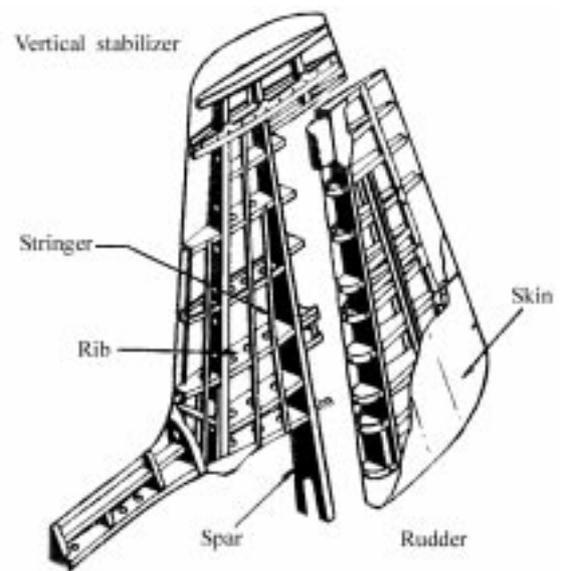
fig.30. Construction features of rudder and vertical stabilizer.

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 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. Fig. 31 shows the shape and location of typical small-aircraft ailerons 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 Fig. 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.
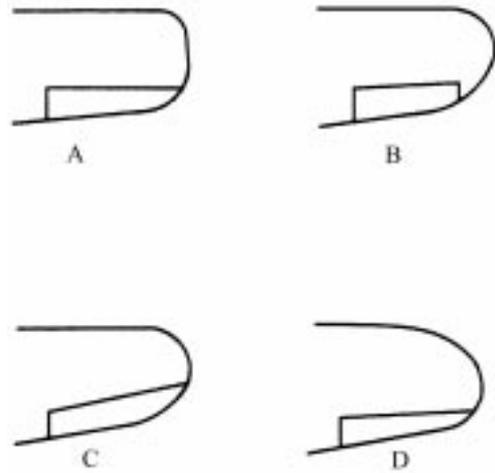
Fig. 31. Aileron location on various wing tip design.

Fig. 32. End view of ailron rib.

Fig. 33. Ailron hinge locations.

Rudder

Rudder control tab

Stabilizer actuated elevator tab

Elevator control tab

Elevator

Stabilizer

Leading edge flaps

Fillet flap

Inboard flap

Inboard spoilers

Control tab

Vortex generators

Outboard aileron

Balance tab

Outboard spoilers

Outboard flap

Inboard aileron
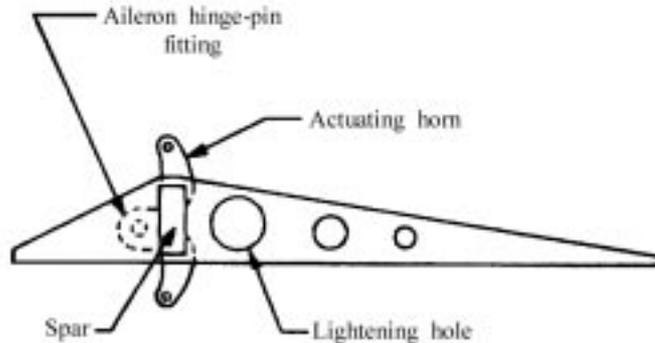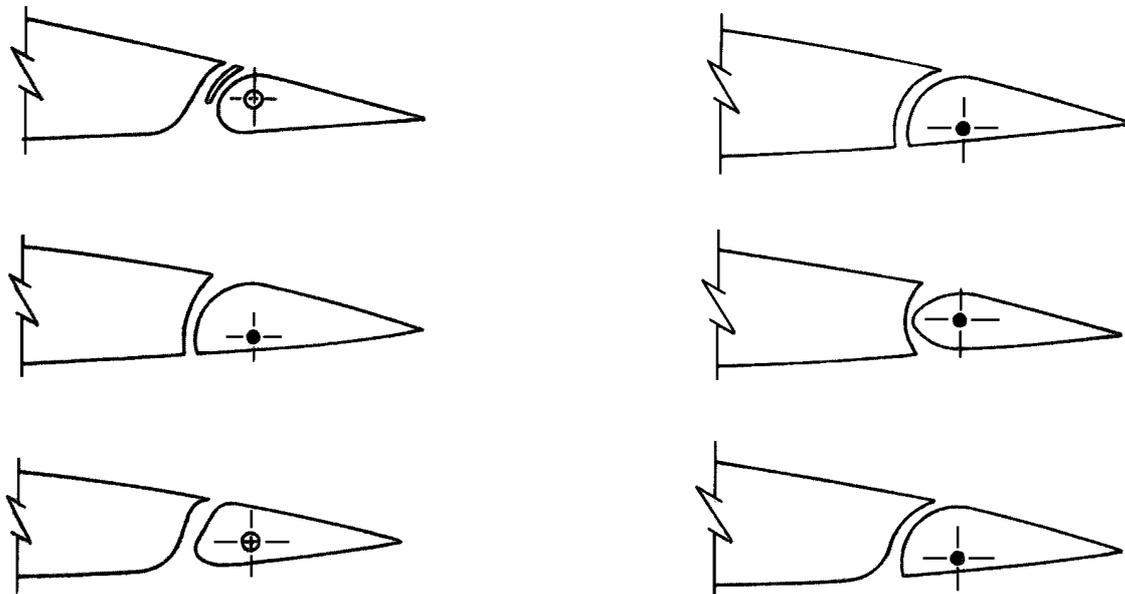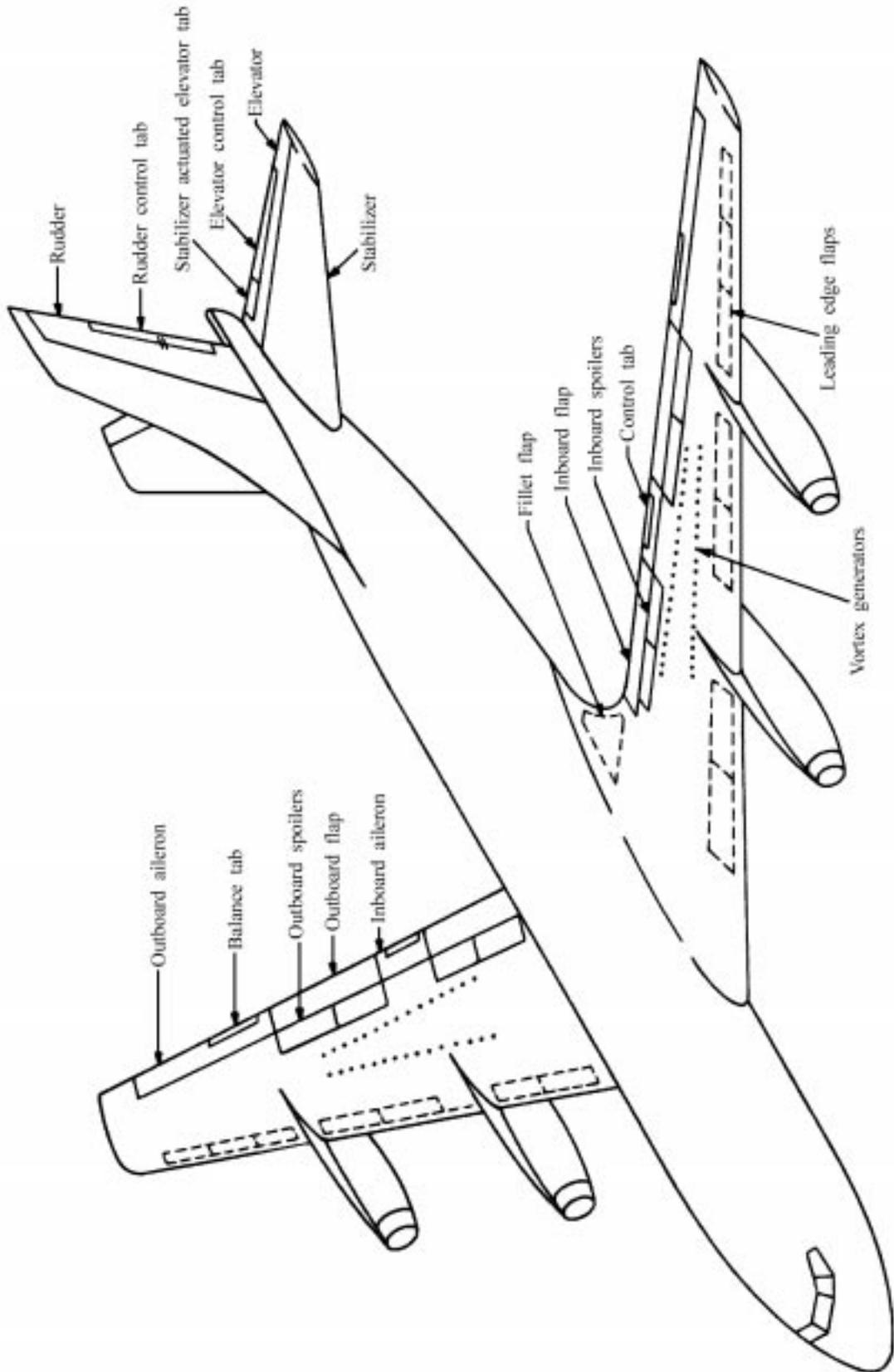
Fig.34. Control surface on a large turbojet aircraft.

Large aircraft may use all-metal ailerons, except for fibber glass tailing edges, hinged to the rear wing spar in at least four place. Fig. 33 shows several examples of aileron installation.

All the control surfaces of a large turbojet aircraft are shown in Fig. 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 aeroplane. 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 aluminium honeycomb panels. Exposed honeycomb edges are covered with sealant and protective finish. The aileron nose taper and extends forward of the aileron hinge line. Each inboard aileron is positioned between the inboard and outboard 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 aluminium 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 (Fig. 35) reduce the force necessary to position and hold the ailerons. The balance panels may be made of aluminium honeycomb skin bonded to an aluminium frame, or of aluminium 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.
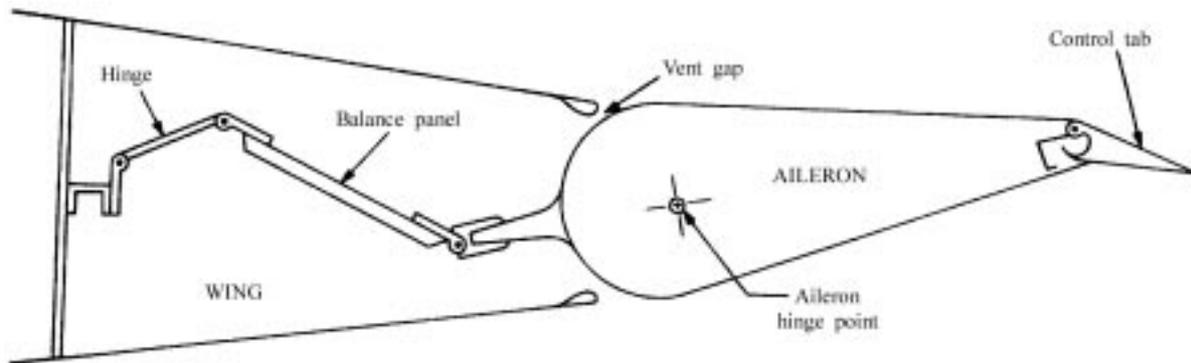
Fig. 35. Aileron balance panel.

Air loads on the balance panels (Fig.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 the ailerons rotate from the streamline position. 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.

Elevators

Elevators are the control surfaces which govern the movement (pitch) of the aircraft around the lateral axis. They are normally attached to hinges on the rear spar of the horizontal stabilizer. The construction of an elevator is similar to that of other control surfaces, and the design of the elevator may be unbalanced or balanced aerodynamically and/ or statically. Typical elevator installations for light aircraft and transports are shown in Fig.5.24 and 5.25.
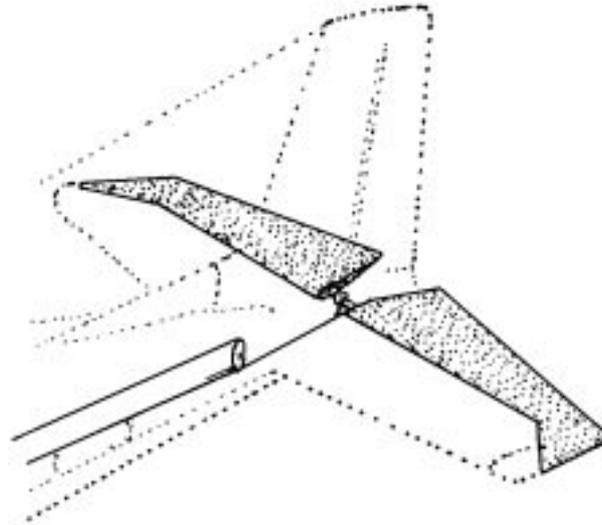
Fig.5.24. The elevator of a light aircraft
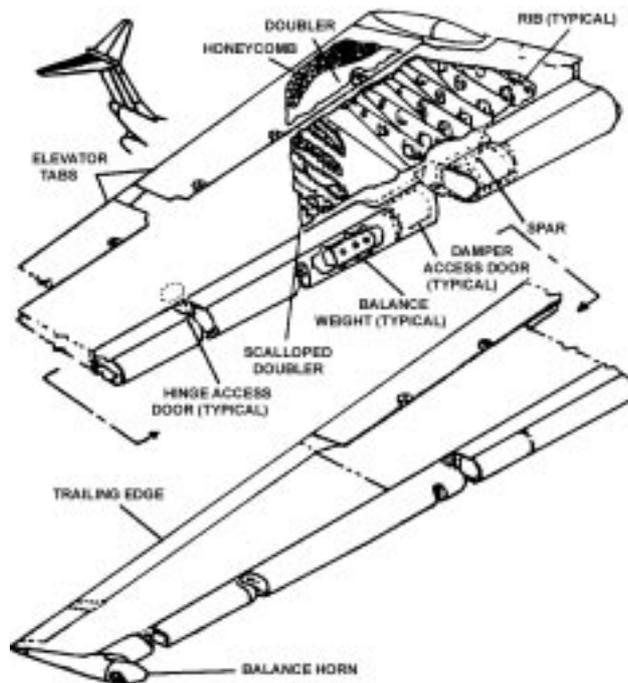
Fig.5.25. The elevator of a DC-9

Rudder

The rudder is the flight control surface that controls the aircraft movement about its vertical axis. The rudder is constructed very much like other flight control surfaces with spars, ribs and skin.

Rudders are usually balanced both statically and aerodynamically to provide for greater ease of operation and to eliminate the possibility of flutter. It should be noted that some light-aircraft rudders do not use any balancing method. Different rudders for light aircraft are shown in Fig.5.23 below.
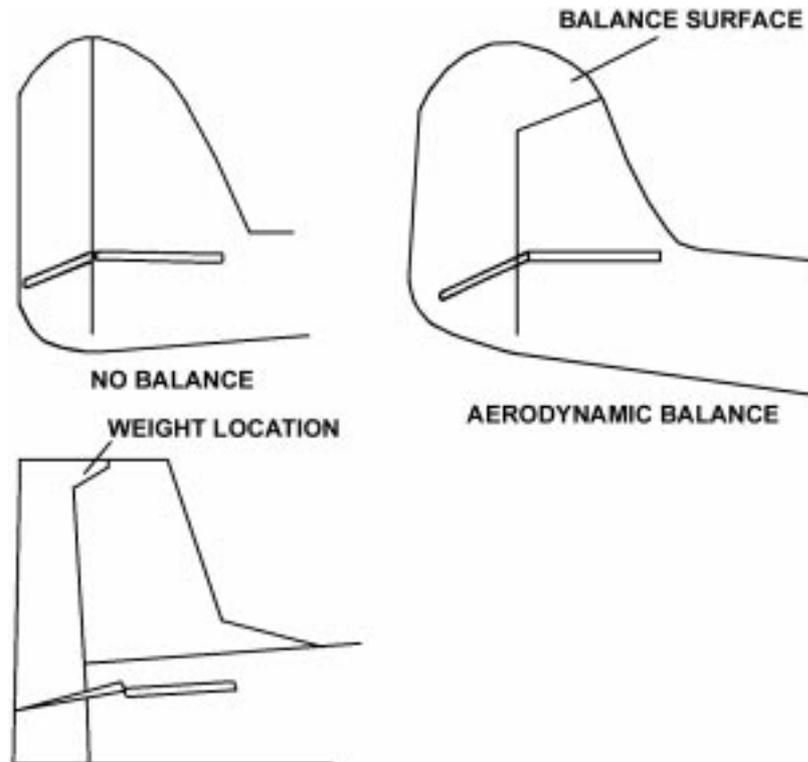
Fig.5.23. Different rudder configuration

Rudders for transport aircraft vary in basic structural and operational design. Some are single structural units operated by one or more control systems. Others are designed with two operational segments which are controlled by different operating systems and provide a desired level of redundancy.

A single-unit rudder is capable of being operated by three different hydraulic systems in the aircraft. A rudder with an upper and a lower segment of which each segment can be operated by a different hydraulic systems.

The rudder with of two segments consists of upper and lower, and each segment consists of a forward and aft section. The forward rudder sections are attached to hinge brackets mounted on the rear spar of the vertical stabilizer. The aft rudder sections are supported by hinge brackets attached to the rear spar of the forward sections. The aft rudder sections are hinged to the forward sections and connected by pushrods to the vertical stabilizer structure. This provides aft-section displacement proportional to forward-section displacement, thus increasing the aerodynamic efficiency of the rudders. Trim and control tabs are not required with this type of rudder design because their functions are performed by the aft sections of the rudder.

Flaps

Wing flaps are used to give the aircraft extra lift. They reduce the landing speed, thereby shortening the length of the landing roll out 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 Fig. 36. The plain flap (Fig. 36A) forms the trailing edge of the wing when the flap is in the up (or retracted) position. It contains both the upper and lower surface of the wing trailing edge.

The plain split flap (Fig. below) is normally housed flush with the under surface 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 (Fig. 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

Fig. 36.Wing flaps.

Fig. 37.Triple slotted trailing edge flap.

Fig.38. Cross section of a leading edge flap.

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 Fig. 37. This type of trailing edge flap system provides high lift for both takeoff and landing. Each flap consists of a fore flap, a mid-flap, and an aft-flap. The chord length of each flap expands as the flap is extended, providing greatly increased flap area. The resulting slots between flaps prevents separation of the airflow over the flap area.

The leading edge flap (Fig. 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.

Fig.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 goose neck hinges attached to fittings in the fixed wing leading edge, and hinged fairing is installed on the trailing edge of each flap. Fig.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 brake, themselves are manufactured in many 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 aluminium 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. Fig. 40 shows the location of a typical rudder tab.

Fig.39. Leading edge flap.

Fig,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 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 tail wheel or a nose wheel. Landing gear arrangements having a nose wheel are usually equipped for nose wheel steering. Nose wheel aircraft are protected at the fuselage tail section with a tail skid or bumper. By means of wheels and tyres (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 aluminium 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 panelling 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 stencilled identification number that is identical to a number stencilled near the opening that they cover. Other access and inspection doors have a stencilled 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 aluminium 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 aluminium bulkheads, extruded longerons, and skin panels or of welded tubular steel.

The major structural components of one type of helicopter are shown in Fig. 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 aluminium 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 aluminium tubing in some models.
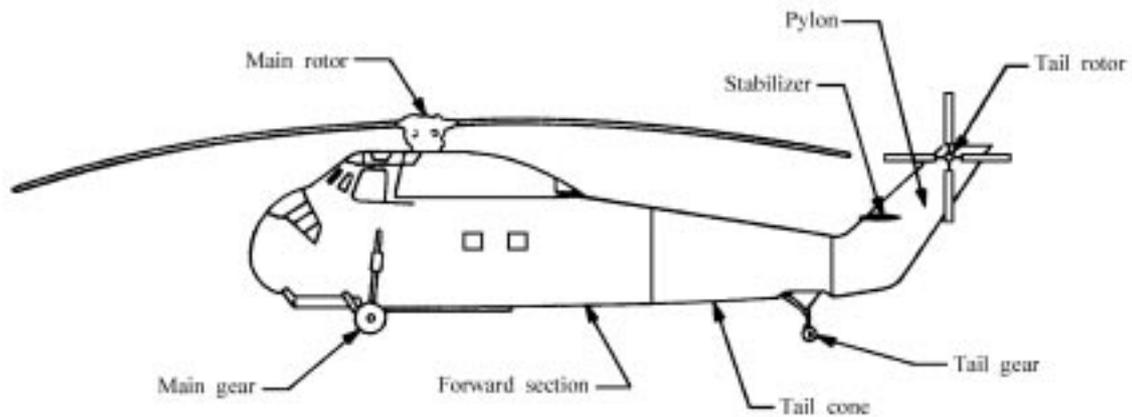
Fig. 41.Typical helicopter structural component.

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

TAIL CONE SECTION
H. Fin
J. Tail cone
K. Tail-cone housing
L. Pylon
M. Tail-end fairing
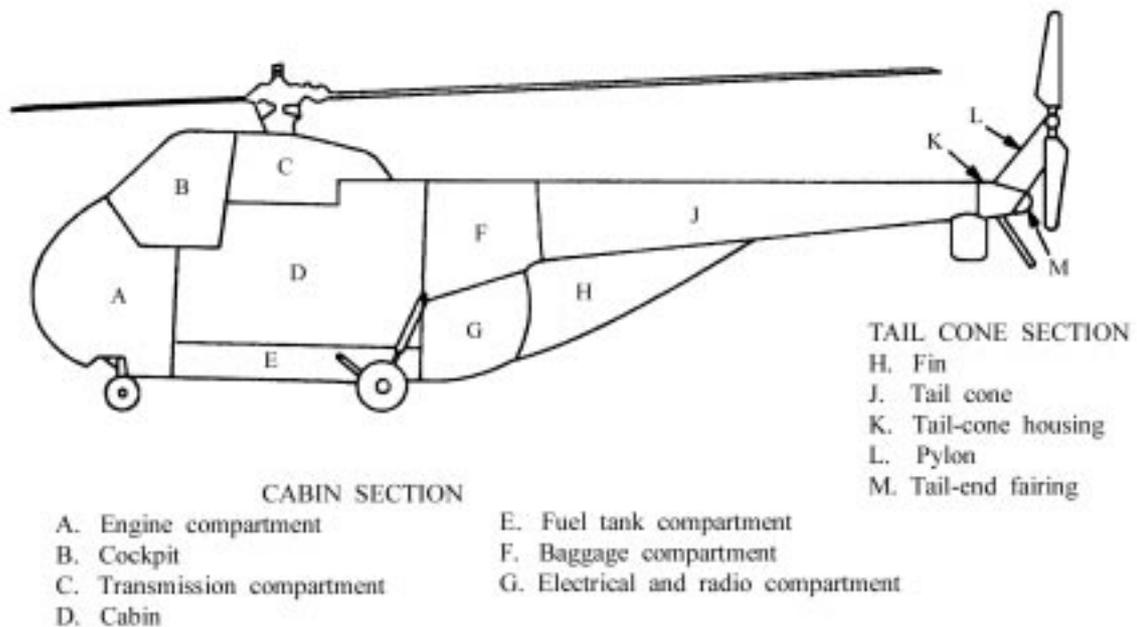
Fig.42. Location of major helicopter components.

A large single-rotor helicopter is shown in Fig. 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 power plants are usually mounted in separate engine nacelles.

As shown in Fig. 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 aluminium alloy construction. The tail-cone housing is bolted to the aft end of the tail cone. Trim stabilizers extend out 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.

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

Transparent materials are used for wind shields 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 (fibber glass) as a lightweight substitute for certain metal parts, since fibber glass is simple to manufacture, has a high strength weight ratio, and resists corrosion.

CHAPTER: 2
HYDRAULIC SYSTEMS

GENERAL PRINCIPLES

Hydraulics is a method of transmitting power through pipes and control devices, using liquid as the operating medium. For certain applications hydraulic systems are used in preference to mechanical or electrical systems for a number of reasons, among which are ease of application of force , ability to increase the applied force as necessary, ease of routing of pipelines, and elimination of backlash between components.

(i) Liquids are, for most practical purposes, incompressible, and this fact enables movement to be transmitted through pipelines, over great distances, without loss of time or motion. However, liquids will expand or contract as a result of temperature changes, and a relief valve is necessary, to prevent damage from excessive pressures, in any closed system which may be subjected to large changes of temperature.

(ii) In a closed static system, pressure exerted on a liquid is transmitted equally in all directions. Below Fig.1 shows a simple arrangement of pistons, cylinders and pipes, which uses this principle to obtain mechanical advantage. The area of piston A is 10 mm^2, and the force applied to it is 10N,. The pressure in the liquid is, therefore, $10N/mm^2$, which is transmitted undiminished to piston B. The area of piston B is $100mm^2$, and the force exerted upon it is thus 100N, representing a mechanical advantage of 10:1. This advantage is obtained at the expense of distance, however, because the area of piston B is 10 times that of piston A and piston B will move only one tenth the distance of piston A.
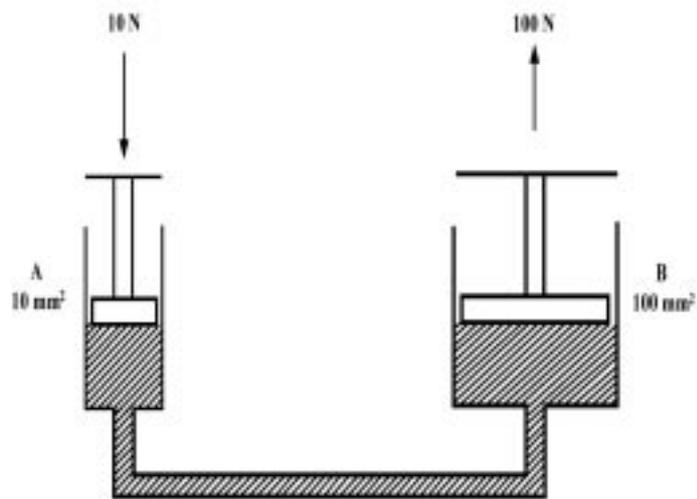
Fig.1 Mechanical Advantage By Hydraulic Means.

(iii) When liquid is in motion, its dynamic characteristics must also be taken into consideration. Friction exist between the molecules of a liquid, and between the liquid and the piping through which it flows; this friction increases with any increase in viscosity or velocity of the liquid. Friction results in some of the power available from a pump being transformed into heat, and in a reduction in pressure throughout the pipelines.

(iv) Any restriction in a pipeline will increase liquid velocity and produce turbulence, resulting in reduced pressure downstream of the restriction. This fact is often exploited in system design and a restrictor is also used to limit the rate of liquid flow, and thus the rate of movement of components such as the landing gear or flaps.

HYDRAULIC FLUIDS

Almost any sort of liquid could be used in a hydraulic system, but the special requirements of aircraft systems have resulted in the use of vegetable, mineral and synthetic-based oils (known as hydraulic fluids) which have the following properties :-

a) They provide good lubrication of components.
b) Their viscosity is low enough to minimise friction in pipelines and to allow high-speed operation of motors and pumps, but high enough to prevent leakage from components.
c) They prevent internal corrosion in the system.
d) They have a wide operating-temperature range.

Fluids are colored for recognition purposes, and fluids to different specifications must never be mixed; fluids to the same specification, but produced by different manufacturers, may be mixed when permitted by the appropriate Maintenance Manual. Use of a fluid which is not approved for a particular system may result in rapid deterioration of seals, hoses and other nonmetallic parts, and may render the system inoperative.

i) Vegetable-based fluid is normally almost colorless, and must be used with pure rubber seals and hoses. It is used in some braking systems, but is not often found in hydraulic power systems.

ii) Mineral-based fluid is normally coloured red, and must be used with synthetic rubber seals and hoses. It is widely used in light aircraft braking systems, hydraulic power systems, and shock-absorber struts.

iii) Phosphate ester based fluid is widely used on modern aircraft, mainly because of its fire-resistance and

extended operating-temperature range. It may be coloured green, purple or amber, and must only be used with butyl rubber, ethylene propylene or tebblon seals and hoses.

iv)   In view of the incompatibility of different fluids, it is important that any containers, or test rigs, used for servicing aircraft, are clearly marked with the type of fluid they contain.

PUMPS

Most modern aircraft are fitted with either fixed volume or variable volume, multi-piston type hydraulic pumps, driven from the engines. Other types of pumps, such as gear or vane positive displacement pumps, may be found in some installations, but these are generally used for powering emergency systems. Hand pumps, where fitted, are often of the double-acting type.

FIXED VOLUME PUMPS

These pumps deliver a fixed quantity of fluid into the system at a particular speed of rotation, regardless of system requirements, and means must be provided for diverting pump output when it is not required in the system.

There are many types like axial piston pump, gear type pump and vane type pumps.

Axial Piston Pump

The cylinder block and drive shaft rotate together, and because of the angle between the cylinder block and shaft axes, each piston moves into and out of its cylinder once each revolution. The stationary valve block has two
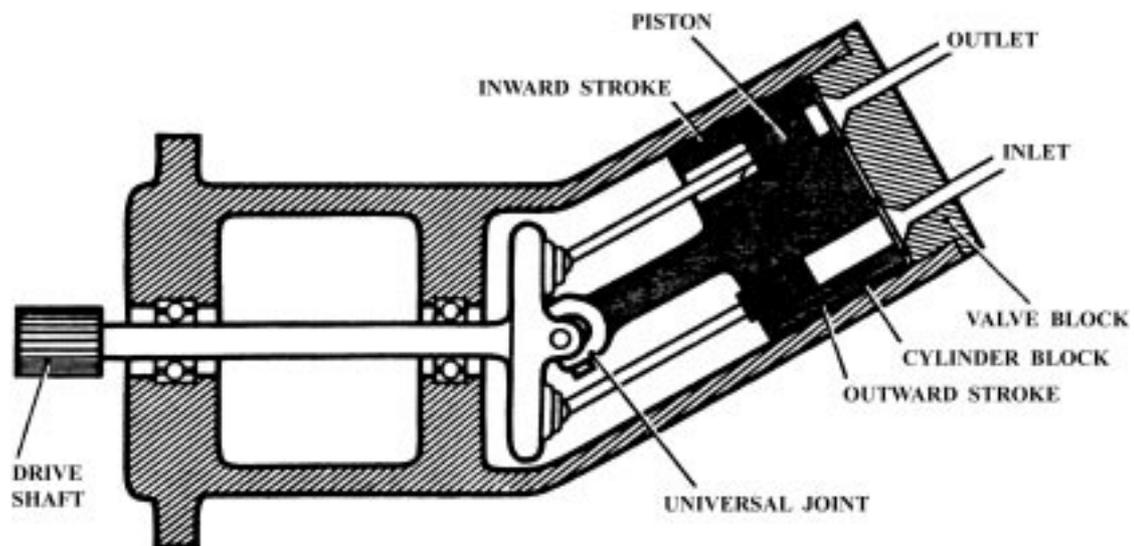
Fig. 2. Axial Piston Pump.

circumferential slots leading to the top of the cylinder block, which are connected to the fluid inlet and outlet ports, and are arranged so that the pistons draw fluid into the cylinders on the outward stroke, and expel fluid into the system on the inward stroke.(See Fig.2)

Gear Type Pump

The gear type power pump consists of two meshed gear that revolve in a housing, the driving gear is driven by aircraft engine or some other power unit, the driven gear meshes with and is driven by driving gear. Clearance between the both as they mesh and between the teeth and the housing is very small. Inlet port of the pump is connected to the reservoir and the outlet port is connected to the pressure line, when the driving gear turns in anti clockwise direction. As the gear teeth passes the inlet port, fluid is trapped between the gear teeth and housing and is then carried around the housing to the out let port. (See Fig.3)
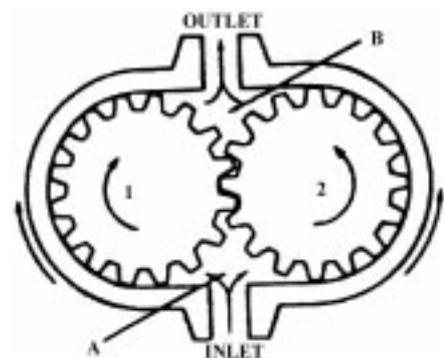
Vane Type Pump

Pump consists of a housing containing four vanes or blades, a hollow steel rotor with slots for the vanes and a coupling to turn the rotor. The rotor is positioned off center within the sleeve. The vanes which are mounted in the slots in the rotor, together with the rotor decide the boar of the sleeve into four sections. As the rotor turns each section in the turn passes one point where its volume at a minimum and another point where its volume is at a maximum. The volume gradually increases from

Fig.3. Gear Type Pump.
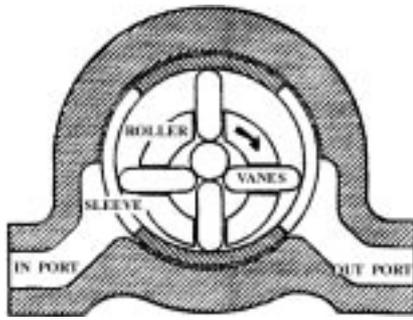
Fig.4. Vane Type Pump.

minimum to maximum during one half of a revolution and gradually decrease from maximum to minimum during the second half of the revolution as the volume of a given section is increasing, that section is connected to the pump inlet port, through a slot in the sleeve. Since a partial vacuum is produced by a increase in volume of the section, fluid is drawn into the section through the pump inlet port and the slot in the sleeve. As the rotor turns through the second half of the revolution and the volume of the given section is decreasing fluid is displaced out of the section through the slot in the sleeve through the outlet port to the system.(See Fig.4)
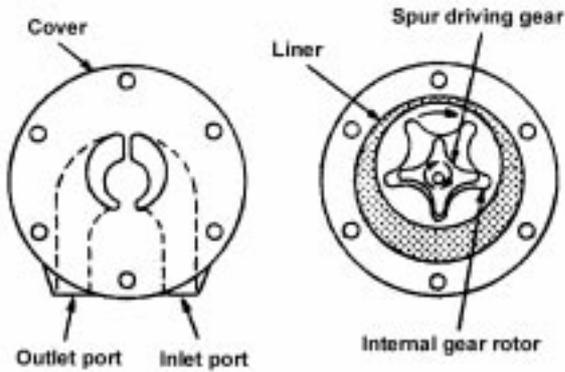
Gerotor Type Pump

A gerotor-type power pump (Fig.5) consists essentially of a housing containing an eccentric-shaped stationary liner, an internal gear rotor having five wide teeth of short height, a spur driving gear having four narrow teeth, and a pump cover which contains two crescent-shaped openings. One opening extends into an inlet port, and the other extends into an outlet port. The pump cover as shown in Fig. has its mating face turned up to clearly show the crescent-shaped openings. When the cover is turned over and properly installed on the pump housing, it will have its inlet port on the left and the outlet port on the right.

During the operation of the pump, the gears turn clockwise. As the pockets on the left side of the pump move from a lowermost position toward a topmost position, the pockets increase in size (Fig.5) resulting in the production of a partial vacuum within these pockets. As the pockets open at the inlet port, fluid is drawn into them. As these same pockets (now full of fluid) rotate over to the right side of the pump, moving from the topmost position toward the lowermost position, they decrease in size. This results in the fluid being expelled from the pockets through the outlet port.

Fig.5. Gerotor-Type Power Pump.

VARIABLE VOLUME PUMP

This type of pump is similar in construction to the fixed volume pump described in pump described in before, but
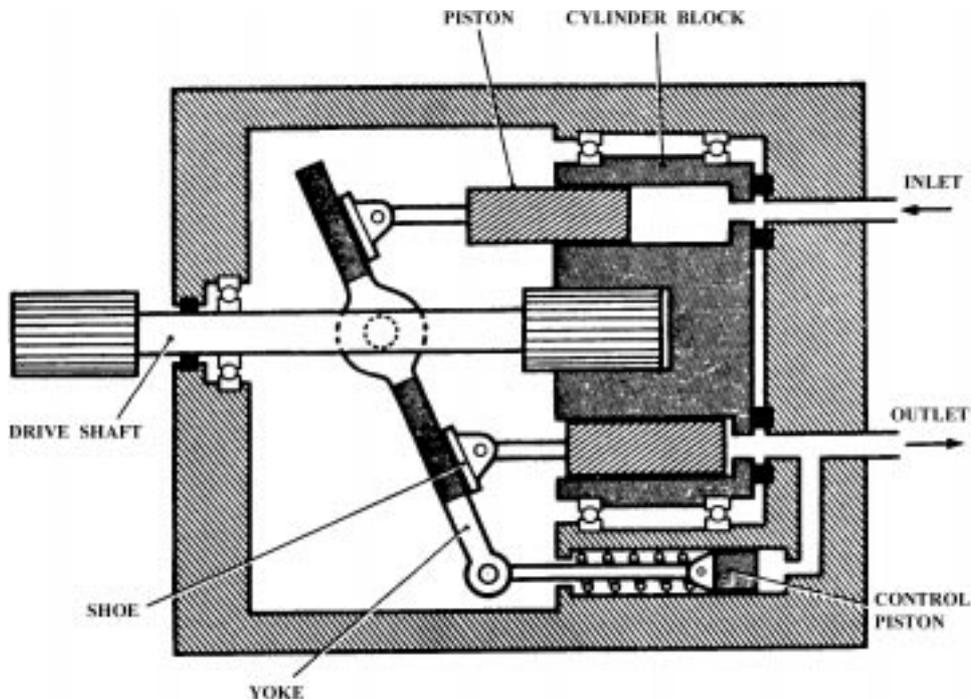
Fig.6. Variable Volume Pump.

the cylinder block and drive shaft are co-axial. The pistons are attached to shoes which rotate against a stationary yoke, and the angle between the yoke and cylinder block is varied to increase or decrease pump stroke to suit system requirements. Fig. 6 shows the operation of the pump. When pressure in the system is low, as would be the case following selection of a service, spring pressure on the control piston turns the yoke to its maximum angle, and the pistons are at full stroke, delivering maximum output to the system. When the actuator has completed its stroke, pressure builds up until the control piston moves the yoke to the minimum stroke position; in this position a small flow through the pump is maintained, to lubricate the working parts, overcome internal leakage and dissipate heat. On some pumps a solenoid-operated depressurizing valve is used to block delivery to the system, and to off-load the pump.

HAND PUMPS

A hand pump is included in some aircraft installations, for emergency use and for ground servicing operations. Fig.7 illustrates a double-acting hand pump (i.e. a pump which delivers fluid on each stroke). As the piston moves upward in the cylinder, fluids drawn in through a non-return valve (NRV) at the inlet connection into the cylinder; at the same time fluid above the piston is discharged through a non-return valve in the outlet connection. As the piston moves downwards, the inlet NRV closes and the transfer NRV opens, allowing fluid to flow through the piston; since the area below the piston is larger than the area above the piston, part of this fluid is discharged through the outlet port. When pressure in the outlet line exceeds the relief valve setting, discharged fluid is by-passed back to the pump inlet.
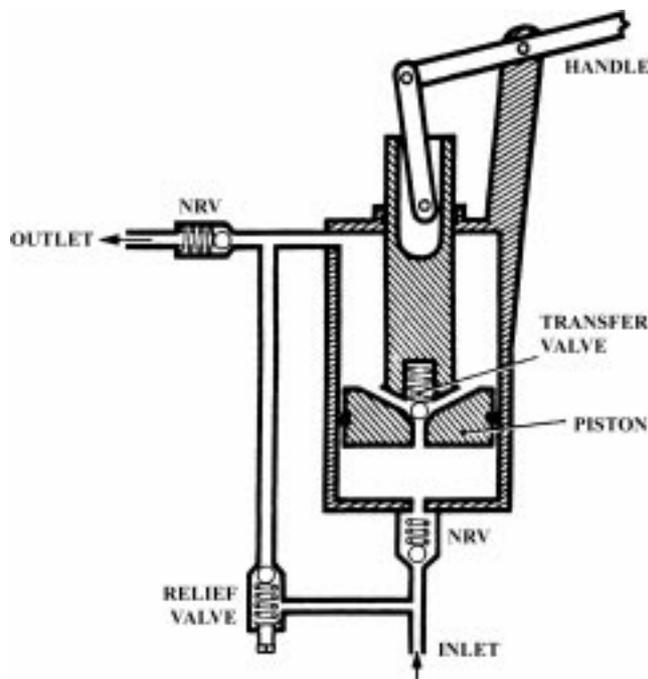
PRESSURE CONTROL

Maximum system pressure is often controlled by adjustment of the main engine-driven pump, but a number of other components are used to maintain or limit fluid pressures in various parts of a hydraulic system, and these sometimes have additional functions.

Fig.7. Double Acting Hand Pump.

Relief Valves

A relief valve is the simplest form of pressure limiting device, and may be used by itself, or within larger components. A relief valve is frequently used as a safety device, e.g. a thermal relief valve, in which case it is adjusted to blow-off at a pressure slightly higher than normal system pressure, and is normally designed to relieve only a small quantity of fluid. In some systems a full-flow relief valve is fitted downstream of the pump, to by-pass full pump output to the reservoir in the event of failure of the cutout valve, or of blockage elsewhere in the system. A simple ball-type relief valve and full-flow relief valve are shown in Fig.8.
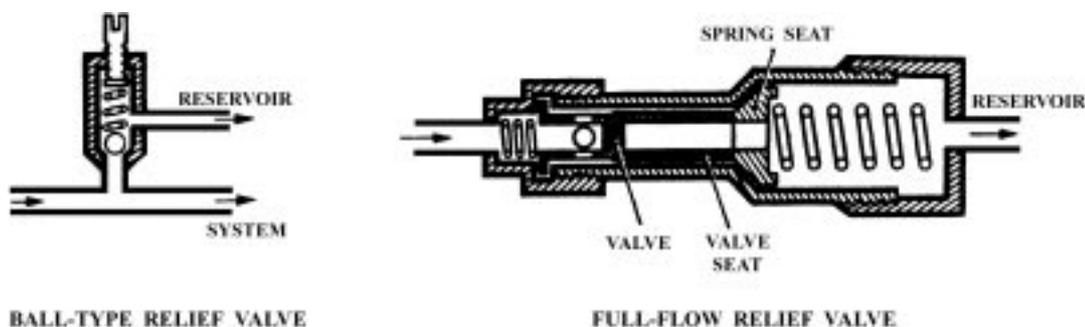
Fig.8. Relief Valves.

Cut-Out Valves

A cut-out valve is fitted to a system employing a fixed volume pump, to provide the pump with an idling circuit when no services have been selected. An accumulator is essential when a cut-out is fitted, since any slight leakage through components, or from the system, would result in operation of the cut-out, and in frequent loading and unloading of the pump.
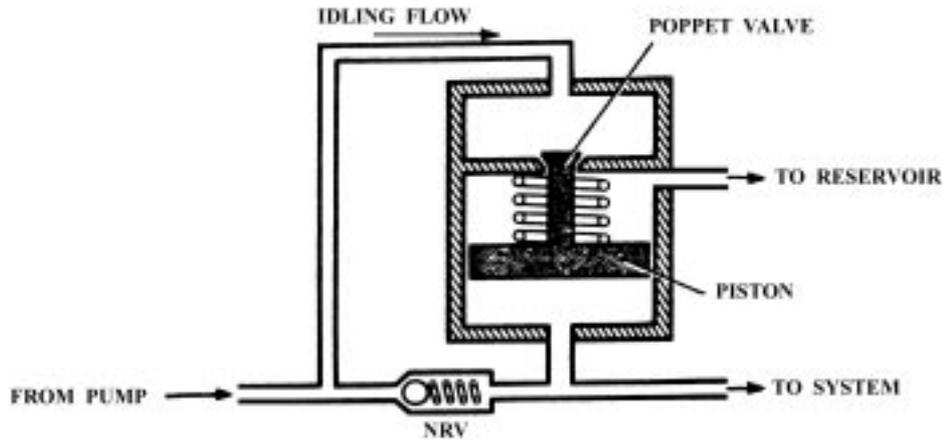
Fig.9. Cut-Out Valve.

Above Fig.9 shows the operation of a cut-out valve. When a service has been selected and the pump is delivering fluid to the system, the NRV is open and equal pressure is applied to the poppet valve and piston; the force of the spring combined with the pressure on the poppet valve, is greater than the force on the piston, so the valve is closed and the return line to reservoir is blocked. When the service selected has completed its travel, pressure builds up in the delivery line to the system until the force applied to the piston is sufficient to lift the poppet valve off its seat; this results in a sudden drop in pressure on the pump side of the poppet valve which snaps the poppet valve open and the NRV closed. Pressure in the return line drops to a low value and the load on the pump is removed. Pressure in the system is maintained by the accumulator until a further selection is made; when pressure drops, and the force on the cut-out piston becomes less than the spring force, the poppet valve closes and pump output is again directed into the system.

Pressure Maintaining Valves

A pressure maintaining valve, or priority valve, is basically a relief valve which maintains the pressure in a primary service at a value suitable for operation of that service, regardless of secondary service requirements. When main system pressure exceeds this pre-determined value, the spring load is overcome, and the valve opens to allow main system pressure to reach the secondary service. A pressure maintaining valve is generally used to safeguard operation of important services such as flying controls and wheel brakes. Fig.10 shows a valve in the open position, pressure being sufficient to move the piston against spring pressure and connect the main supply to the sub-system.

Pressure Reducing Valves

A pressure reducing valve is often used to reduce main system pressure to a value suitable for operation of a service
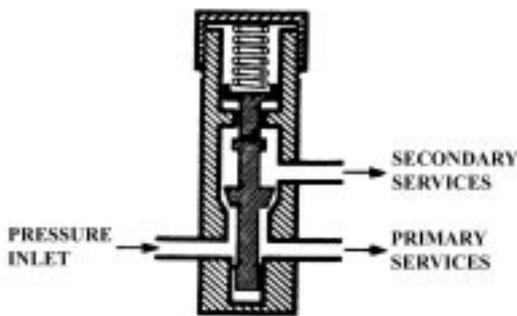
Fig.10. Pressure Maintaining Valve.
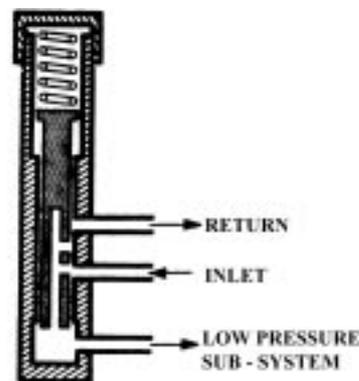
Fig.11. Pressure Reducing Valve.

such as the wheel brakes. (Fig.11) illustrates a pressure reducing valve, which also acts as a relief valve for the service operating at reduced pressure. Fluid enters the inlet port, and flows through the valve to the sub-system; when the fluid pressure exceeds the spring-loading on the valve, the valve is lifted and gradually covers the inlet port until sub-system pressure reaches the specified value. If sub-system pressure increases for any reason, the valve is lifted further and uncovers the return port to relieve excess pressure.
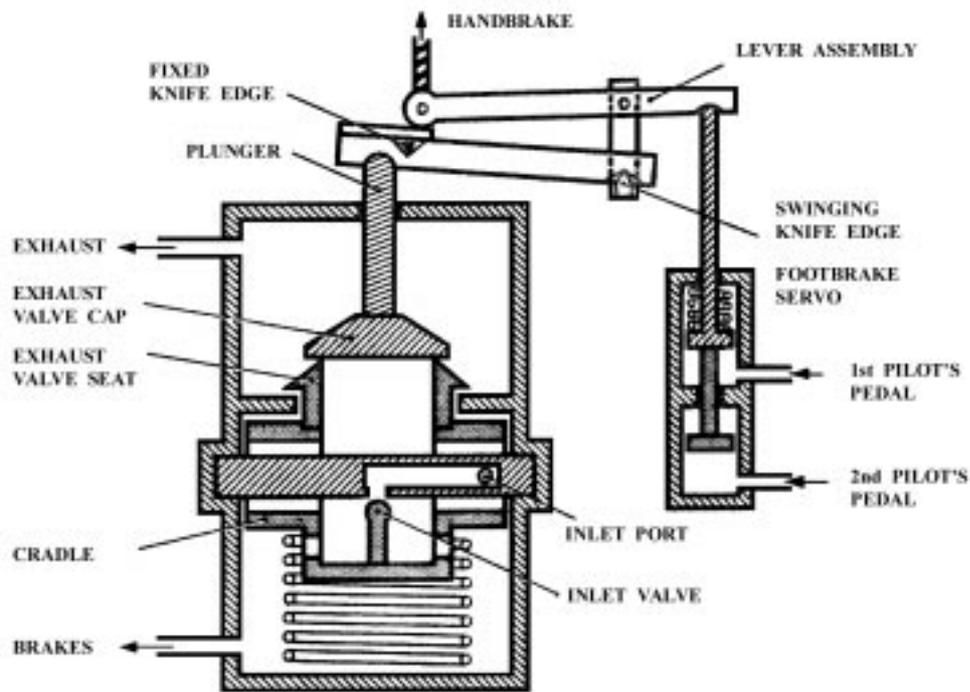
Fig.12. Brake Control Valve.

Brake Control Valves

A brake control valve is essentially a variable pressure reducing valve, which controls pressure in the brake system according to the position of the pilots' brake pedals. The valve usually contains four elements, one pair for the brakes on each side of the aircraft, to provide duplicated control. Fig.12 illustrates a single element, in this case operated by a slave servo from the brake pedal.

When either pilot's brake pedal on the appropriate side is depressed, or the hand brake is operated, the servo piston applies load to the linkage on the control valve, which, via the lever assembly and plunger, presses down the exhaust valve cap. This action initially closes the gap between the exhaust valve cap and the exhaust valve, valve seat, then moves the cradle down to open the inlet valve, and to direct fluid to the brakes. Pressure builds up in the brakes and valve, until it is sufficient, assisted by the spring, to overcome the inlet pressure, to force the cradle and exhaust valve seat against the exhaust valve cap, and to close the inlet valve. An increase in the load applied to the valve linkage will be balanced by increased delivery pressure, and a decrease in the load applied will be balanced by relief of delivery pressure past the exhaust valve. When the brake pedals are released, the exhaust valve cap lifts, and exhausts pressure from the brakes to the reservoir.

FLOW CONTROL

The components described in this paragraph are used to control the flow of fluid to the various services operated by the hydraulic system.
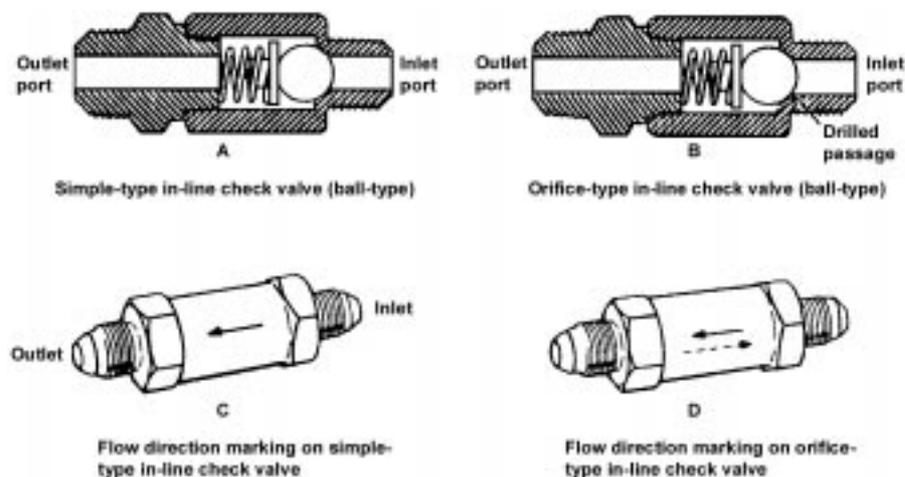
Fig.13. NRV (Check Valves).

Non-return Valves (Check Valves)

The most common device used to control the flow of fluid is the non-return valve, which permits full flow in one direction, but blocks flow in the opposite direction. Simple ball-type non-return valves are included in Fig.13 but design may vary considerably. When a non-return valve is used as a separate component, the direction of flow is indicated by an arrow moulded on the casing, in order to prevent incorrect installation.
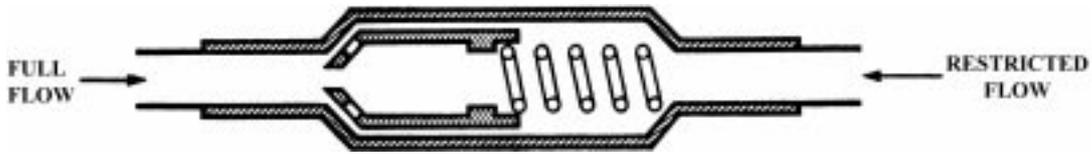
Fig.14.   Restrictor Valve.

Restrictor Valves

A restrictor valve may be similar in construction to a non-return valve, but a restrictor valve is designed to permit limited flow in one direction and full flow in the other direction; the restriction is usually of fixed size, as shown in Fig 14. A restrictor valve is used in a number of locations, in order to limit the speed of operation of an actuator in one direction only. It may, for instance, be used to slow down flap retraction or landing gear extension.

SELECTORS

The purpose of a selector is to direct fluid to the appropriate side of an actuator, and to provide a return path for fluid displaced from the opposite side of that actuator. Many selectors are simple four-way valves, connecting the pressure and return lines to alternate sides of the actuator, without a neutral position, but selectors in open-centre

4-WAY ROTARY VALVE   4-WAY ROTARY VALVE   4-WAY SLIDE VALVE
WITH BLOCKED NEUTRAL   WITH OPEN NEUTRAL   WITH BLOCKED NEUTRAL

P = PRESSURE

R = RETURN

A = ACTUATOR

4-WAY AUTO - RETURN SLIDE VALVE WITH BLOCKED NEUTRAL
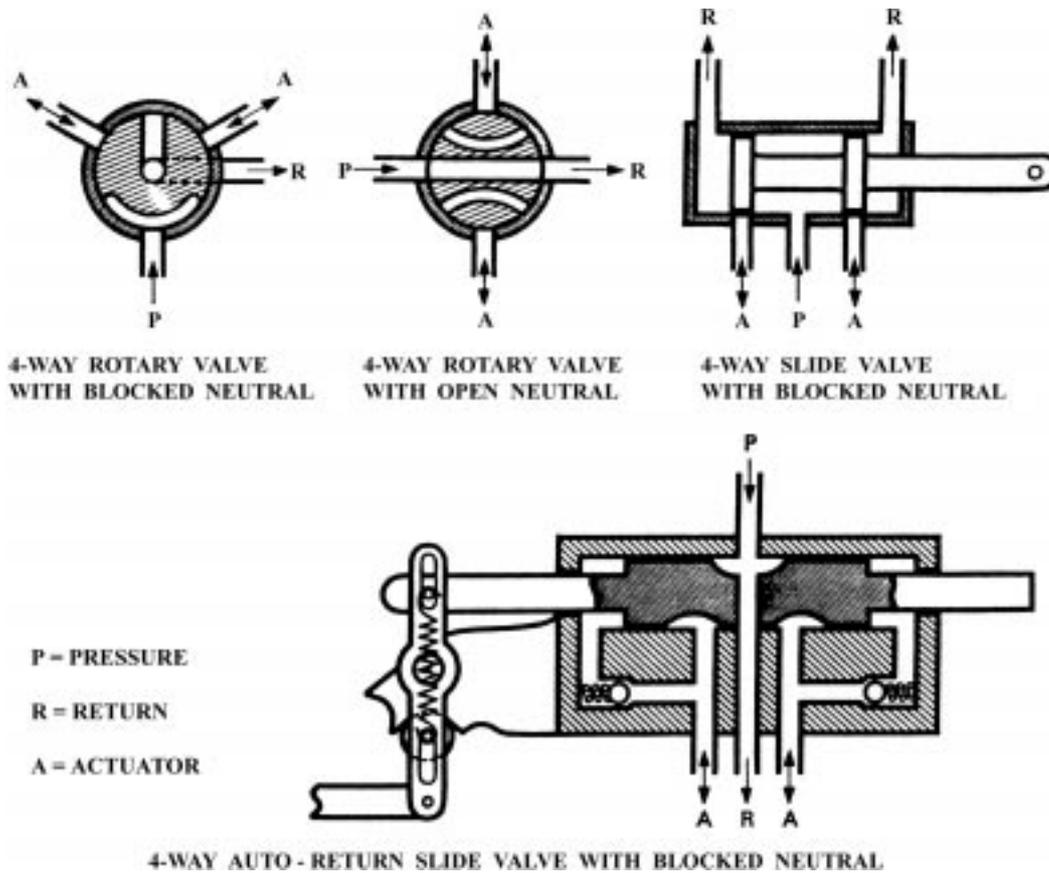
Fig.15.   Manual Selector Valve.

systems often lock fluid in the actuators while providing an idling circuit for the pump. Selector valves are generally manually operated, and some typical examples are illustrated in Fig. 15.

It is sometimes necessary to be able to hold the actuator in an intermediate position. On some aircraft this is achieved by using a selector which blocks both lines to the actuator when it is in the neutral position, the selector being manually returned when the desired actuator position is reached. However, as this could be distracting for the pilot at a critical stage of flight, a feed-back mechanism is often used, which automatically returns the selector to neutral whenever a
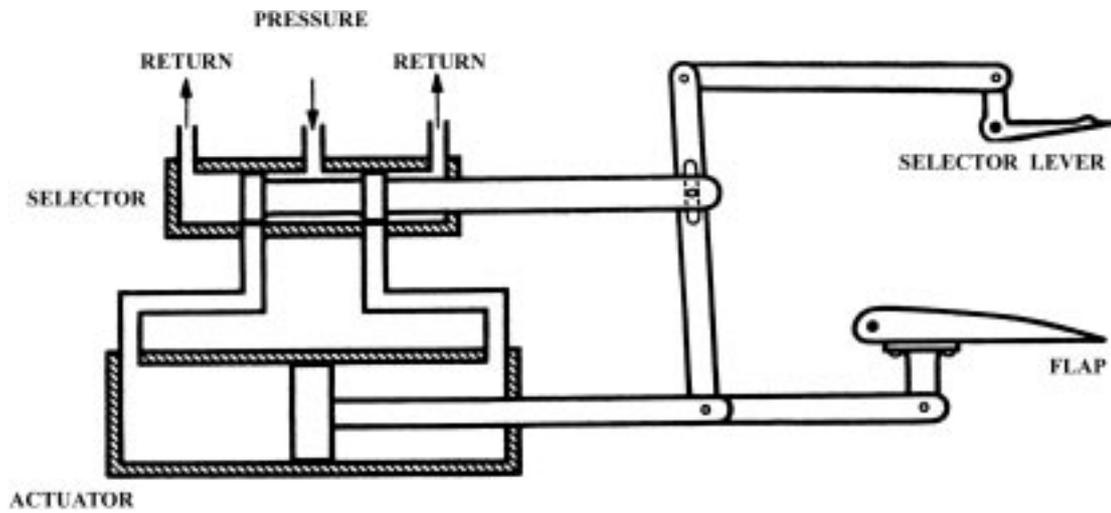
Fig.16. Follow-Up Linkage.
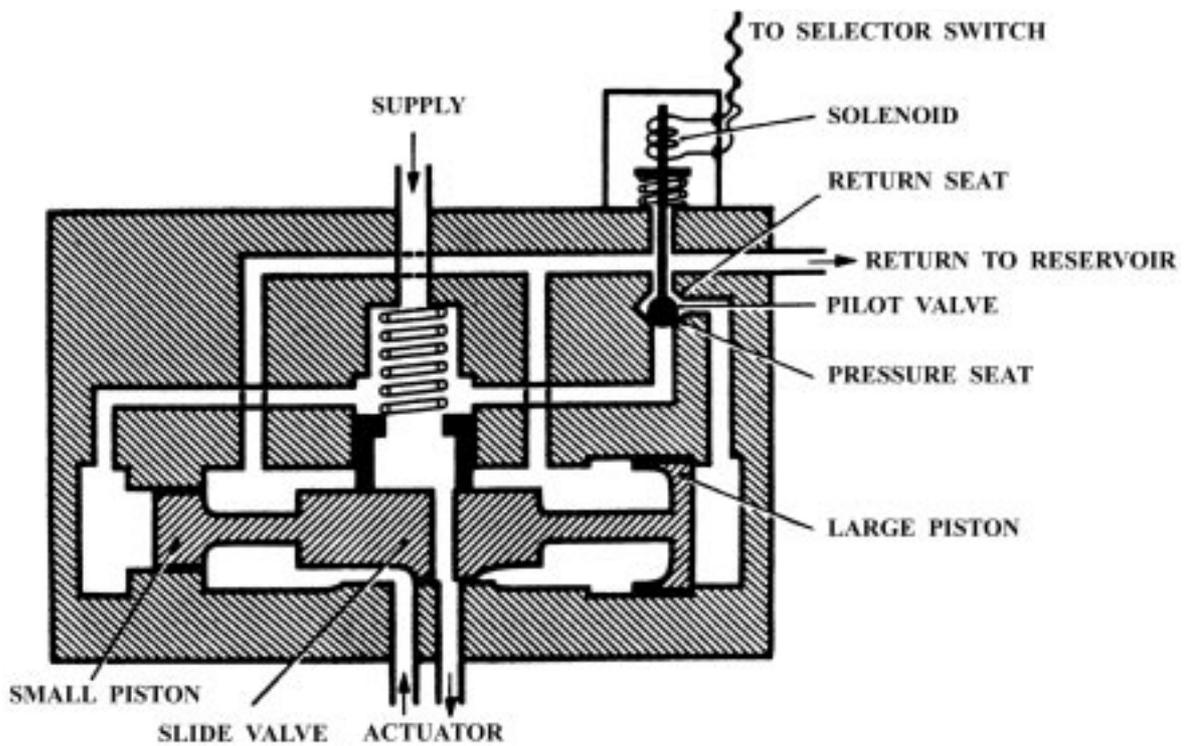
Fig.17. Electrical Selector Valve (2 Ways).

selected position is reached. Fig.16 shows, diagrammatically, a method which is used in a flap circuit to enable any intermediate position to be held; the selector would normally operate in a gated quadrant.

Electrically-operated Selectors

It is sometimes convenient to locate a selector valve at a position remote from the crew compartment, and to eliminate the need for extensive mechanical linkage the selector is normally operated electrically. The selector shown in Fig.17 is a typical electrically-operated two-way valve, which may be used, for example, for emergency operation of the flaps or landing gear. With the solenoid de-energized, the pilot valve is spring-loaded against the return seat, and fluid from the emergency system passes to both sides of the slide valve. Since the right hand end of the valve is of large diameter than the left the valve moves to the left and fluids passes to the actuator to extend its ram; fluid from the opposite side of the actuator passes through the selector to the return line. With the solenoid energised, the pilot valve is held against the pressure seat, and supply pressure acts on the left hand side of the slide valve only, the right-hand side being open to return; the slide valve moves to the right, and directs fluid to retract the actuator ram, the opposite side of the actuator being open to return.
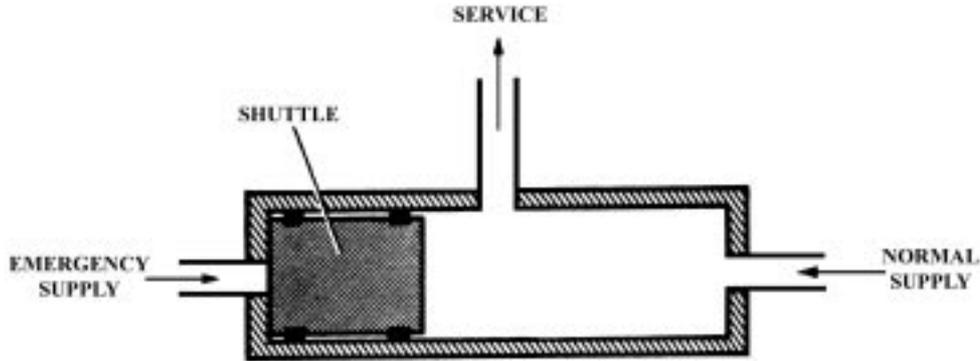
Fig.18.   Shuttle Valve.

SHUTTLE VALVES

These are often used in landing gear and brake systems, to enable an emergency system to operate the same actuators as the normal system. During normal operation, free flow is provided from the normal system to the service and the emergency line is blocked. When normal system pressure is lost and the emergency system is selected, the shuttle valve moves across because of the pressure difference, blocking the normal line and allowing emergency pressure to the actuator. A typical shuttle valve is shown in Fig. 18.
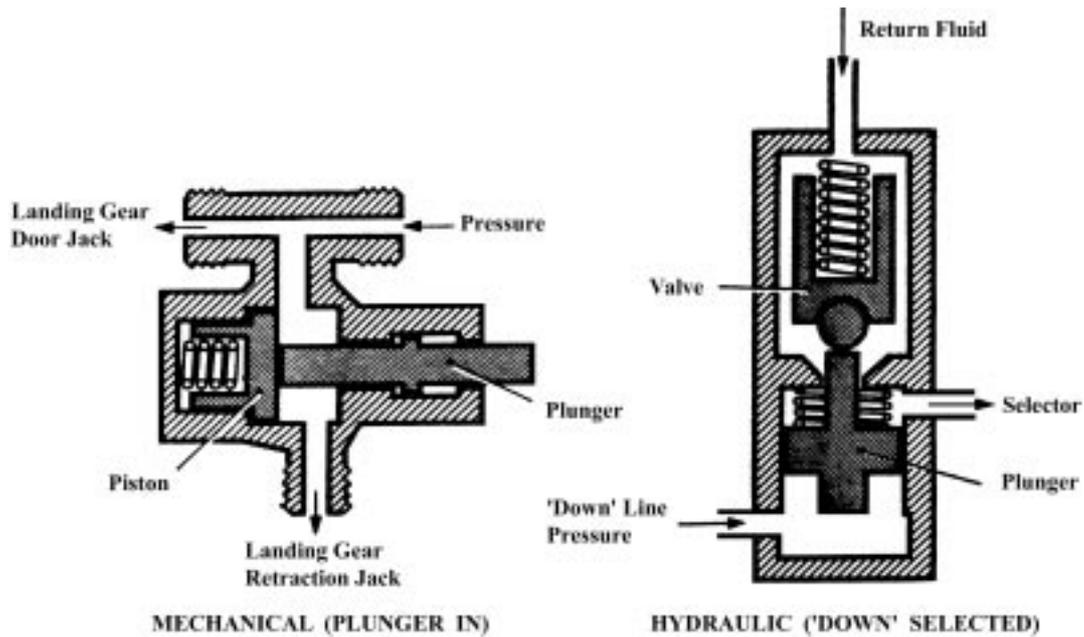
Fig. 19. Sequence Valve.

SEQUENCE VALVES

Sequence valves are often fitted in a landing gear circuit to ensure correct operation of the landing gear doors and jacks. Examples of mechanically operated and hydraulically operated sequence valves are illustrated in Fig.19.

Mechanically operated sequence valves ensure that the landing gear does not extend until the doors are open, and that the landing gear is retracted before the doors close. Completion of the initial movement in the sequence results in part of the mechanism operating the plunger of the sequence valve, and allowing fluid to flow to the next actuator.

During extension of the landing gear, pressure in the 'up' lines could exceed pressure in the 'down' lines, because of the force of gravity acting on the landing gear, and thus result in partial closing of the doors. This is prevented by fitting a hydraulically operated sequence valve in the 'up' line, which blocks return flow until down line pressure, acting on the plunger, is sufficient to overcome the spring and open the valve. The ball valve is virtually a non-return valve, which does not significantly restrict flow when the landing gear is selected up.
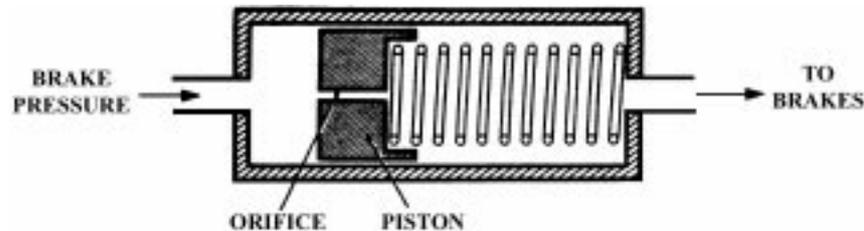
Fig.20. Modulator.

MODULATORS

A modulator is used in conjunction with the anti-skid unit in a brake system. It allows full flow to the brake units on initial brake application, and thereafter a restricted flow. Fig.20 shows a modulator, the swept volume of which would be equal to the operating volume of the brake cylinders. During initial operation of the brake control valve, the piston is forced down the cylinder against spring pressure, and the brakes are applied. Subsequent fluid feed to the brakes, necessitated by anti-skid unit operation, is through the restricting orifice, and is very limited. This limited flow allows the anti-skid unit to completely release the brakes when necessary, and conserves main system pressure. When the control valve is released, the piston returns to its original position under the influence of the spring and the return fluid.
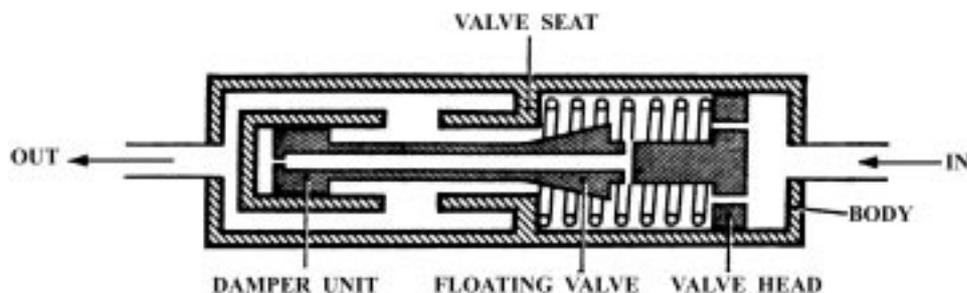
Fig.21. Flow Control Valve.

Flow Control Valves

A flow control valve may be fitted in a hydraulic system to maintain a constant flow of fluid to a particular component; it is frequently found upstream of a hydraulic motor which is required to operate at a constant speed. A typical flow control valve is shown in Fig.21, and consists of a body and a floating valve. Flow through the valve head is restricted by an orifice, which creates a pressure drop across the valve head. At normal supply pressure and constant demand, the pressure drop is balanced by the spring and the valve is held in an intermediate position, the tapered land on the valve partially restricting flow through the valve seat, and maintaining a constant flow through the outlet. If inlet pressure rises, or demand increases, the pressure differential across the valve head also increases, and moves the valve to the left to reduce the size of the aperture and maintain constant flow. The spring loading is increased by the valve movement, and again balances the pressure drop. Similarly, if inlet pressure drops or demand decreases, the valve takes up a new position, slightly further to the right, so as to maintain a constant flow.

ACCUMULATORS

An accumulator is fitted to store hydraulic fluid under pressure, to dampen pressure fluctuations, to allow for thermal expansion, and to provide an emergency supply of fluid to the system in the event of pump failure. A non-return valve fitted upstream of an accumulator, prevents fluid from being discharged back to the reservoir.

Three different types of accumulator are illustrated in Fig. 22, but many other types are used. Accumulators of the type shown in (a), in which the gas is in contact with the fluid, are seldom used on modern high-pressure systems, as there is a possibility that the gas may be dissolved into the fluid, and thus introduced into the system. For this reason the accumulators shown in (b) and (c) are most commonly used.

The gas side of the accumulator is charged to a predetermined pressure with air or nitrogen. As hydraulic pressure builds up in the system, the gas is compressed until fluid and gas pressures equalize at normal system pressure. At this point the pump commences to idle, and system pressure is maintained by the accumulator. If a service is selected, a supply of fluid under pressure is available until pressure drops sufficiently to bring the pump on line.

The initial gas charge of the accumulator is greater than the pressure required to operate any service, and the fluid volume is usually sufficiently large to operate any service once; except that brake accumulators permit a number of brake applications.

The gas side of an accumulator is normally inflated through a charging valve, which may be attached directly to
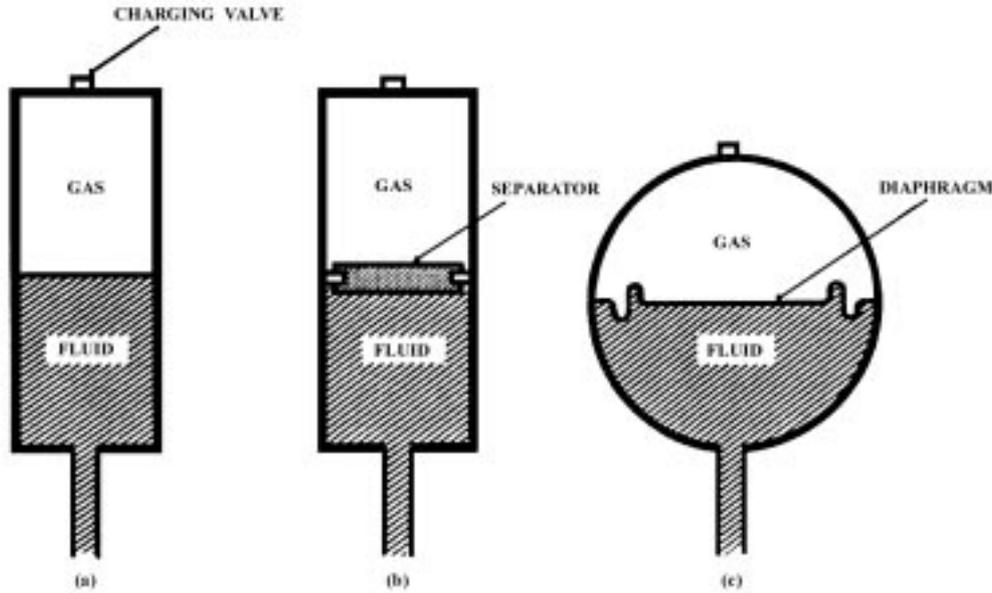
Fig.22. Accumulators.

the accumulator, or installed on a remote ground servicing panel and connected to the accumulator by means of a pipeline. The charging valve usually takes the form of a non-return valve, which may be depressed by means of a plunger in order to relieve excessive pressure.

RESERVOIRS

A reservoir provides both storage space for the system fluid, and sufficient air space to allow for any variations in the volume of fluid in the system which may be caused by thermal expansion and actuator operation. Most reservoirs are pressurized, to provide a positive fluid pressure at the pump inlet, and to prevent air bubbles from forming in the fluid at high altitude . On modern jet aircraft, air pressure is normally supplied from the compressor section of an engine, but it may be supplied from the cabin pressurization system. Air entering the reservoir is filtered, and, in some cases, provision is also made for the removal of moisture.

A reservoir also contains a relief valve, to prevent over-pressurization; connections for suction pipes to the pumps, and return pipes from the system; a contents transmitter unit and a filler cap; and, in some cases, a temperature sensing probe. In systems which are fitted with a hand pump, the main pumps draw fluid through a stack pipe in the reservoir. This ensures that, if fluid is lost from that part of the system supplying the main pumps, or supplied solely by the main pumps, a reserve of fluid for the hand pump would still be available. Show in Fig.23.

ACTUATORS

The purpose of an actuator is to transform fluid flow into linear or rotary motion. Fig.24 illustrates three types of simple linear actuator, which are used for different purposes in an
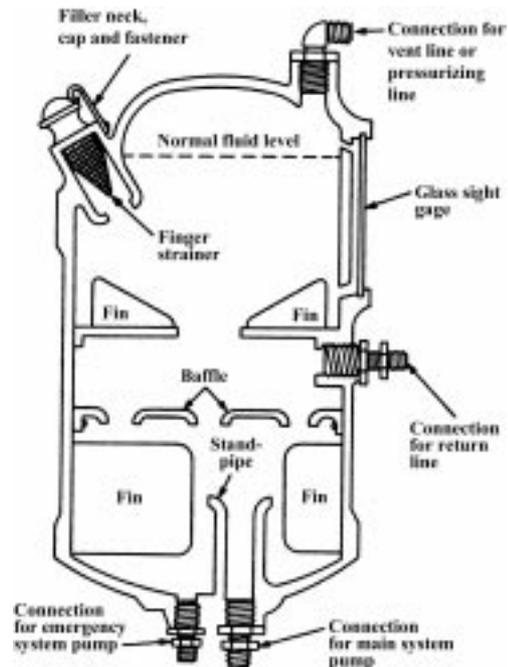
Fig.23. Reservoir, "in-line".

aircraft hydraulic system. Numerous refinements to the simple actuator will be found in use, and these may include such features as internal locking devices, auxiliary pistons and restrictors, each designed to fulfil a particular requirement. Details of a particular actuator should be obtained from the appropriate Maintenance Manual.

The single acting actuator is normally used as a locking device, the lock being engaged by spring pressure and released by hydraulic pressure. A typical application is a landing gear up-lock.

The double-acting actuator is used in most aircraft systems. Because of the presence of the piston rod the area of the top of the piston is greater than the area under it. Consequently, more force can be applied during extension of the piston rod. Therefore, the operation which offers the greater resistance is carried out in the direction in which the piston rod extends; for example, in raising the landing gear.

A balanced actuator, in which equal force can be applied to both sides of the piston, is often used in applications

SINGLE-ACTING   DOUBLE-ACTING   BALANCED
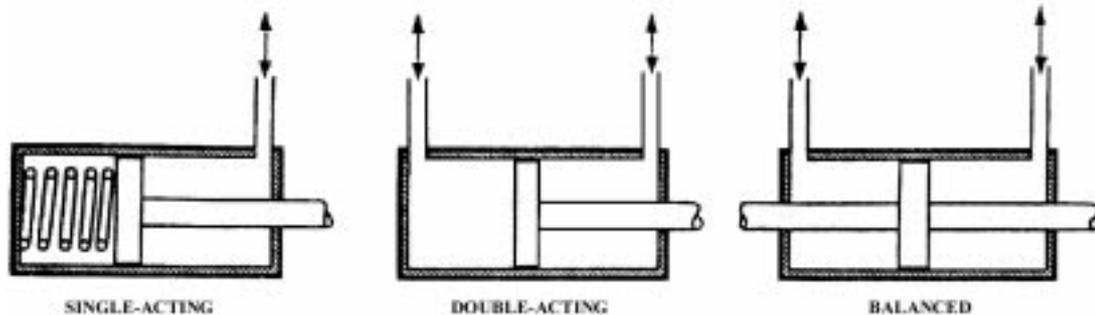
Fig.24. Actuators.

such as nose-wheel steering and flying control boost systems. Either one or both sides of the piston rod may be connected to a mechanism.

Hydraulic motors are a form of rotary actuator, and are sometimes connected through gearing to operate a screw jack, or to drive generators or pumps. In some aircraft they are used for driving a hydraulic pump unit, thus enabling power to be transferred from one hydraulic system to another without transferring fluid. The construction of a hydraulic motor is generally similar to the construction of a variable volume multi-piston pump. Hydraulic pressure directed through the inlet port forces the pistons against the angled yoke, causing rotation of the cylinder block and drive shaft. A starter valve is used to initiate rotation in the correct direction, and a governor, driven from the cylinder block, meters fluid to a control piston, altering the angle of the yoke according to the load placed upon the motor.

FILTERS

Main filters are fitted in both suction and pressure lines in a hydraulic system, in order to remove foreign particles from the fluid, and to protect the seals and working surfaces in the components. In addition, individual components often have a small filter fitted to the inlet connection. Main filters usually comprise a filter head containing inlet and exhaust valves, and a sump which houses the filter element. Installation of the sump normally opens the valves, and removal of the sump normally closes them, so that the filter element can be removed without the need for draining the complete system.

Some filters are fitted with a device which senses the pressure differential across the filter element, and releases a visual indicator, in the form of a button, when the pressure differential increases as a result of the filter becoming clogged. False indication of element clogging, as a result of high fluid viscosity at low temperature, is prevented by a bi-metal spring which inhibits indicator button movement at low temperatures. Other filters are fitted with a relief valve, which allows unfiltered fluid to pass to the system when the element becomes clogged; this type of filter element must be changed at regular intervals.

Paper filter elements are usually discarded when removed, but elements of wire cloth may usually be cleaned. Cleaning by an ultrasonic process is normally recommended, but if a new or cleaned element is not available when the element becomes due for check, the old element may be cleaned in trichloroethylene as a temporary measure.

SEALS

Seals perform a very important function in a hydraulic system, in preventing leakage of fluid. Static seals, gaskets and packing are used in many locations, and these effect a seal by being squeezed between two surfaces. Dynamic seals, fitted between sliding surfaces, may be of many different shapes, depending on their use and on the fluid pressures involved. 'U' and 'V' ring seals are effective in one direction only, but 'O' rings and square section seals are often used where pressure is applied in either direction.

Dynamic seals require lubrication to remain effective, and wetting of the bearing surface, or a slight seepage from the seals, is normally acceptable. Where high pressures are used, an 'O' ring is normally fitted with a stiff backing ring, which retains the shape of the seal and prevents it from being squeezed between the two moving surfaces. Seals are made in a variety of materials, depending on the type of fluid with which they are to be used ; if a seal of an incorrect material is used in a system, the sealing quality will be seriously degraded, and this may lead to failure of the component. Seals are easily damaged by grit, and a wiper ring is often installed on actuators to prevent any grit that may be deposited on the piston rod from contaminating the seals.
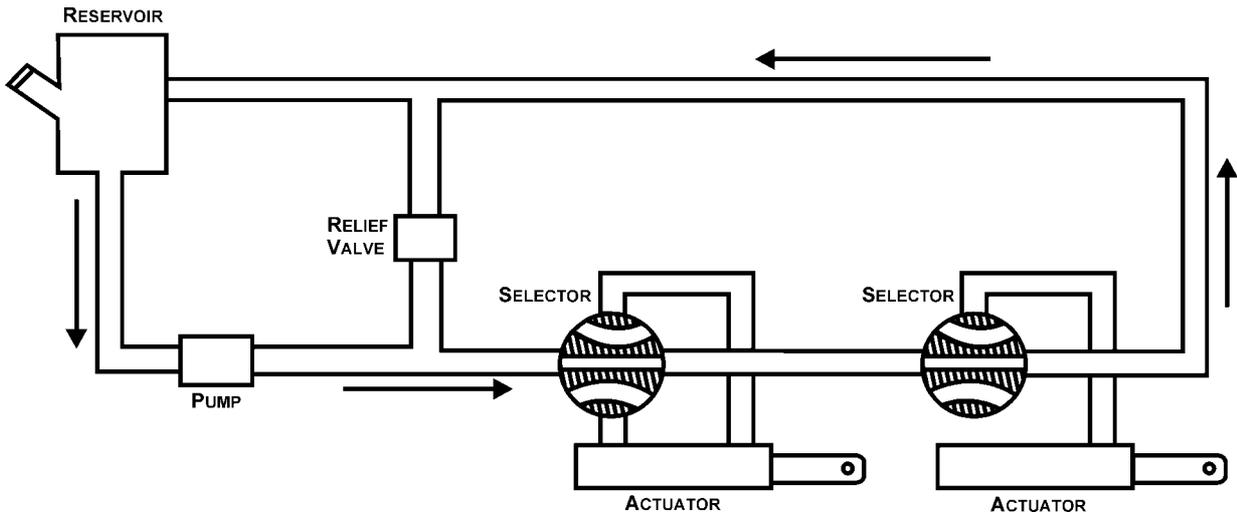
Fig.25. Open Centre System.
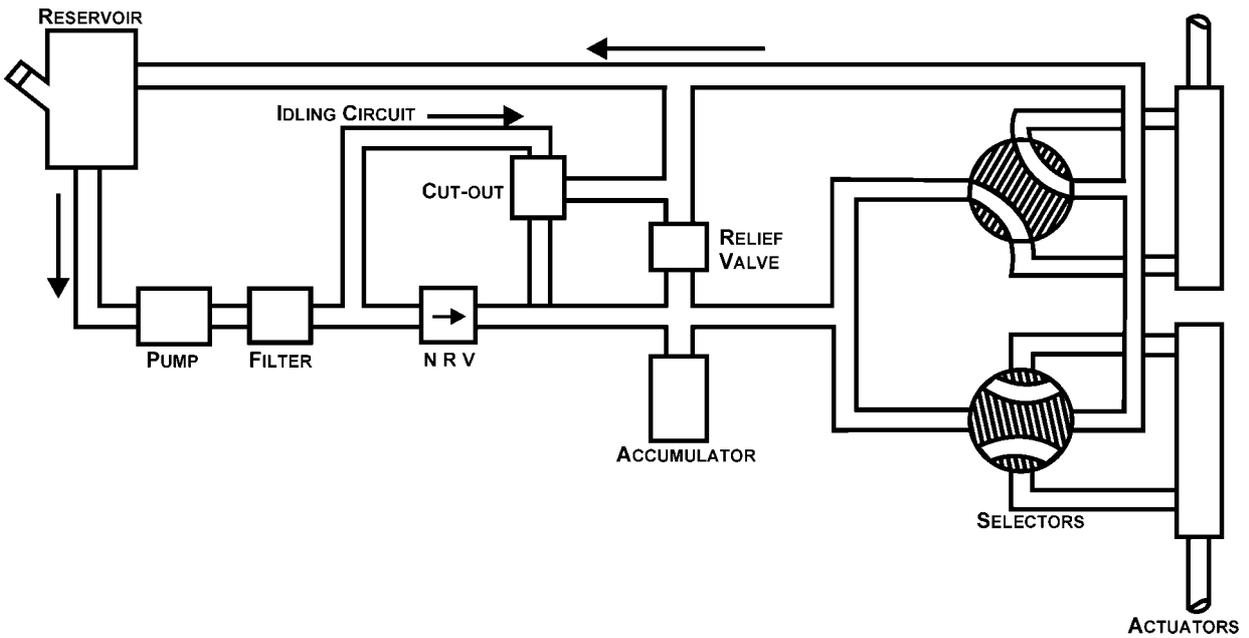
Fig.26.Closed System.

BASIC HYDRAULIC SYSTEMS

There are two main types of system in use, the open-centre system and the closed system. The former is frequently found on light aircraft, and the latter, or a combination of the two, is found on most large aircraft.

Open-centre System

The main advantage of this system is its simplicity, and the main disadvantage is that only one service can be operated at a time. When no services are being operated, the pressure in the system is at a low value, pump output passing directly to the reservoir. Fig.25 shows a simple open-centre system which contains all the components necessary for operation. It should be noted, however, that when the actuator reaches the end of its travel, pressure will build up and remain at the relief valve setting until the selector is returned to neutral. This imposes a high load on the pump, which is normally overcome by fitting automatic-return selectors.

Closed System

With this type of system, operating pressure is maintained in that a part of the system which leads to the selector valves, and some method is used to prevent over-loading the pump. In systems which employ a fixed volume pump an automatic cut-out valve is fitted, to divert pump output to the reservoir when pressure has built up to normal operating pressure. In other systems a variable volume pump is used, delivery being reduced as pressure increases, whilst in some simple light aircraft systems, operation of an electrically-driven pump is controlled by a pressure-operated switch. A simple closed system is illustrated in Fig.26.

Power Packs

A power pack system is one in which most of the major components, with the exception of the actuators, and, with some systems, of the pumps, are included in a self-contained unit. The system may operate on either the open-centre or the closed system principle, and is widely used in light aircraft.
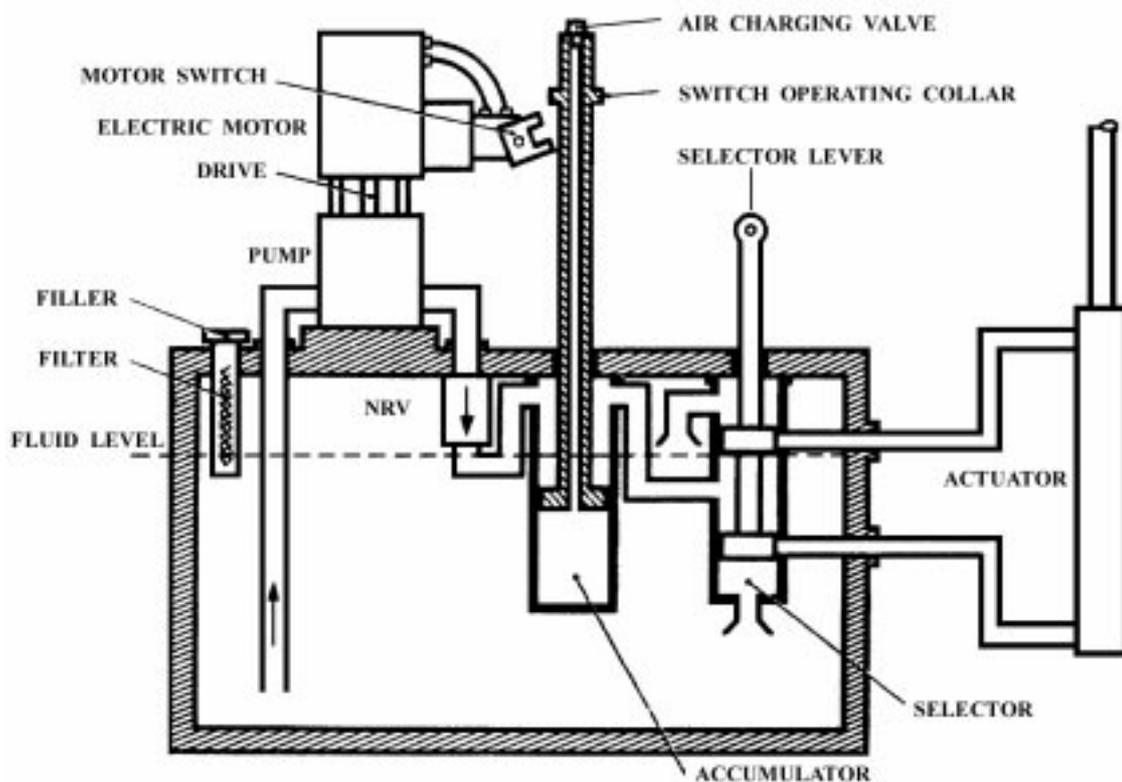
Fig.27. Power Pack.

Fig.27 shows a simple power pack used for raising and lowering the landing gear. Power is provided by the accumulator, which is automatically re-charged by operation of the electrically-operated pump. When a selection is made, pressure in the accumulator drops and the plunger is raised until its collar contacts the trip switch arm, providing electrical power to the pump motor. As pressure builds up in the system, the accumulator plunger lowers until it contacts the switch arm and cuts off power to the pump motor. Pressure is constantly maintained between the pump cut-in and cut-out pressures, and power is constantly available for operation of the landing gear.
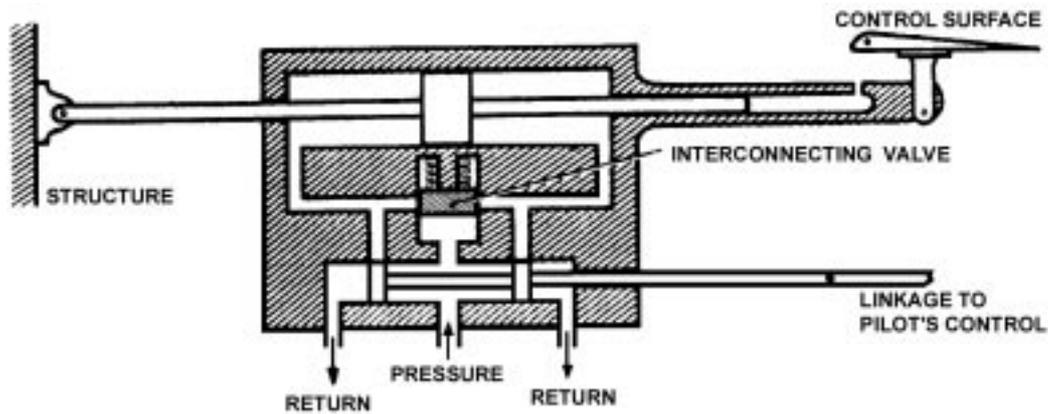
Fig.28. Servo-Control Unit.

POWERED FLYING CONTROLS

Because of the high loads imposed on the flying control surfaces, modern transport aircraft are provided with power-operated or power-assisted controls. Because of the importance of the flying control system, hydraulic power to each control surface is provided by at least two independent hydraulic systems (sometimes using separate actuators) plus an emergency system operated by electrical power or by ram air turbines. In addition, some systems allow for reversion to manual operation of the control surfaces, or tabs, in the event of all hydraulic systems failing.

A hydraulic sub-system for the operation of the flying controls, is often fed through a priority valve, which ensures that fluid under pressure is always available; the sub-system may also have a separate accumulator.

The unit which moves a control surface is a combined selector valve and actuator, usually known as a servo-control unit, the selector being connected by cables and rods to the pilot's controls. A typical servo-control unit is illustrated in Fig.28. With hydraulic power available, operation of a pilot's control moves the spool in the selector, thus directing fluid to one side of the actuator and opening a return path from the other side. Movement of the actuator operates the control surface, and at the same time moves the selector back towards the neutral position. When control surface movement corresponds to the deflection of the pilots' control, the selector is in the neutral position, and fluid is locked in the actuator. When no hydraulic pressure is available, the interconnecting valve opens under spring pressure and the actuator is free to move. The control may then be operated by alternative servo-control units, or by manual linkage, depending on the particular installation.

An alternative method of operating the flying controls is by means of self-contained powered flying control units (PFCU's). Control surfaces are divided into sections, and each section is operated by a separate PFCU, thus providing duplication to guard against failure of a unit. Each unit is controlled by mechanical linkage from the pilots' controls, and some units also accept electrical inputs from the auto-pilot and auto-stabilizer. The mechanical input rod to each unit is telescopic and spring loaded, so that failure of one PFCU will not prevent operation of the associated control system. In the event of failure, or when a unit is inoperative, the actuating ram is mechanically locked in the neutral position, thus preventing movement of the associated section of the control surface. Actual operation is basically similar to that of the servo-control unit described previously, but each PFCU is a self-contained hydraulic system, and is not connected with the main hydraulic system, or with other PFCU's. The main body of each PFCU acts as a reservoir, and houses all the components necessary for operation of the unit, including electrically driven pumps and hydraulic actuator.

CHAPTER: 3
FUEL SYSTEMS

GENERAL

There are two main types of fuel used in aircraft, aviation gasolene, which is used in piston engines, and aviation kerosene, which is used in turbo-jet and turbo-propeller engines. It is most important that the correct type and grade of fuel, as indicated in the appropriate Maintenance Manual, should be used.

Gasolene

Aviation gasolene (AVGAS) is the lighter of the two fuels, having a relative density of approximately 0.72. The only grade of AVGAS generally available is grade 100L, which has an octane rating of 100 and a low lead content. Where different grades of fuel were previously specified for use in a particular engine, the use of AVGAS may necessitate additional checks and maintenance to be carried out. Automobile fuel must not be used instead of non-leaded aviation fuel.

Gasolene has powerful solvent properties, and it is essential that it does not come into contact with certain components such as transparent panels and tyres. Personal contact may also result in skin infections, and it should be noted that some of the additives used in gasolene are poisonous.

Kerosene

The fuel generally used in civil turbo-jet and turbo-propeller engines is known as AVTUR (Specification D Eng. RD 2494). It has a relative density of approximately 0.8, a high flash point, and does not give off easily-ignitable vapours at normal ground temperatures. In many instances the use of AVTAG (Specification D Eng. RD 2486) is permitted in civil aircraft, but this fuel is lighter, and has a lower flash point; the 'wide-cut' formula for this fuel includes gasolene, and it should, consequently, be treated as highly flammable.

Fuel Quality Control

The quality of the fuel delivered to an aircraft must be carefully controlled. Engines will operate satisfactorily when a small amount of water and dirt are present in the fuel, but the quantities must be strictly limited.

Bulk storage tanks should frequently be checked for contamination. Fuel is usually drawn from these tanks through a floating suction, which ensures that the contents of the lower part of the tank, where contaminants may have collected, are not drawn off.

After a refuelling vehicle has been filled from a storage tank, it should be left to stand for at least ten minutes, then approximately one gallon of fuel should be drawn from the sump in order to check its quality. If sediment is found, further samples should be taken, until the result is satisfactory. Suspended water in kerosene will give the fuel a cloudy appearance, and free water may often be readily visible, but in any case, a chemical water detection method should be used. If water is found, the vehicle should be driven a short distance, left to stand for a further period, and another sample taken. This process may be repeated until a clean sample is obtained. During normal use, fuel samples should be taken daily. The refueller delivery line should contain a 5 micron filter, and all equipment should be kept scrupulously clean. Nozzle caps should be removed immediately prior to refuelling, and replaced immediately after refuelling.

Hydrant installations are often used for direct refuelling of aircraft, and the associated tanks are generally fitted with a floating suction and a water separator. Samples should be taken from the storage tank sumps, pipelines and dispenser unit daily, and should be checked for water, sediment, and other contamination.

If signs of microbiological contamination are found in a sample, the storage tank should be checked for contamination. Contaminated tanks must be cleaned before being used to refuel aircraft.

FUEL SYSTEMS FOR SMALL AIRCRAFT

A simple fuel system may consist of a gravity feed tank, a filter, a shut-off valve, and suitable rigid and flexible pipes between these components and the engine. The tank would be vented to atmosphere, and a means of indicating the fuel quantity, would be provided. This type of system is adequate for a single piston-engined, high wing aeroplane, and is often used. However, larger, multi engined aircraft, particularly those fitted with turbo-propeller or turbo-jet engines, require a more sophisticated system, with facilities to enable transfer of fuel, electronic control of refuelling and defuelling, and controls and indicators for many functions not necessary in a simple system.

Fig. 1 illustrates a simple fuel system such as may be used on a modern light aircraft. A rigid aluminium alloy tank, or a flexible tank, is housed in each wing, and feeds fuel to a selector valve, the control for which is located in the cabin. From this point fuel is fed through a filter and booster pump to the engine carburettor.

Each fuel tank is fitted with a vent pipe, which has its open end outside the wing structure, in order to ensure that atmospheric pressure is maintained in the tank. A non-return valve (NRV) in the tank prevents fuel from siphoning through the vent pipe, and bleed hole in the NRV prevents the build-up of pressure as a result of fuel expansion, when the NRV is closed. Coarse mesh filters are generally fitted at the filler openings, and at the outlet pipes, in order to prevent large objects from passing into the system. A drain valve, fitted to the lowest point in each tank, is used to drain off fuel and any water which may have collected through condensation, or have been introduced during refuelling. The fuel tanks of light aircraft should be filled as soon as possible after a flight, to minimize condensation; a small quantity
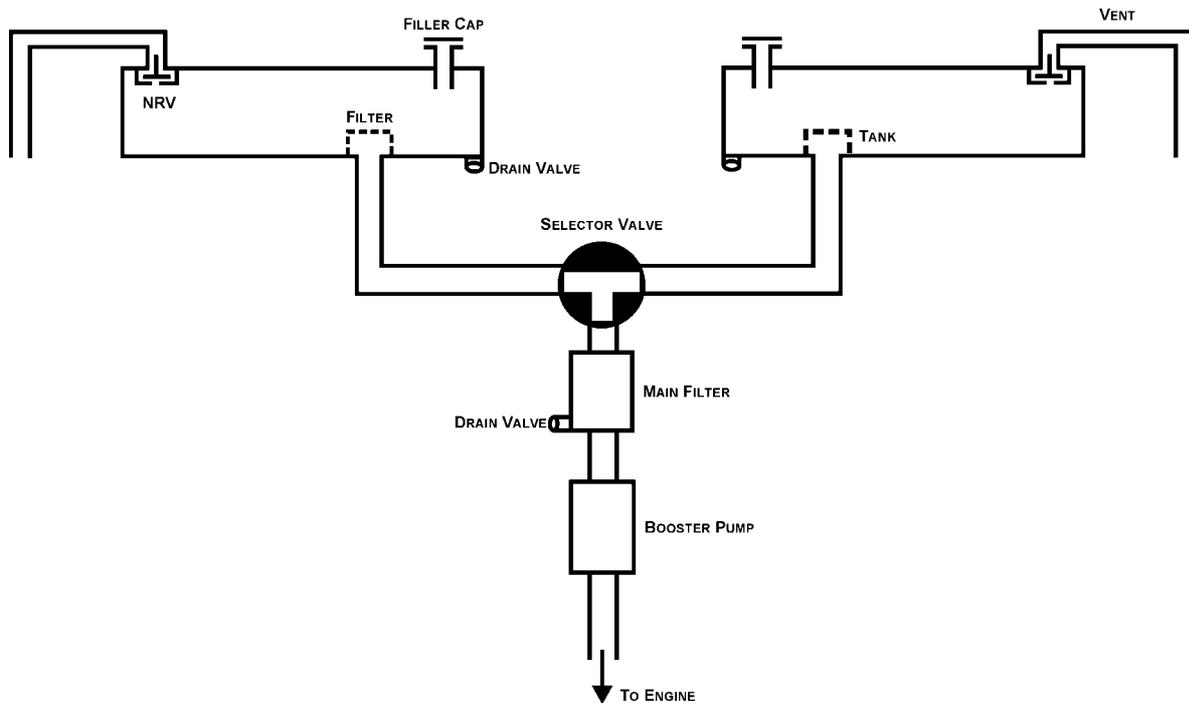
Fig. 1. Simple Fuel System.

of liquid should be drained off through the tank and main filter drain valves before flight, in order to remove any water which may have accumulated. Tanks are fitted with a contents gauge, which may be a float operated mechanical unit, a float operated electrical unit, or an electrical capacitance type unit .

The selector valve enables the engine to be fed from individual tanks, or both tanks together, and an OFF position is also usually provided to enable the supply to be turned off. This latter position is particularly important with those high wing aeroplanes which have engines fitted with float chamber carburettors, since a small leak past the float valve could result in complete loss of fuel when the aircraft is parked; it is also essential to be able to turn off the fuel supply in the event of an engine fire. Selector valves are usually rotary valves, and the operating lever may be mounted directly on the valve, or located remote from the valve and connected to it by mechanical linkage. In either case it is important that the operating lever is accurately aligned with the valve, and represents the true position of the valve at all selected position; a dent at each position assists proper selection.

In some systems an additional valve may be fitted in the fuel feed line, to isolate the tanks for maintenance purposes. This valve will usually be wire locked to the ON position for normal operations.

The main fuel filter is usually fitted to the lowest point in the system, so that water and sediment, being heavier than fuel, will collect at this point. The filter is designed to remove both water and dirt from the fuel by trapping them in the sediment bowl. The sediment bowl is attached to the body of the filter by a quick-release fitting, thus assisting easy removal for cleaning and examination of the filter element.

The booster pump is electrically operated, by direct current, and is fitted to ensure a positive fuel supply to the engine for starting , take-off, climb, high altitude, flight through turbulence, and landing, and to safeguard the engine in the event of engine driven pump failure. Pumps are usually of the centrifugal type, and are sometimes fitted with two speed controls, the higher speed being used for emergency operation. Pumps are often mounted in the bottom of the fuel tanks, but in some cases are located in the fuel lines as illustrated in Fig.1 above.

Seals are fitted between the pump and its motor to prevent fuel and vapor from leaking into the motor. However, any slight leakage which does occur is drained overboard, and some motors are vented by passing air through the casing.

Different types of pumps are used in some instances, but the inherent advantages of centrifugal pumps, are that they separate fuel and vapor, thus providing a vapor free fuel supply, and they do not require pressure relief or by-pass valves.

Pipelines aft of the firewall in light aircraft fuel systems are generally made from aluminium alloy, and are joined by standard aircraft couplings; because of the fuel requirements of small piston engines, the pipelines are seldom larger than 25 mm (1 in) diameter. Fuel pipelines in British aircraft (except those inside the tanks) are labelled, for recognition purposes, in accordance with British Standard M23. The marking consists of an adhesive label wrapped around the pipe at intervals, with the word FUEL in black, on a red background, and a symbol in the form of a black fourpointed star on a white background. In addition, the word FLAM (flammable) and the purpose of the pipe (e.g. VENT) may be added.

Fuel tanks are marked, adjacent to the filling point, with the type of fuel required and the usable tank capacity. The filling points of other systems are also marked, in order to prevent a system from being filled with the incorrect fluid.

FUEL SYSTEMS FOR MULTI-ENGINED AIRCRAFT

A fuel system for a typical multi-engined aircraft is illustrated in Fig.3. The basic requirements for the system are the same as those described in paragraph 4, but the multiplicity of engines necessitates additional tanks, piping, valves and pumps. In addition, different venting and refuelling systems are necessary, and additional functions such as fuel jettisoning, fuel heating, cross-feeding, and instrumentation have to be provided for.

Fuel Feed

In modern turbine-powered aircraft, the fuel is usually contained in a number of integral tanks , in the wings and centre section, and, occasionally, in the fin. Individual engines are usually fed from an associated tank, or group of tanks, but cross-feed and inter-engine valves may be provided to enable the engines to be fed from any desired group of tanks, and also to permit fuel transfer between tanks. Fuel supplies for auxiliary power-units and combustion heaters, where fitted, are normally taken direct from a suitable tank or from a feed line.

Pumps

In the fuel system illustrated in Fig.3, two booster pumps are fitted in each tank.. These pumps are designed for continuous operation, and either pump can supply the needs of any one engine. In the event of failure of both pumps in a tank, fuel is drawn from that tank by the associated engine-driven, low-pressure pump, via the suction valve, but in some cases this may be inadequate to provide full engine power at high altitude, and operating limitations may be imposed. The booster pumps are electrically operated, but, unlike the pumps fitted to light aircraft, may be operated by alternating current. They vary considerably in design, but are usually powered by induction motors, and may include a two stage impeller. In some instances the motor is of the flooded type, in which the motor runs submerged in fuel, thus obviating the need for seals. Overheat protectors are usually fitted, which cut off power to the motor when the pump temperature rises above a predetermined value. Pumps are often fitted in isolation chambers within the fuel tank, which enables them to be removed and re-fitted without draining the tank.

Valves

Low-pressure valves, cross feed valves and inter-engine valves, are usually ball-type, full-flow valves, and may be either mechanically or electrically operated. A typical valve is illustrated in Fig.2, in this type a form of pressure relief
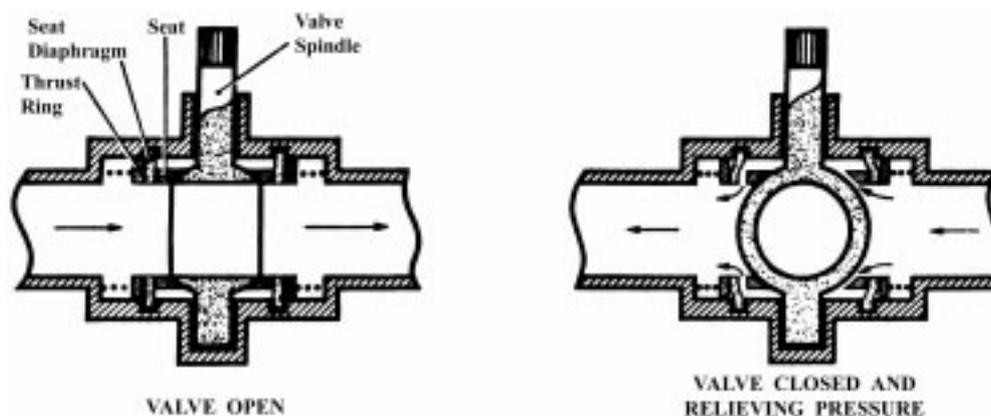
Fig. 2. Ball Type Valve.

is provided, to bleed off excess pressure which may occur, through variations of temperature downstream of the valve, when the valve is closed. This is a two position valve only, and either internal or external mechanical stops are provided, to limit movement to 90^0; a visual indication of valve position is also provided. When the valve is electrically operated, a reversible electric motor, equipped with an electromagnetic brake, is mounted on the valve casing, and drives the valve through a gear train. Limit switches cut off power to the motor at the fully-open and fully-closed positions, and the brake operates automatically as the motor is de-energized; the brake is magnetically released when a reverse selection is made. The limit switches may also be used to operate position indication lights or magnetic indicators in the crew compartment.

Suction valves are fitted to enable fuel to be drawn from the tanks by the engine driven pumps; they are closed when booster pumps are operating normally. A suction valve is illustrated in Fig.4; it is a simple flap type valve, which closes when a pressure exists in the pipeline, and opens when suction is applied to the pipeline.

Non-return valves may be fitted in several places in the fuel system, to provide flow in one direction only. A typical non-return valve is illustrated in Fig.5. The casing is marked with an arrow to show the direction of flow, and, in the valve illustrated, an interference spider is fitted to the inlet side, in order to prevent the valve from being fitted the wrong way round.

Venting

The tank venting system provides positive venting of the tanks during flight. A ram air intake maintains a slight positive pressure in the vent system, thus decreasing fuel vaporization, and preventing negative pressures in the tanks
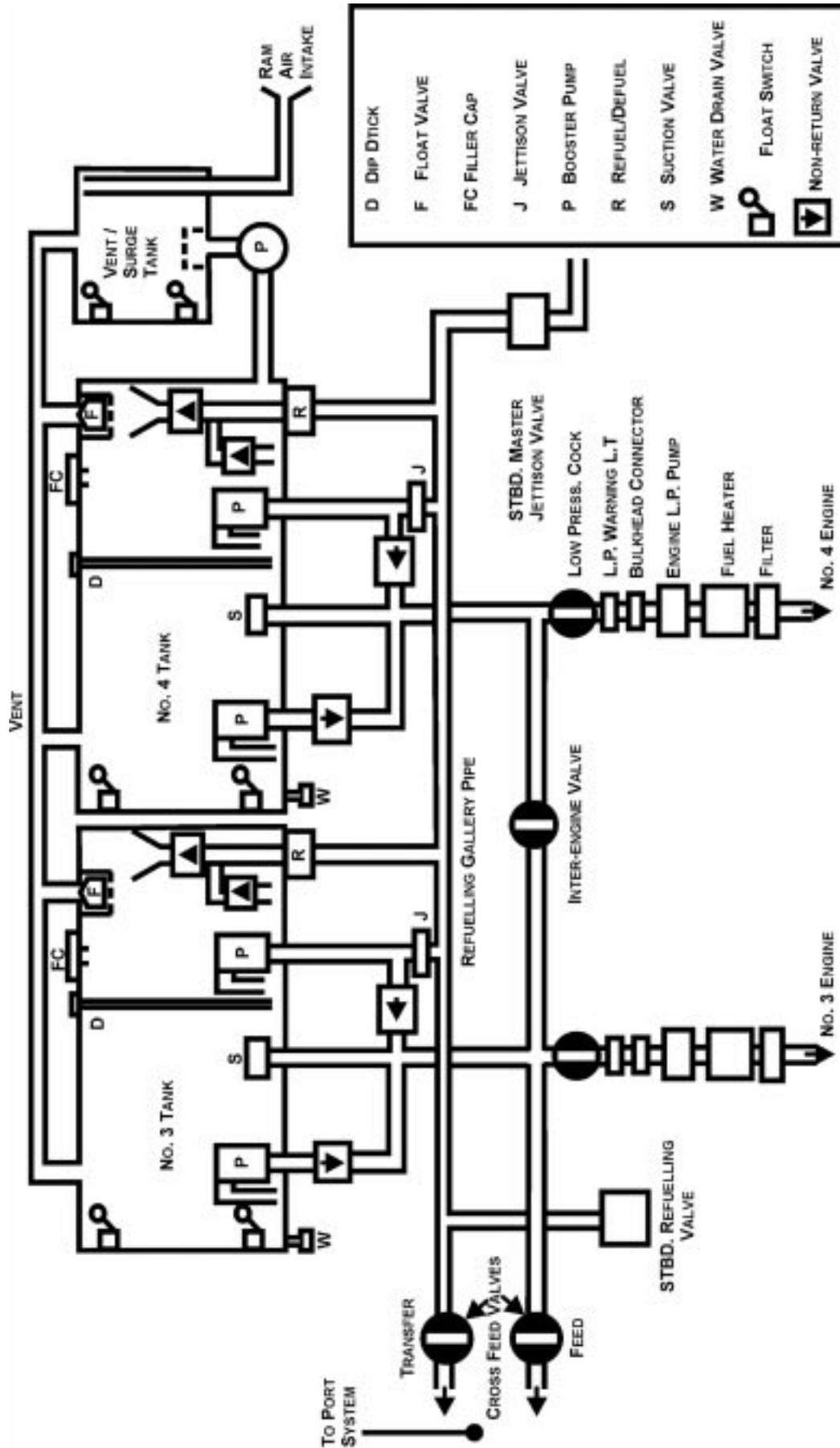
Fig.3 Fuel System For Multi Engined Aircraft.
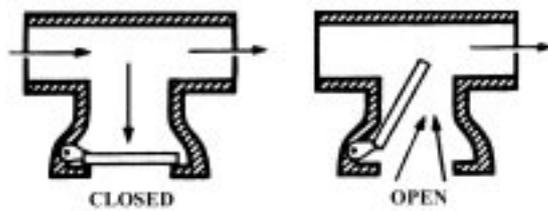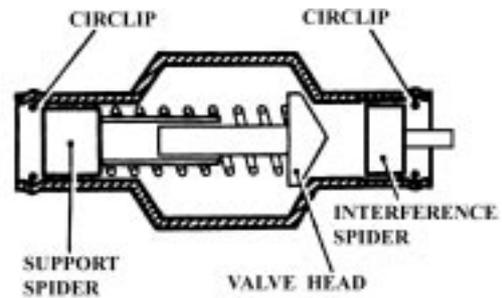
Fig.4. Suction Valve.   *Fig.5. Non Return Valve.*

through changes in aircraft attitude and fuel usage. In some aircraft, the vent system also prevents the building up of dangerous pressures in the tanks during refuelling, should the automatic cut-off fail, by dumping excess fuel. Generally, there are two vent pipes in each tank, the inboard vent is open-ended, but the outboard vent is fitted with a float valve, the purpose of which is to minimize fuel transfer both between tanks and into the vent/surge tank during changes of aircraft attitude. Fuel which is spilled into the venting system, collects in the vent /surge tank. On some aircraft the vent/surge tank drains under gravity into the main tanks, but on other aircraft an automatic pumping system is used. The pumping system may operate on a continuous basis, using 'jet' pumps, or on an intermittent basis using float switches and a separate electrically-operated pump. In a jet pump, output from a normal booster pump passes through a jet nozzle,
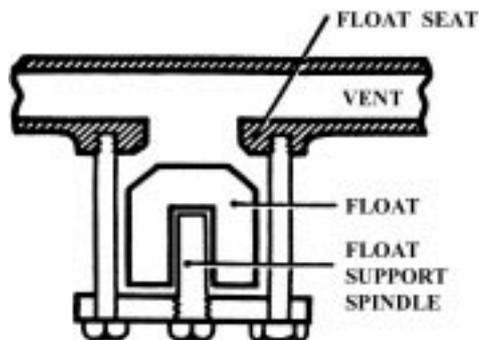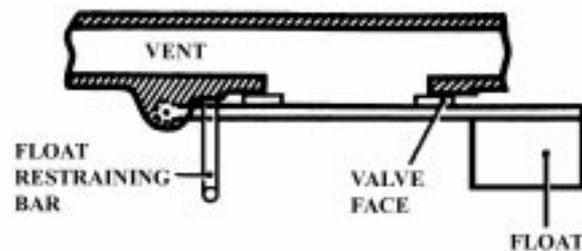
Fig.6. Vent Valve.   *Fig.7. Float Switch.*

which is contained within a concentric pipe leading from the vent/surge tank. The flow of fuel through the jet nozzle automatically draws fuel from the vent/surge tank. With an intermittent system, a high-level float switch switches the transfer pump on, thus transferring fuel from the vent/surge tank to a main tank, and a low-level float switches the transfer pump off. A time-delay may be incorporated in the pump circuit, to prevent intermittent operation as a result of fuel surge.

Vent valves are generally either a caged cylindrical float which itself acts as a valve to close the vent, or a simple lever-type flap valve; typical examples are shown in Fig.6.

Compartments in which rigid or flexible tanks are contained, and bays or conduits through which fuel system pipes pass, are usually ventilated and drained to prevent the build-up of vapour pressure, and to release condensation or fuel which may have leaked into them. These regions are invariably sealed to prevent vapour leakage into crew and passenger compartments, and pressure tests are normally required at specified intervals, and after repairs have been carried out or components have been replaced.

A typical load control panel, suitable for the system illustrated in Fig.7; it is in the form of a 'mimic' diagram of the relevant parts of the fuel system, and includes a master switch, automatic/manual selector switch, switches for each refuel/defuel valve, a function (refuel/defuel) switch, contents indicators for each tank, and magnetic indicators to shown the position of each refuel/defuel valve.

Fuel Jettisoning

Many transport aircraft are equipped with a means of jettisoning excess fuel in an emergency. Fuel is pumped or drained from each tank through a stand pipe, which ensures that a pre-determined quantity of fuel remains. One type of system makes use of the refuelling gallery pipe, which is extended outboard to a position near each wing tip, and terminates in a large diameter open-ended pipe at each trailing edge. One of the booster pumps in each tank, which may be run at a higher speed for the jettisoning operation, is used to off-load the fuel, and the fuel feed to the engines is protected by non-return valves. Individual jettison valves are located at selected tank outlets, and a master jettison valve is located adjacent to each discharge nozzle; this type of system is illustrated in Fig. below. In another type of system, fuel is jettisoned through a pipe in each wing, the pipe being lowered into the airstream by an electrically-
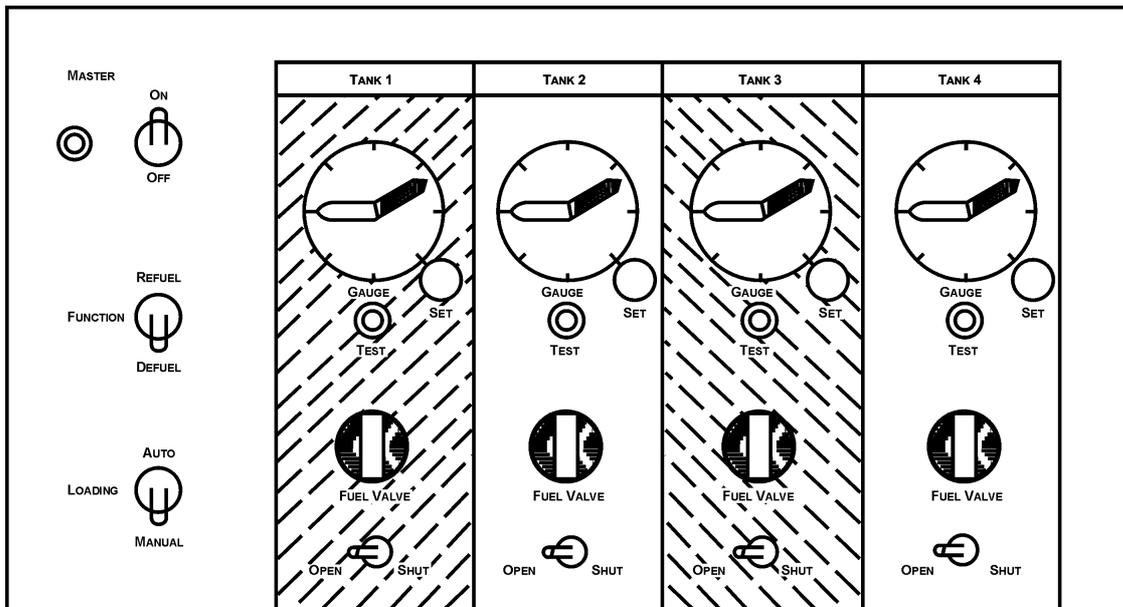
Fig.8. Load Control Panel.

operated actuator. A short manifold is fitted between the main tanks in each wing, and a jettison valve controls flow from each tank into the manifold; auxiliary tanks are fed into the main tanks by the normal transfer valves, the transfer pumps being inter connected with the circuits operating the jettison valves. When the jettison pipe is in the retracted position it forms a seal at the manifold, and acts as a master jettison valve; the circuits to the jettison valves are not armed until this pipe is locked in the extended position. Both types of systems are controlled from a special panel at the crew station, which contains switches for the pumps and valves, and warning lamps or magnetic indicators to show the positions of the valves and the jettison pipes.

Controls and Indicators

All controls and indicators for the main fuel system, are grouped together on a fuel control panel in the crew compartment. To simplify control and management of the system, the various components are arranged in the form of a mimic diagram as in Fig. 8 which shows a fuel control panel suitable for use with the system. In addition to the fuel quantity gauges fitted to the fuel control panel and load control panel, most large aircraft are also provided with a means of physically checking the quantity of fuel in each tank, during maintenance. For the methods described below, the aircraft must be levelled both laterally and longitudinally to obtain accurate readings.

A 'dip stick' is a rod with a screwed fitting at the top, which screws into a mating fitting in the top skin of the tank. It protrudes into the tank and is calibrated to indicate the contents of the tank between certain limits. When unscrewed, the fuel level is indicated by the limit of fuel-wetting on the rod.

A 'drip stick' consists of a short outer tube, which is attached to an adaptor in the lower wing skin and protrudes upwards into the tank, and a long inner tube (calibrated in gallons or inches), which slides in the outer tube, and is secured to the adaptor by a bayonet fitting. The gap between the tubes is sealed against fuel leakage. To check fuel contents, the inner tube is unlocked and slowly withdrawn downwards; when the top of this tube falls below the fuel level, fuel will flow through it, and drain out of a hole in its base. The length of tube protruding from the adaptor, will indicate the tank contents. The volume of fuel, in gallons, may be obtained from tables provided in the aircraft Maintenance Manual.

A 'magnetic level indicator' is similar to a drip stick, but the top of the outer tube is sealed. A magnet mounted on a float which surrounds the outer tube rises and falls with the fuel level. A magnet is also mounted inside the top of the inner tube, and when this tube is unlocked, it may be carefully withdrawn downwards until the magnetic fields coincide. At this point the inner tube will be magnetically supported, and the contents will be indicated in the same way as with a drip stick.

Fuel Heating

Water may enter in the fuel system during refuelling, or as a result of condensation in the tanks, and, when the fuel temperature falls below 0^0C, the suspended water droplets may freeze. These frozen droplets collect at the low pressure filters, and may restrict or block fuel flow to the engines. To prevent this, a filter by-pass and blockage indicator may be fitted, or a de-icing additive such as methylalcohol may be used in the fuel. However, in most large aircraft provision is made for heating the fuel before it enters the filters.

Fuel heaters are usually heat-exchangers, and may utilize engine oil, or air tapped from the engine compressors, as the heating medium. On some aircraft the engine oil coolers, which are in continuous use, are oil/fuel heat exchangers, and serve the additional purpose of heating the fuel. A heat exchanger operated by hot compressor air may be used in addition to the oil cooler, or may be used by itself for the purpose of heating the fuel. Oil/fuel heat exchangers are
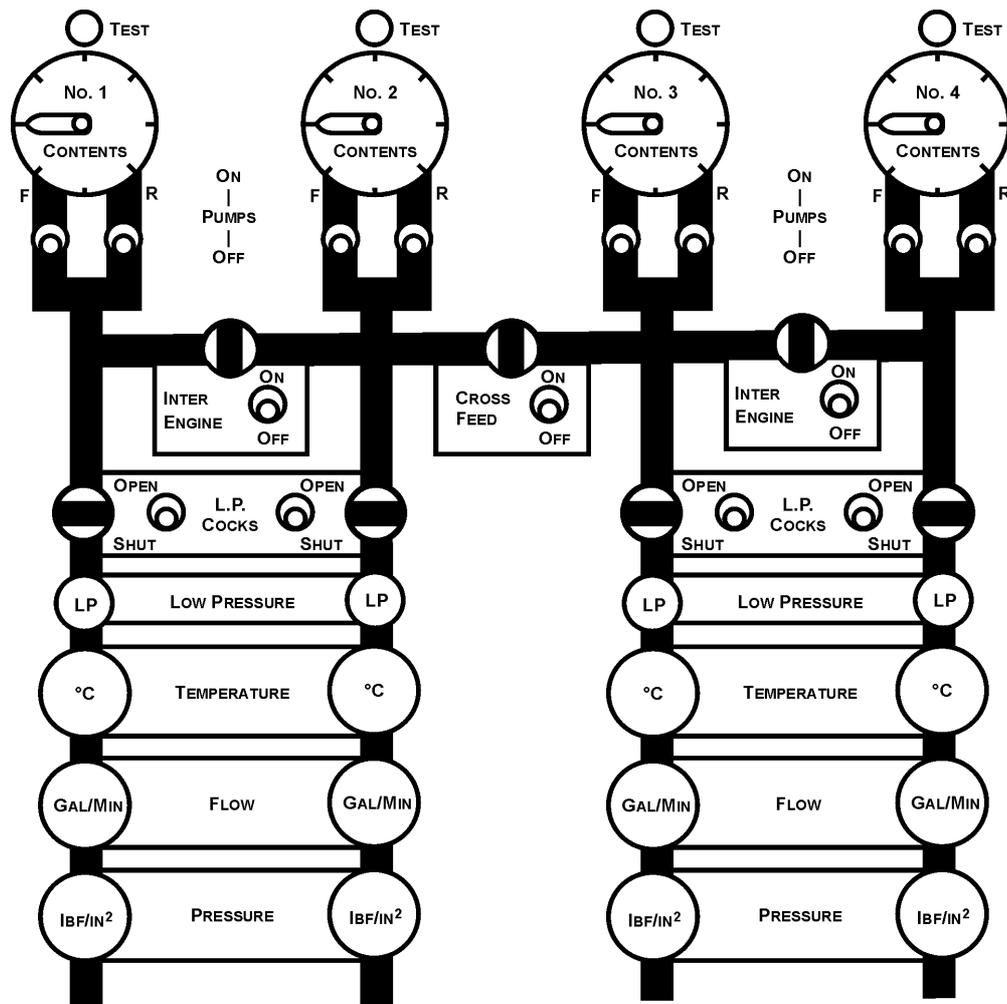
Fig. 9.Fuel Control Panel.

automatic in operation, oil flow being thermostatically controlled, but air/fuel heat exchangers may be either manually or automatically controlled.

A manually controlled fuel heating system usually consists of a pressure differential switch on the fuel filter, which operates a warning lamp in the crew compartment, and an electrically-operated valve on the heat exchanger, which is controlled by a switch adjacent to the warning lamp; a second warning lamp may also be included, to signify that the heating valve is open. When fuel flow through the filter becomes restricted by ice, the differential pressure across the filter increases, until it is sufficient to operate the icing warning lamp. The heat-exchanger valve should then be opened to admit hot compressor air to the heat-exchanger and to warm the fuel. Fuel temperature on the outlet side of the filter is indicated by an instrument on the fuel control panel. With this type of system, the period and frequency of operation of the heat exchanger may be limited.

An automatically controlled fuel heating system consists of a thermostatically controlled air inlet valve on the heat exchanger, which progressively opens and closes to maintain fuel outlet temperature within pre-set limits above 0^0C. Actual fuel temperature is indicated on an instrument on the fuel control panel, but no action is required by the crew.

CHAPTER: 4
PNEUMATIC SYSTEMS

PNEUMATIC SYSTEMS

The use of a compressed-air system to operate an aircraft's services usually represents a saving in weight compared to a hydraulic system, since the operating medium is freely available, no return lines are necessary, and pipes can be smaller diameter. Systems having operating pressures of up to $24 \, MN/m^2$ are in use, and provide for the rapid operation of services when this is required. However, compressed air is generally not suitable for the operation of large capacity components, leaks can be difficult to trace, and the results of pipeline or component failure can be very serious.

Extensive high-pressure pneumatic systems powered by engine-driven compressors are generally fitted on the older types of piston-engined aircraft and are used to operate services such as the landing gear, wing flaps, wheel brakes, radiator shutters and, at reduced pressure, de-icing shoes. There are some modern aircraft which also use a high-pressure pneumatic system, however, and there are many aircraft which use pneumatic power for the emergency operation of essential services; the latter type of system is usually designed for ground-charging only.

Low-pressure pneumatic systems such as are used on most turbine-engined aircraft for engine starting, de-icing, and cabin pressurization, are supplied with compressed air tapped from the engine compressor.

TYPICAL SYSTEM

This paragraph describes both a typical high-pressure pneumatic system, and the types of components which could be used.

The system illustrated in Fig.1 contains two separate power circuits, each of which is supplied by a four-stage compressor driven from the gearbox of one main engine, and a common delivery pipe to the high-presser storage bottles and system services. A multi-stage cooler attached to each compressor cools the air between each of the compression stages, and a means is provided for off-loading the compressor when the system is not being used.

Air is drawn through an inlet filter into each compressor, and is discharged through an oil-and-water trap, a chemical dehydrator, a filter and a non-return valve, to the main storage bottle and system. Overall control of main system pressure is provided by means of a pressure regulator, but pressure relief valves are included to prevent excessive pressures in the system, which may be caused by regulator failure or by an increase in temperature in the pipelines and components. Pressure reducing valves are used to reduce the pressure supplied to some components.

A storage bottle for the emergency system is pressurized through a non-return valve from the main system supply, and maintains an adequate supply of compressed air to enable the landing gear and flaps to be lowered, and the brakes to be applied a sufficient number of times to ensure a safe landing.

Isolation valves are fitted to enable servicing and maintenance to be carried out without the need to release all air from the system, and pressure gauges are provided to indicate the air pressure in the main and emergency storage bottles.

COMPONENTS

The types of components used in a high-pressure pneumatic system will vary considerably between aircraft, but the examples considered in this paragraph are typical of the components which may be found in current use.

Compressors

A positive-displacement pump is necessary to raise the air pressure sufficiently for the operation of a pneumatic system, and a piston-type pump is generally used. Some older types of aircraft are fitted with a single-cylinder piston pump, which provides two stages of compression and raises the working pressure to approximately $3MN/m^2$ (450 1bf/in^2). To obtain higher working pressures further compression stages are required.

The compressor illustrated in Fig. 2 has two stepped cylinders, each of which houses a stepped piston; a plunger attached to the head of No. 2 cylinder. The reciprocating motion of the main pistons is provided by individual cranks and connecting rods, the cranks being rotated by a common drive gear, and rotating in the same direction. Air passing between each compression stage is routed through an integral cooler, and lubrication is provided by an oil feed connection from the main engine lubrication system.

Compression depends on the volume of each successive stroke being smaller than the stroke preceding it; the induction strokes for each cylinder and the four compression strokes are accomplished during each revolution of the cranks. Operation of the compressor is as follows :-

    (a)   On the downward stroke of No.1 piston, air is drawn into the cylinder head through a filter and non-return valve (NRV).

    (b)   On the upward stroke of No. 1 piston, air is compressed in the cylinder, opens a NRV in the cylinder head, and passes to the annular space formed between the steps of the cylinder and piston.

    (c)   The next downward stroke of No. 1 piston compresses air in the annular space in this cylinder and forces it through a NRV into the annular space formed between the steps of No. 2 cylinder and piston. No. 2 piston is approximately 90^0 in advance of No. 1 piston, and is moving upwards as No. 1 piston approaches the bottom of its stroke.
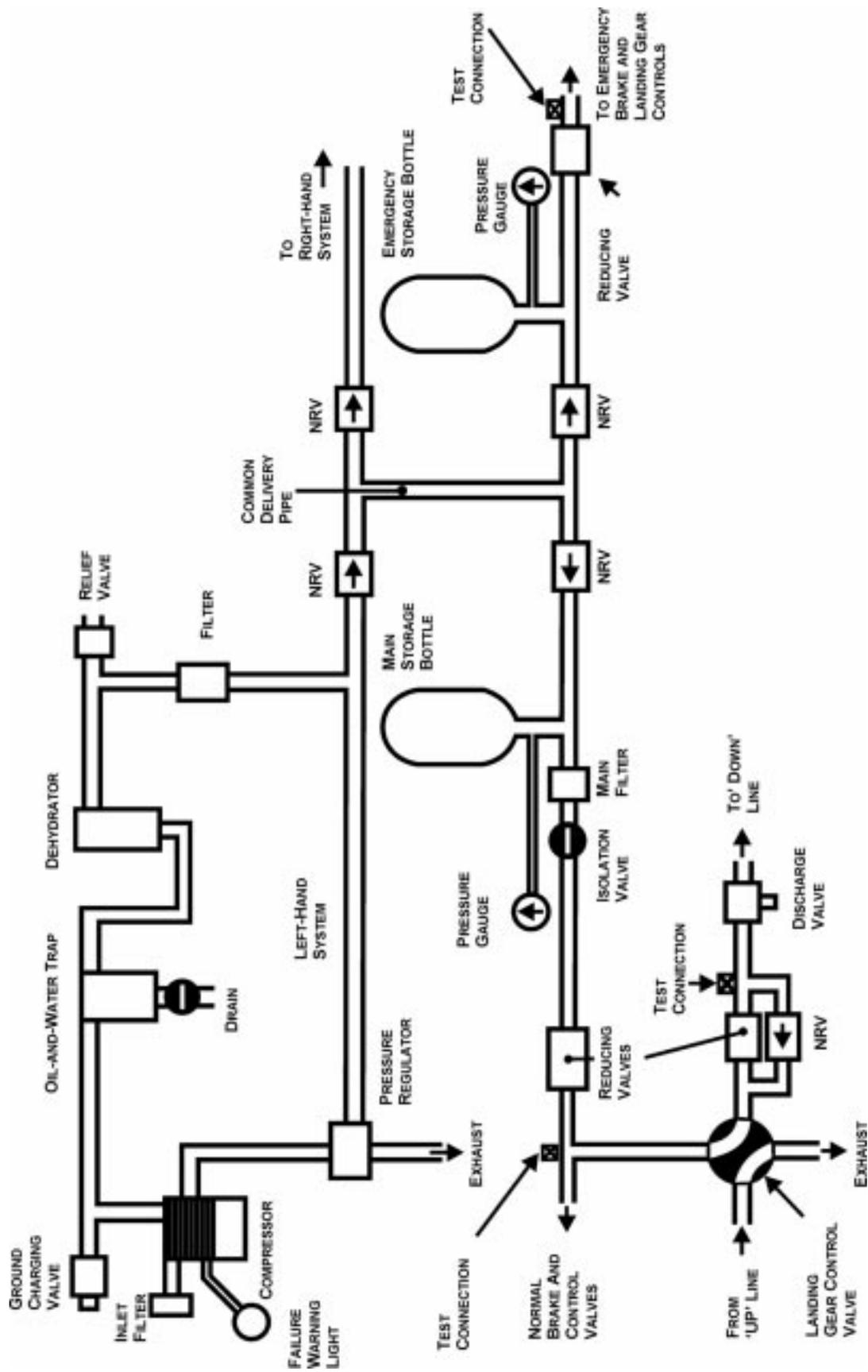
Fig.1 Typical High Pressure Pneumatic System.

(d)   On the downward stroke of No. 2 piston, air is compressed in the annular space at the bottom of the cylinder, and passes through a NRV into the small cylinder formed in No. 2 cylinder head.

(e)   On the upward stroke of No. 2 piston, the plunger attached to it also moves upwards, further compressing the air in the small cylinder and passing it through a NRV to the system.
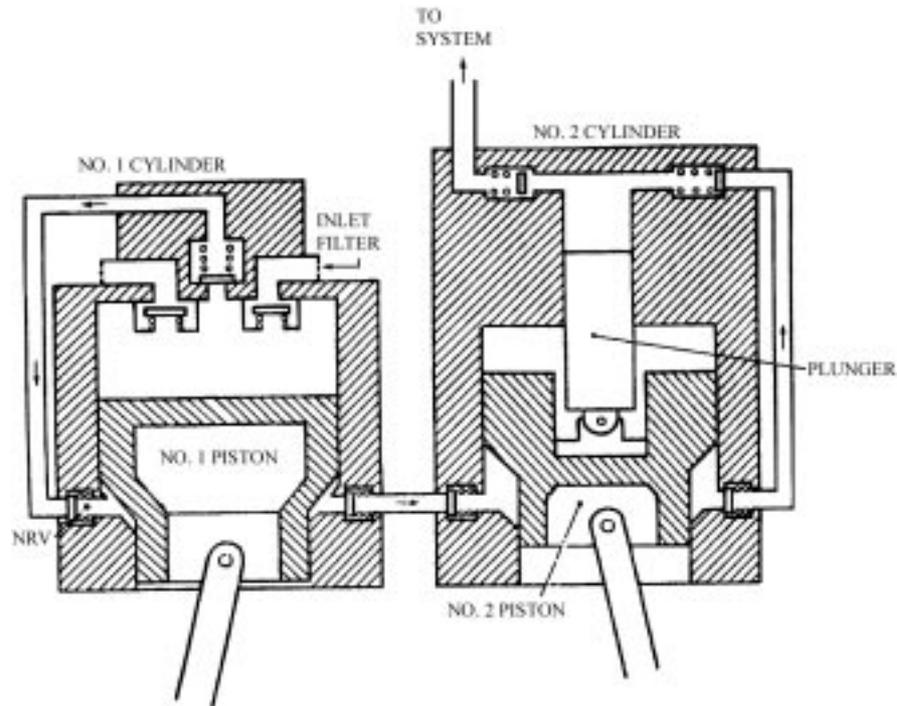
Fig. 2. Air Compressor.
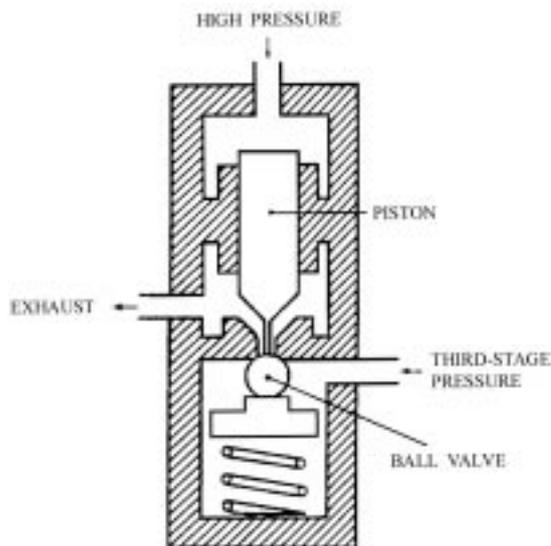
Fig. 3. Pressure Regulator.

A pressure warning transmitter is fitted at the second stage outlet, and third stage pressure is connected to the pressure regulator.

Pressure Regulator

The pressure regulator is fitted to control the maximum pressure in the system and to off-load the compressor when the system is idle. With the regulator illustrated in Fig. 3, system pressure is fed to the top connection and acts on a piston, the lower end of which is in contact with the ball of a spring loaded ball valve. At the predetermined maximum system pressure, the air pressure on the piston overcomes spring pressure and the ball valve is opened, releasing third-stage compressor pressure to atmosphere and allowing the pump to operate at second-stage pressure only. If any pneumatic services are operated, or a leak exists in the system, the air pressure trapped in the storage bottle and pipelines will drop, and the ball valve in the pressure regulator will close. The compressor will thus be brought back on line until the maximum system pressure is restored.

Oil-and-water trap

The oil and water trap is designed to remove any oil or water which may be suspended in the air delivered by the compressor. It consists of a casing with inlet and outlet connections at the top and a drain valve in the bottom. Air entering the trap does so through a stack pipe, which includes a restriction and a baffle to prevent the air flow stirring up any liquid or sediment in the bottom of the container. Air leaving the trap also passes through a stack pipe, to prevent liquid or sediment entering the system during aircraft manoeuvres.

Dehydrator

To protect pneumatic systems from malfunctioning due to moisture freezing in the components and pipelines, the compressed air may be dehydrated by a substance such as activated alumina, or it may be inhibited by a small quantity

of methanol vapour. The handling of methanol presents some difficulties, however and because of its corrosive nature systems must be specially designed for its use : activated alumina is, therefore, more generally used.

Activated alumina is housed in a container through which the compressed air passes after leaving the oil and water trap, and which generally contains a filter at the outlet end. The charge of alumina in the container will gradually become saturated with moisture, and should be changed at the specified intervals. The number of flying hours at which the alumina charge is changed is normally determined by the aircraft manufacturer through practical experience.

Storage Bottles

In a pneumatic system the storage bottles provide the reservoir of compressed air which operates all services, the compressors being used to build up system pressure when it falls below the normal level. The volume of the actuators and pipelines determines the size of the bottles required for the normal and emergency operation of the pneumatic services.

Storage bottles are generally made of steel, and may be of wire-wound construction for maximum strength. Bottles are generally mounted in an upright position, and a fitting screwed into the bottom end contains the supply connection and, usually, a connection to an associated pressure gauge, together with a drain valve by means of which any moisture or sediment may be removed. Stack pipes are provided at the supply and gauge connections in the fitting, to prevent contamination passing to the system or pressure gauge. Pressure testing of high-pressure storage bottles is required at specified periods, and the date of testing is usually stamped on the neck of the bottle.

Pressure Reducing Valves

Some services operate at pressures lower than the pressure available in the air bottle, and are supplied through a pressure reducing valve. This low pressure is, in some instances, further reduced for the operation of, for example, the wheel brakes, by the fitting of a second pressure reducing valve.
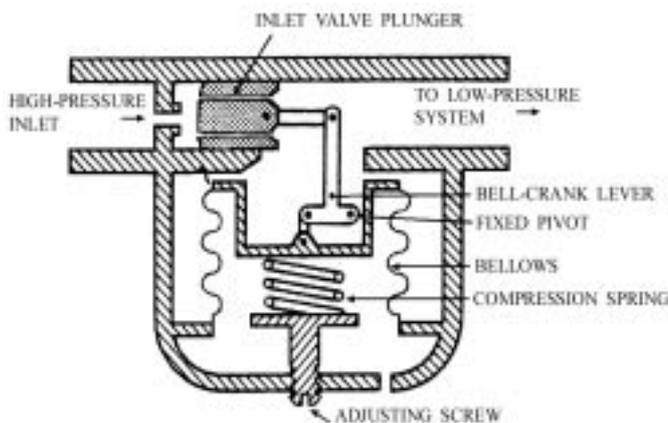
Fig.4.Pressure Reducing Valve.

Fig.4, illustrates the operation of a pressure reducing valve. When pressure in the low-pressure system is below the valve setting, the compression spring extends, and, by the action of the bell-crank mechanism, moves the inlet valve plunger to admit air from the high-pressure system. As pressure in the low-pressure system increases, the bellows compresses the spring and returns the inlet valve plunger to the closed position. The inside of the bellows is vented to atmosphere, and the valve thus maintains a constant difference in pressure between the low pressure system and atmospheric pressure.
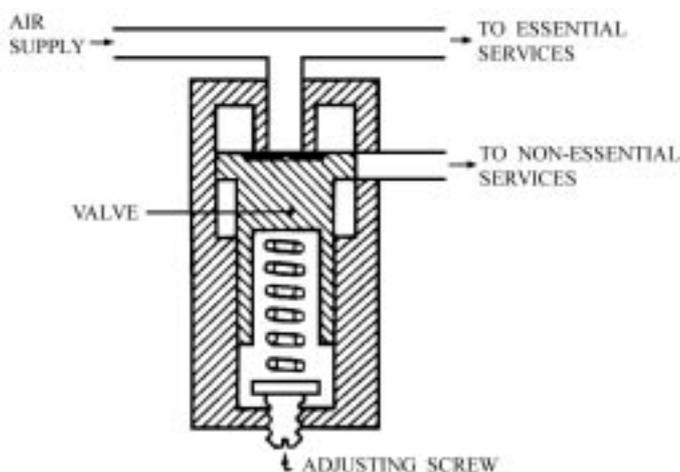
Pressure Maintaining Valve

A pressure maintaining valve is designed to conserve air pressure for the operation of essential services (e.g. landing gear extension and wheel brake operation), in the event of the pneumatic system pressure falling below a predetermined value.

Fig.5 illustrates the operation of a typical pressure maintaining valve. Under normal circumstances air pressure is sufficient to open the valve against spring pressure and allow air to flow to the nonessential services. Should the pressure in the storage bottle fall below a value pre-set by the valve spring, however, the valve will close and prevent air passing to the non-essential services.

Fig.5.Pressure Maintaining Valve.

Control Valves

Compressed air stored in the bottle is distributed to the various pneumatic services, and directed to the various types of actuators by means of control valves, which may be manually or electrically operated.

Electrically Operated Control Valve

The electrically-operated control valve for a pneumatic landing gear retraction system is illustrated in Fig.6. Selection of the landing gear position is made by either of two push-buttons (marked 'up' and 'down') which are mechanically interconnected to prevent operation of both buttons at the same time. These buttons, when depressed, supply electrical power to the 'up' or 'down' solenoid as appropriate. Actuation of this solenoid lifts an attached pilot valve, supplying compressed air to the cylinder at the bottom of the associated valve; the piston moves downwards, and the valve guide attached to it opens the inlet valve, admitting compressed air to the appropriate side of the landing gear actuators. At the same time the beam attached to the extension of this piston transfers movement to the valve guide in the opposite valve, allowing air from the opposite side of the actuators to exhaust to atmosphere.
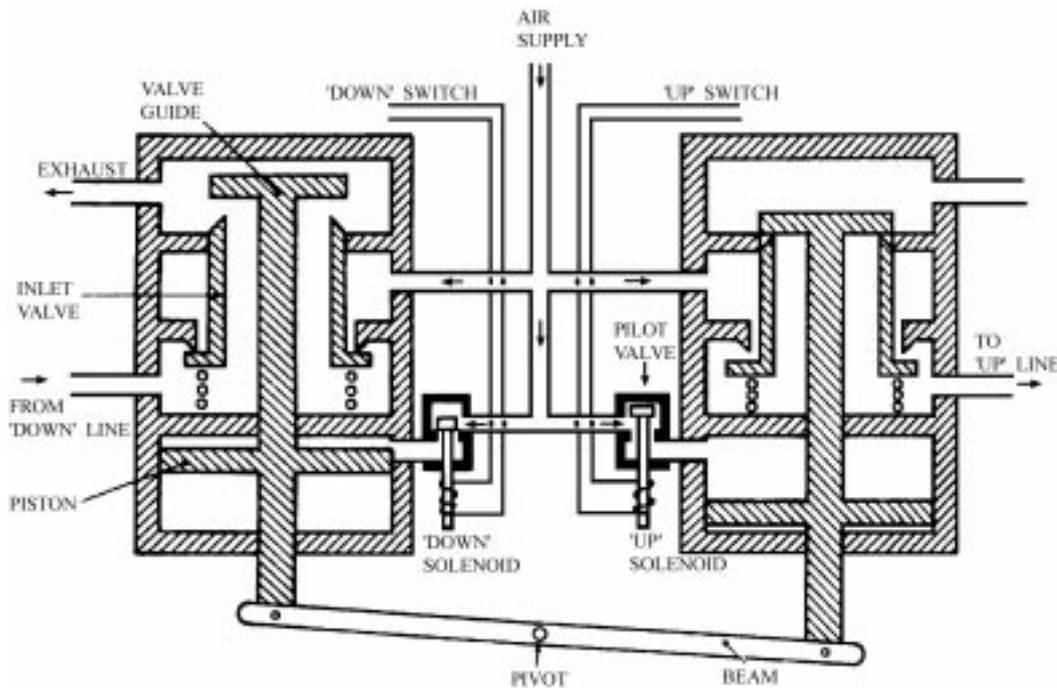
Fig.6. Electrically Operated Control Valve.

Manually Operated Control Valve

The valve illustrated in Fig.7 is a simple two-position valve, and may be used as an isolation valve in some systems. The sleeve valve is operated by a cam, and is spring-loaded to the 'off ' position; linkage from the cam spindle connects the valve to an operating lever. When used as an isolation valve the operating lever would normally be wire locked in the 'on' position, and would only be used to permit servicing operations to be carried out.

Brake Control Valve

Some older types of aircraft may be fitted with a type of brake control valve (known as a dual-relay valve) by means of which total brake pressure is applied by the operation of a single hand-control, and distribution to either or both brakes is effected by means of a mechanical connection to the rudder bar. The type of brake control valve illustrated in Fig. 8 is used on some modern aircraft and is operated by linkage from brake pedals attached to the rudder bar; separate valves supply compressed air to the brake units on each wheel. Operation of the valve is as follows :

a) In the 'off ' position the inlet valve is closed and pressure in the brake line is connected to the exhaust port.

b) Pressure applied to the associated brake pedal is transmitted via the brake linkage to the valve sleeve, which moves up to close the exhaust valve. Further pressure applied through the valve sleeve and lower spring tends to open the inlet valve, and air pressure in the brake line combined with the force exerted by the upper and centre springs tends to close it. This produces a balanced condition in which any increase in the force applied to the valve sleeve results in a higher air pressure in the brake line, and a decrease in the force applied to the valve sleeve result in opening of the exhaust valve and a reduction in the air pressure in the brake line.

Actuators

The purpose of an actuator is to transform the energy of the compressed air into linear or rotary motion. Actuators in pneumatic systems are normally of the linear type, and are similar in construction and operation to those described
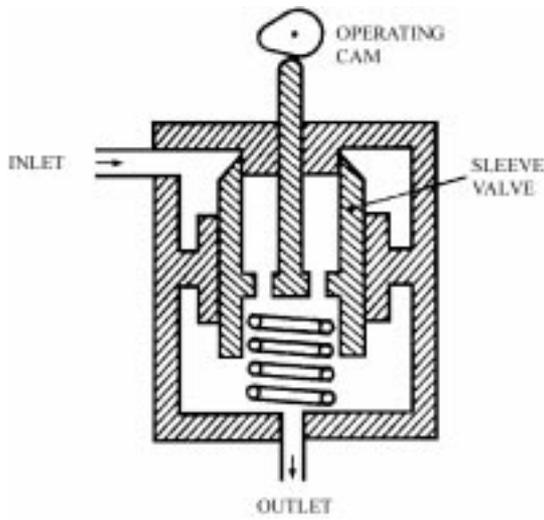
Fig.7. *Manually Operated Control Valve.*
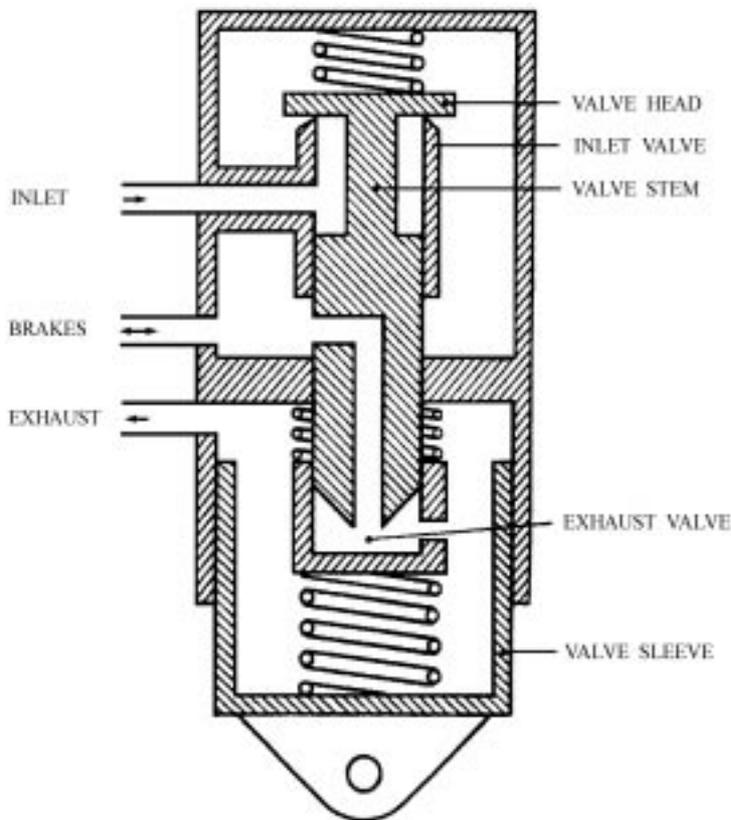
Fig.8. *Brake Control Valve.*
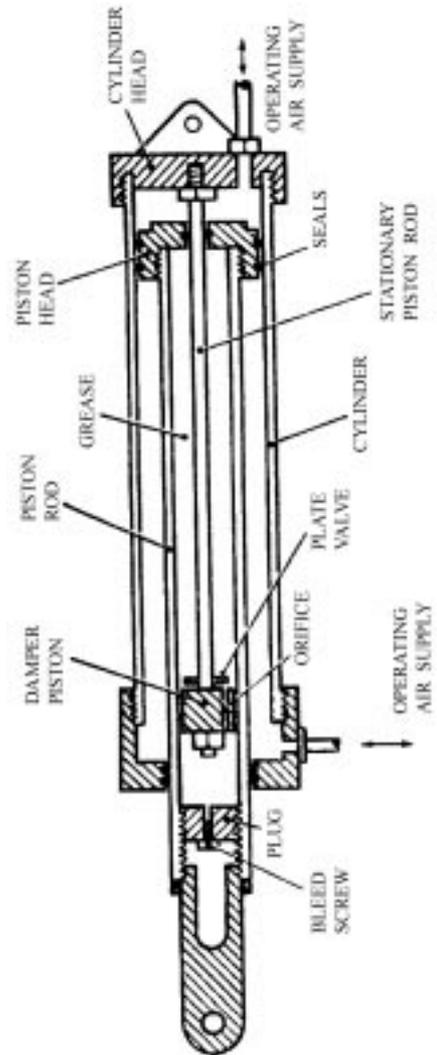
Fig.9 *Damped Actuator.*

in before for hydraulic system. Because of the nature of the operating medium, however, actuators in pneumatic systems are often damped to prevent violent operation of the service. A typical damped actuator is illustrated in Fig. 9 the damping in this case being obtained by forcing grease through the annular space between the inner wall of the piston rod and a stationary damper piston : an orifice and plate valve in the damper piston provide less damping action when the piston rod retracts than when it extends. This type of actuator could be used, for example, to operate the landing gear and to restrict the rate of extension.

CHAPTER: 5
AIR CONDITIONING

GENERAL

The air conditioning system of an aircraft is designed to maintain selected temperature conditions within flight crew, passengers and either compartments, and comprises five principle sections: air supply, heating, cooling, temperature control, and distribution. In some aircraft humidity control section also forms part of the air conditioning system.

In pressurised aircraft, the air conditioning and pressure installation systems are intrinsically linked, and it is the controlled discharge of pressurised and conditioned air, which maintains the elected cabin altitude. For further information on aircraft pressurisation systems and cabin pressure control equipment.

Brief descriptions of some principal units which form a typical air conditioning system are given in the relevant air conditioning cycles. Basically two types of Air conditioning cycles are used.
(I) Air cycle system (II) Vapour cycle system.

I   AIR CYCLE SYSYEM

There are two types of Air Cycle System:
(1) Ram air system
(2) Engine bleed air system

RAM AIR SYSTEM

AIR SUPPLY

This method is adopted in certain small types of unpressurised aircraft utilising either combustion heating or engine exhaust heat exchanger systems. A typical system is diagrammatically illustrated in Fig.1. Typical location for ram air intake are at the nose of an aircraft or in a dorsal fairing at the base of the fin or vertical stabiliser. The air after circulating through the cabin, is discharged to atmosphere via a spill vent.

HEATING

The method of heating the air depends on the type of air supply system and one of the methods outlined in the following paragraphs may be adopted.

Combustion heating

This method is normally associated with a direct type of ram air ventilating system, and depends for its operation on the combustion of a fuel and air mixture within a special cylindrical combustion chamber (Fig.1).

Air for combustion is obtained from a blower and the fuel is metered from the aircraft fuel system by a solenoid-operated control valve. A filter and safety valve are also incorporated in the fuel supply line to the combustion chamber. The fuel - air mixture is ignited by a spark plug, the burning gases travelling the length of the combustion chamber and passing through transfer passages to an exhaust outlet. Ventilating air from the ram air intake passes through the heater and is heated by contact with the outer surfaces of the combustion chamber.

Blower operation and supply of fuel is normally controlled by a single switch. Regulation of the cabin temperature is carried out by the manual setting of a mechanically controlled switch installed in the ducting downstream of the heater.

Engine exhaust heating

The method is also associated with ram air ventilating systems, but heating of the air supply is effected in a simpler and more direct manner. Air enters through an intake connected to a heater muff which surrounds the exhaust pipe of a piston engine exhaust system. After heating, the air passes into the cabin via a chamber through which cold air also flows from an intake situated either in the fuselage or in the wing depending on the installation. Mechanically operated valves are provided to control the mixing of the airflows and so regulate the temperature.

COOLING

In ram air supply systems the cooling method is of the simplest type whereby the cold air can be directly admitted to the cabin via adjustable louvres. In the more complex systems cooling may be accomplished by either the air cycle or the vapour cycle method.

TEMPERATURE CONTROL

Control of air temperature conditions in passenger cabins, flight crew and other compartments, is accomplished by modulating the valves installed in the air ducting of heating and cooling sections of the air conditioning system. The methods of control vary and depend on the type of aircraft and the air conditioning system employed. In general, two principal methods are adopted, mechanical and electromechanical. The information given on these two methods in the following paragraph is of a general nature, and reference should always be made to specific Aircraft Maintenance Manuals for full operating details.
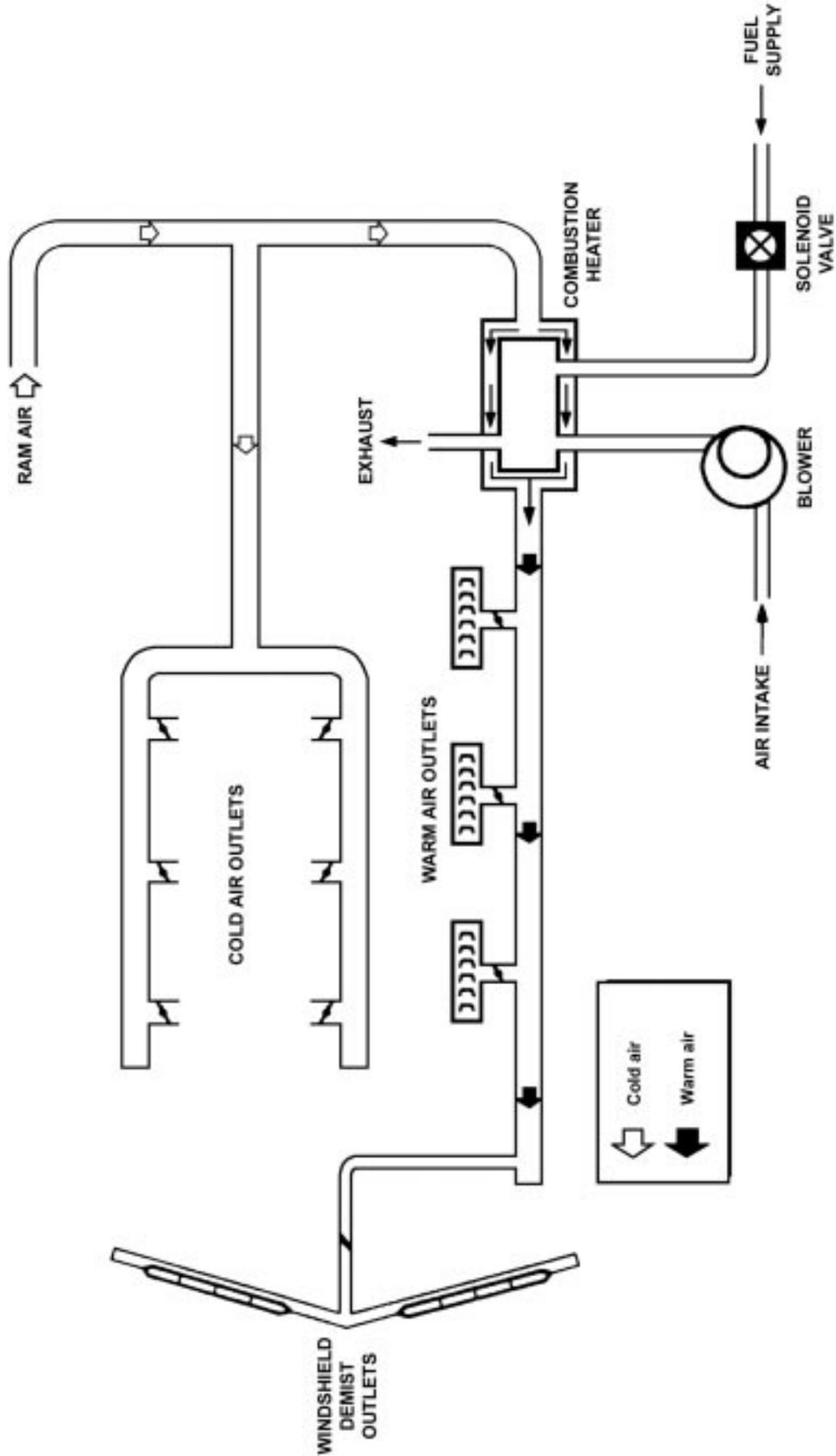
Fig.1. Typical ram air system.

Mechanical control

One mechanical method, which, for example, is employed in aircraft utilising an engine exhaust heating system, and consists of valves which can be manually positioned to regulate the temperature by varying the proportions of hot and cold air passing through a mixing box before delivering it to the cabin. In some installations, hot and cold air enters the cabin through separate valves and ducting.

Electromagnetic control

The electromechanical method of temperature control used in some types of combustion heating system, is also used in all air conditioning systems which utilise the compression method of heating, and air cycle or vapour cycle methods of cooling. In a combustion heating system, the electrical power supply to the solenoid valve is automatically controlled by the duct thermostat. When the temperature of the air flowing from the heater exceeds the thermostat setting, the thermostat de-energises the solenoid valve to isolate the fuel supply to the heater. As the heater cools, the thermostat opens the valve to restore the fuel flow and combustion process. By cycling on and off, the heater maintains an even temperature in the cabin.

ENGINE BLEED AIR SYSTEM

This method is adopted in certain types of turbojet aircraft, in which hot air, readily available from main engine compressors is tapped off and supplied to the cabin. Before the air enters the cabin it is passed through appropriate control valves and a temperature control system to reduce its pressure and temperature. A typical bleed air system of the 'bootstrap' type is illustrated diagrammatically in Fig.2.

AIR SUPPLY

Auxiliary power unit (APU)

The auxiliary power unit, where fitted, is an independent source of pressurised air. Operation of the APU is , however, subject to certain limitations. Fig.2 diagrammatically illustrates a typical system employing an auxiliary power unit.

Compressors or blowers

This method is utilised in some types of turbojet, turbo propeller and piston-engine aircraft, the compressors or blowers being driven by the engines via accessory drives, gear boxes or bleed air. Fig.3 diagrammatically illustrates a typical system employing an air displacement type of blower.

Air is drawn in through a ram air intake located in a wing leading edge or an engine nacelle fairing. A filter unit may be provided to protect the blower rotors from foreign matter and to ensure a clean air supply. In order a reduce the level of noise emanating from the blower, silencers are incorporated in the main supply ducting.

HEATING

Engine bleed air system employs compression heating. This system of heating relies on the principle whereby the air temperature is increased by compression and forms the basis of the heating method employed air supply system utilising engine driven compressors or engine bleed air.

COOLING

The operation of an air cycle cooling system is based on the principal of dissipating heat by converting its energy into work. The principle components of a typical system are the primary and secondary air-to- air heat exchangers, a turbo-compressor cold air unit and a water separator. The interconnection of these components in a 'bootstrap' arrangement, is illustrated in Fig.2.

Heated air is directed though air passages of a matrix assembly within the primary heat exchanger and is pre-cooled by air entering a ram air intake and passing across the matrix. The pre-cooled air then enters the cold air unit via the axial inlet of the compressor and is compressed by the action of the compressor impeller and diffuser assembly. The air leaves the compressor outlet and passes through a matrix assembly of the secondary heat exchanger which dissipates a large proportion of heat produced by compression. From the secondary heat exchanger the air enters the turbine of the cold air unit. The air expands through the turbine and in causing the latter to drive the compressor, sufficient pressure drop across the turbine is achieved to cause further cooling of the air.

The water separator (coalescer) is installed downstream of the cold air unit to extract a percentage of free moisture from the air which subsequently ventilates and pressurises the cabin. Air from the cold air unit turbine enters the separator and passes through an assembly in which the moisture in the air coalesces into large water droplets. The droplets are then carried by the air to a separator assembly which extracts the water. The water is then drained away through a drain line to an overboard vent, or into the heat exchanger ram air supply to provided additional cooling. To ensure that the flow of air to the cabin is maintained in the event of the water separator assembly becoming obstructed by ice, a safety valve is normally provided. In some systems the water separator is combined with in airflow silencer unit.

TEMPERATURE CONTROL
Electromagnetic control

In systems utilising compression heating, air cycle, or vapour cycle methods of cooling, the electromechanical temperature control system is designed to automatically modulate actuator motors which control particular valves. A
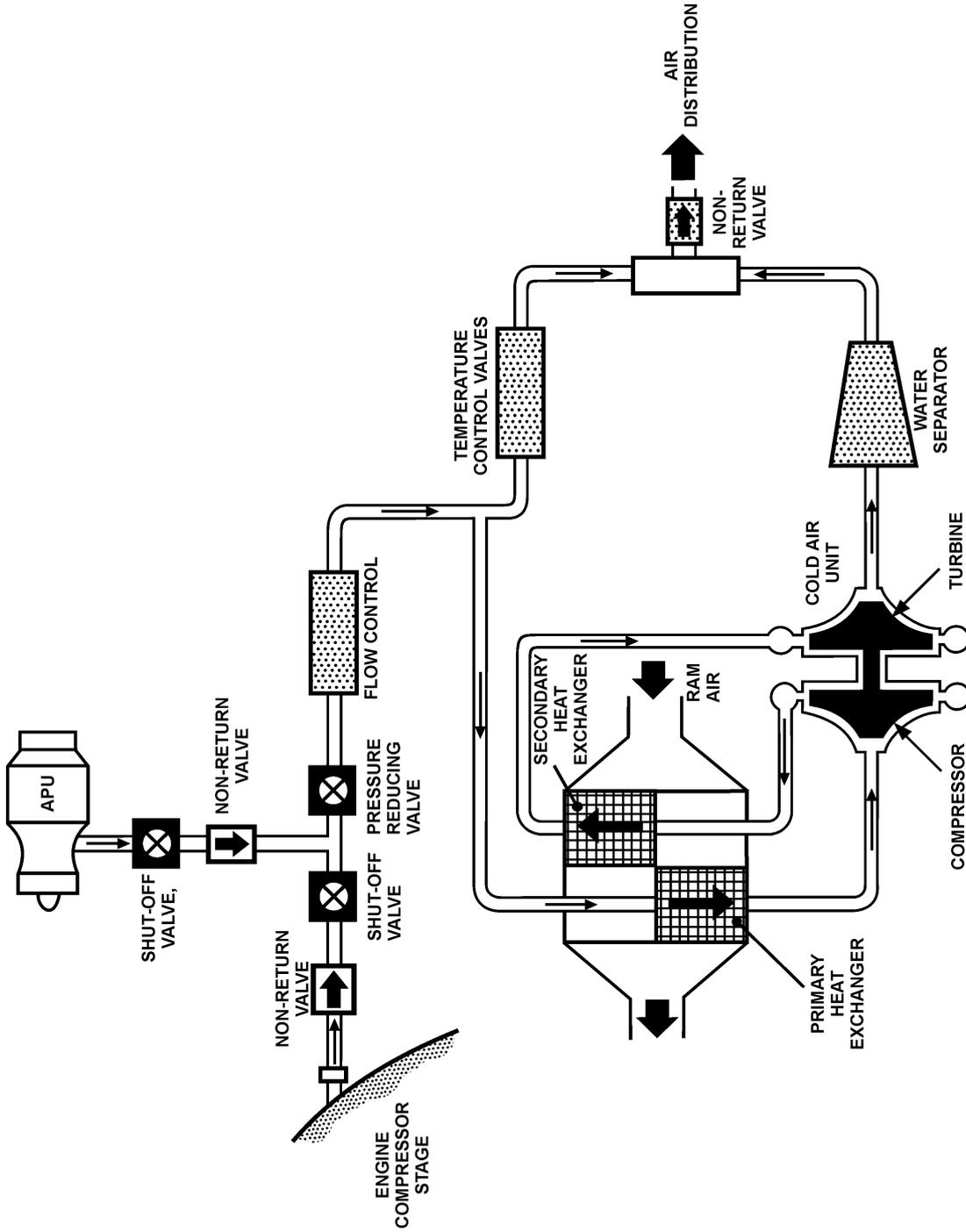
Fig.2. Typical bleed air (Bootstrap) system.
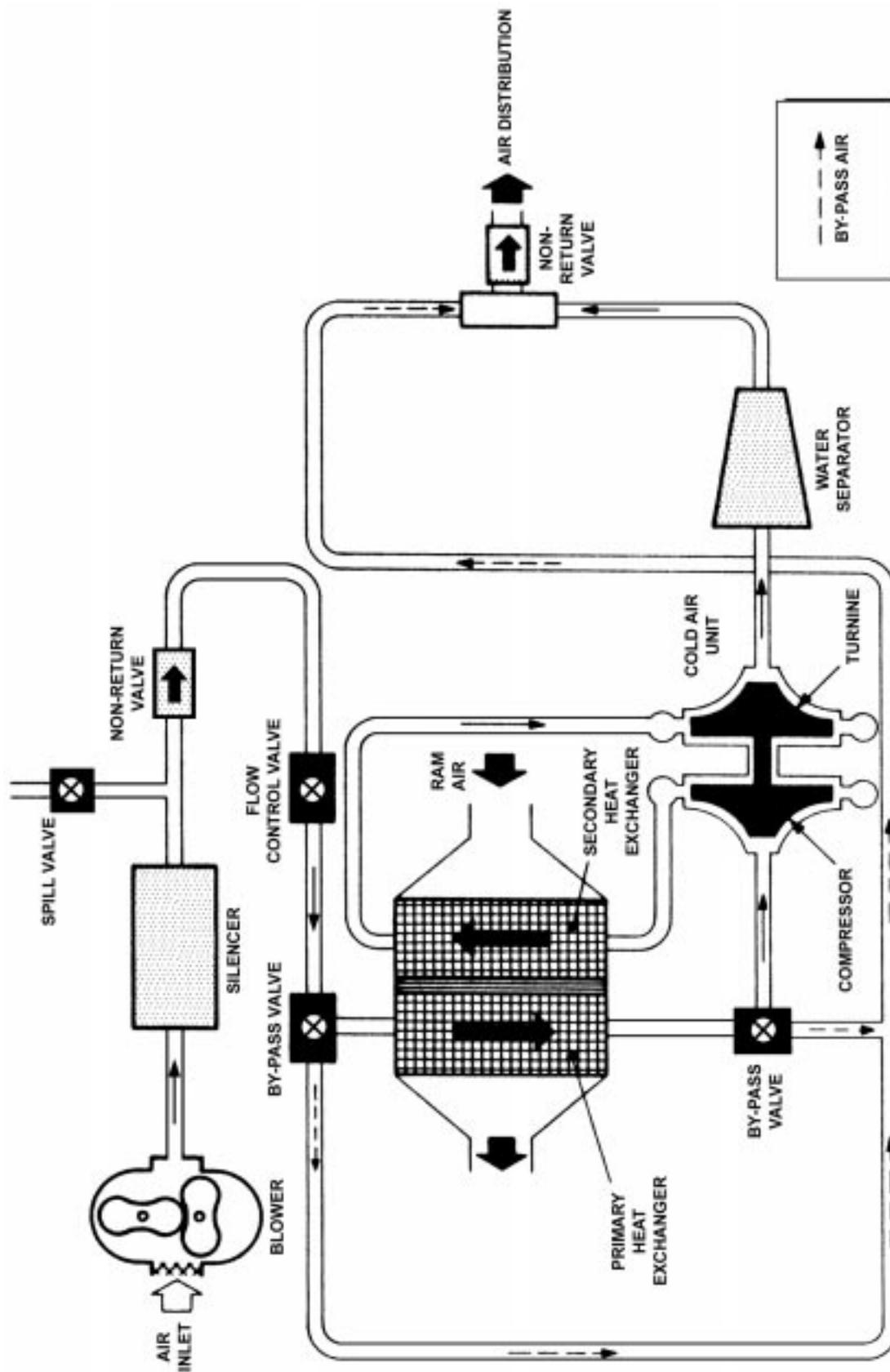
Fig.3. System employing a displacement type blower.

HIGH PRESSURE LIQUID
LOW PRESSURE LIQUID
LOW PRESSURE VAPOUR
HIGH PRESSURE VAPOUR

LIQUID RECEIVER

EXPANSION VALVE

EVAPORATOR

CONDENSER

FAN

RAM AIR

AIR DISTRIBUTION

MAIN AIR SUPPLY

TURBINE

COMPRESSOR

TEMPERATURE CONTROL
VALVE SYSTEM
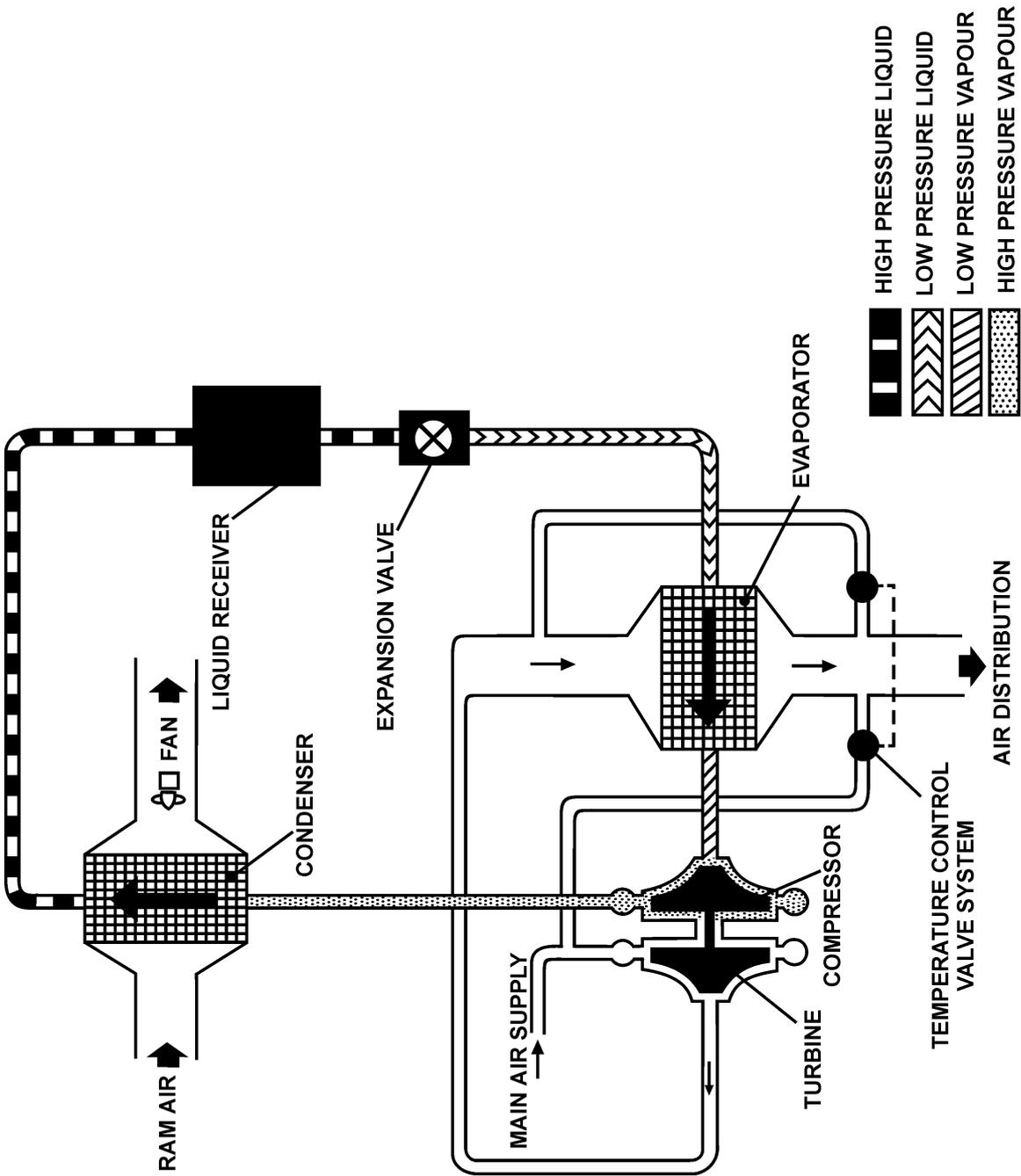
Fig.4. Vapour cycle cooling system.

typical system comprises a duct temperature sensing element, a temperature selector, cabin temperature sensing element and automatic control unit. These components are electrically interconnected to form a resistance bridge circuit which is only in balance when the cabin air temperature is at the selected valve.

If the bridge circuit is placed out of balance by a resistance change in either of the sensing elements due to temperature variation, or by varying the selector switch setting, an error signal is produced which is fed to an amplifier stage of the control unit. The amplified signal is then fed to the appropriate actuator motors which position their respective valves to adjust the air flows and so correct the temperature change until the bridge circuit is restored to a balanced condition. Manual controls are provided to permit overriding of the automatic circuit, low temperature and high temperature limit control devices are also provided and respectively they prevent icing in the water separator, and ensure that upper limits of supply air temperature are not exceeded.

II VAPOUR CYCLE SYSTEM

The principal of vapour cycle cooling is based upon the ability of a refrigerant to absorb heat through a heat exchanger in the process of changing from a liquid into a vapour. The major components of a typical system and their interconnection with each other is diagrammatically illustrated in Fig.4, these components are generally mounted together to form a refrigeration pack, and comprise the following:

(a) *A liquid receiver:* to provide a storage area for the liquid refrigerant.

(b) *A thermostatic expansion valve:* to control and meter the liquid refrigerant into the evaporator.

(c) *An evaporator:* which is a form of heat exchanger designed to extract heat from the main air supply prior to distribution into the aircraft.

(d) *A compressor:* to provide the motive force for refrigerant re-circulation, and in conjunction with the thermostatic expansion valve, maintain a pressure differential between the condenser and evaporator. The effect of this differential improves both vaporisation and condensation of the refrigerant as follows. The compressor in drawing vapour from the evaporator assembly, decrease the effective pressure acting upon it, the consequence of which reduces the boiling point of the refrigerant. Conversely, on the discharge side of the compressor, vapour pressure is increased. This has the effect of increasing the boiling point and condensation point of the refrigerant, which returns to a liquid state when the latent heat is removed in the condenser.

NOTE: The coupled turbine of the compressor may be driven by an independent air supply (e.g. a tapping from a wing de-icing system), the main air supply, or electrically

(e) *A condenser:* which is a form of heat exchanger designed to extract heat from the vaporised refrigerant.

(f) *A condenser fan:* which provides (in the absence of ram air), cooling air for the condenser.

(g) *The refrigerant:* which is a low boiling point volatile liquid such as; ammonia, sulphur dioxide, or dichlorodifluoromethane generally referred to by the trade name of 'Freon'.

The Vapour Cycle is as follows

(a) Liquid refrigerant passes from the liquid receiver to the thermostatic expansion valve for controlled release into the matrix of the evaporator.

(b) Heated air from the main air supply system (prior to entry into the cabin distribution system) passes through the evaporator matrix and by induction releases heat into the liquid refrigerant.

NOTE: The main air supply entering the distribution system is now at a reduced temperature.

(c) As a consequence, the liquid refrigerant boils to a vapour.

(d) The vaporised refrigerant is then drawn into the compressor, compressed to a high pressure and temperature to enter the condenser.

(e) The condenser; cooled by ram air, reduces the temperature of the vaporised refrigerant, and as a consequence returns the vapour back to a liquid form which then flows back to the liquid receiver to repeat the cycle.

DISTRIBUTION

The air used for conditioning purposes is distributed by a ducting system the layout of which depends on the type of aircraft and its air conditioning system. In a basic system, such as that employing a ram air supply and combustion heating (Fig.1) the ducting is generally in two distinct sections and provides for separate flows of cold and heated air. The outlets for cold air are normally of the adjustable louvre type and are installed so that air flows from such points as below hat racks, cockpit and cabin sidewalls.

Heated air is distributed through outlet grilles situated at floor level, the degree of heat being regulated by mechanical valves directly controlled at the outlets, or by control knobs in the flight compartment. The heated air duct also has a branch duct which directs heated air to the wind shield panels for demisting purposes.

In larger aircraft the air conditioning equipment is normally grouped together in its own compartment or bay. The conditioned air is distributed to passenger cabins through underfloor and hat rack ducting, the latter containing outlet grilles and the requisite number of individual adjustable cold air louvres which are supplied from a cold air source. The distribution of air to flight crew compartments may, in some cases, be through separate ducting or it may be through ducting tapped into the passenger cabin ducting. Typical locations for the air outlets are at floor and roof levels and in sidewalls.

Tapping are taken form the cabin and flight crew compartment ducting systems for supplying warm air to cabin windows and wind shields for demisting purposes. After circulation the air is exhausted to atmosphere through the discharge or outflow valves in the pressurisation system.

MATERIALS

Materials used in the manufacture of typical ducting systems are light alloy, plastic, fibre glass reinforced plastic and stainless steel, the latter being normally used for the hot air sections of engine bleed air supply systems. There are various methods of joining the duct sections together and to components. In those most commonly used the joints are made by flanges and ring clamps of V-section, by rubber sleeves fitted over the ends of duct sections and secured either by adjustable clamps or by a rubber adhesive, and by bolted flanges.

Fibreglass, formed into blanket sections by a covering of synthetic material e.g. nylon, is used for lagging of duct sections. To permit longitudinal movement of ducting as it expands and contracts, expansion bellows, sliding clamps and gimbal mountings are provided in some the larger aircraft systems.

HUMIDITY CONTROL

In some aircraft operating for long periods at high altitudes, it is necessary to increase the moisture content of the air used for conditioning and pressurising the cabin in order to overcome physical discomfort arising from low relative humidity. Various humidity control methods may be adopted but a typical system consists of humidifier unit supplied with water (from and individual at tank or galley water system) and also with air under pressure. The water and air supplies; which are controlled by electromagnetic valves, pass through a jet nozzle system within the humidifier in such a manner that the water is atomises and enters the distribution ducting in the form of a fine spray.

At the other extreme, operation of aircraft at low altitude and on the ground in regions of high relative humidity, necessitates a reduction of the moisture content of the air supply. In addition to the passenger comfort aspect, it is necessary to decrease the humidity in order to reduce condensation and its effect.

GROUND AIR CONDITIONING

In some aircraft provision is made for the conditioning of cabin air while an aircraft is on the ground. The methods adopted depend on the type of aircraft and the associated air conditioning system.

In aircraft employing combustion heating systems, cabin heating is normally obtained by switching on the heater and a ventilating fan located in the main air supply ducting. On the ground, limited cooling of the cabin air can be obtained by switching on the ventilating fan.

For heating the cabin air in aircraft equipped with an engine exhaust heating system it is necessary for the engines to be running, and for the mechanical air flow control valves to be appropriately adjusted to provide the desired conditions.

Aircraft using more complex methods of air conditioning are often provided, with special external connection to which ground service equipment can be coupled. These units supply either preconditioned air into the main cabin air distribution system or pressurised air into the air conditioning packs. In some cases ground service equipment may be used when carrying out ground test procedures.

In addition to the ground connections, some aircraft are equipped with an auxiliary power unit for use in the absence of ground conditioning units. Electrically operated blowers may also be fitted for use either as simple cool air ventilators, or in conjunction with a 'bootstrap' air conditioning system, to provide a flow of cooling air to the heat exchangers.

INSTALLATION

The information given in the following paragraphs is of a general nature, and is intended as a guide to the procedures associated with the installation of the principal component of air conditioning systems. Full details are contained in the Maintenance Manuals for specific aircraft types and reference must therefore always be made to these documents.

Compressors and blowers

Before installation a check should be made to ensure that units are free from damage and that ducts air inlets and outlets, and mating surfaces are free from oil, dust and other foreign matter. Rotors should also be checked for freedom of rotation observing any special precautions and procedures specified for the appropriate types of unit.

Pipes, metering units and filter of bearing lubricating oil systems should also be inspected for cleanliness and signs of cracks or other damage. Priming of the lubricating oil system should be carried out as specified in the Component and Aircraft Maintenance Manuals.

Units must be adequately supported during installation to ensure that their weight is not allowed to bear on parts of the main drive; for example, a quill shaft which drives a displacement blower. In some aircraft employing compressors a special hoist is provided for installation and removal of units and this should be used in the prescribed manner.

After a compressor or blower has been lowered on to the engine or gearbox mounting pad, its securing nuts or bolts, as appropriate, should be torque-tightened to the values specified in the Aircraft Maintenance Manual. In some compressors installations the units must be secured by bolting them to the casing of their respective engines via link assemblies.

Inlet and outlet duct attachment flanges should be clean and free from damage. In displacement blower systems, manifold normally provide for the attachment of duct sections to the blower casing. The bolts securing each manifold to the blower. are, in some cases of different lengths. This must be re-fitted in their correct position before tightening to avoid distortion of the inner face of the blower casing. New sealing rings should be fitted between duct section and corresponding attachment points on compressors and blowers, and sections should fit squarely and not be subjected to undue strain or load.

Combustion heaters

Before installation, combustion heaters should be inspected, and when necessary, pressure tested in the manner

prescribed in the Aircraft Maintenance Manual to ensure that no fuel or combustion products leak into the cabin air supply.

Heaters should be installed in the manner specified in the Aircraft Maintenance Manual concerned taking care that air and fuel leakages do not occur at duct joins or connections. There should be no connection between the combustion air and cabin air supplies and no leakage of air or exhaust gas into the aircraft.

Equipment associated with the heating system such as flow valves, air regulators, thermostatic devices and ducts should be correctly interconnected, and mechanical movements, flows and temperature settings checked and adjusted.

After the installation of a heater the system should be ground tested in the manner specified in the relevant Aircraft Maintenance Manual.

Engine exhaust heaters

When installing heater muffs around piston engine exhaust systems it must be ensured that they are in such isolation that exhaust gases cannot enter the muff and subsequently be discharged into the heating and ventilating system. Cooling air intakes and hot air ducting should be installed so that no obstruction or leakage of the air supply can occur. All joins should be correctly aligned and clamps securely fixed.

Heat exchangers

Before installation, heat exchangers should be inspected to ensure that no foreign matter has entered the various connection, that there are no evident cracks or other damage and that ram air passages are free from obstruction.

Heat exchangers are heavy units and they must therefore be adequately supported during installations to prevent them fouling ducting, other system components and parts of the aircraft structure.

The fore-and-aft and transverse clearances for mounting flanges and bolts should be checked to ensure that they are within the limits specified in the relevant Maintenance Manuals. Mounting bolts should be tightened to the appropriate torque values.

New seals and O-rings should be fitted to the joints between system ducts, cooling air inlet and outlet flanges, and charge-air connections. Nuts, bolts and clamps should not be over tightened as connections flanges may distort and cause damage to adjacent brazed joints. After installation the joints should be leak tested in accordance with the procedure laid down in the relevant Aircraft Maintenance Manual.

If disturbed during installation of a heat exchanger, cooling air shutters of flaps should be tested and adjusted as necessary. Moveable parts should operate freely, and the limits switches of electrical actuators should isolate the power supply when the shutter or flap has moved through its full travel.

Cold air units

When installing cold air units care is necessary to exclude dirt and oil from the air ducts and casings. Dirt and other foreign matter may damage the rotating parts and oil may introduce unpleasant or flammable vapours into the cabin air supply. Duct attachment flanges, unit mounting flanges, and casings, should be examined for signs of burns, cracks, distortion or other damage.

Units with integral wet sump lubrication should be primed with oil to be approved specification to ensure that all bearings surfaces have been lubricated. Reference should be made to the Maintenance Manuals of relevant units for details of the lubricants required. The unit should be supported on a bench in the normal operating attitude while the quantity of oil specified for the unit is poured in. To ensure that oil is distributed to the bearings, the rotating assembly of the unit should be spun over by hand at the same time checking that the rotation is free and without noise or vibration. The unit should then be drained and installed in the aircraft and after securing it to its appropriate mounting, refilled with oil to the level marked on the sump dipstick.

NOTE: In some cold air units, air bearings are used to support the main rotating assembly, which do not allow free rotation from the idle state.

The lubricants recommended for Cold Air Units are various and possibly incompatible with each other. Therefore, when priming or servicing these units, care should be taken to ensure that the oil is of the correct type and specification and the containers used are clean and free from contamination of any kind.

New seals should be fitted between the air distribution ducts and attachment flanges on the cold air unit, and when securing the ducts it should be ensured that they fit squarely and are not subjected to undue strain or load. Leak checks on units should be carried out during functional testing of the air conditioning system.

Refrigeration systems

The individual components of a refrigeration system can usually be removed and installed separately. However the Maintenance Manuals appropriate to the system and aircraft should always be referred to before attempting such work. Some of the general precautions applicable to closed Cycle System are as follows:

(a)   Gloves and goggles should be worn when handling liquid refrigerants which can be harmful to the skin and eyes.

(b)   Before filling a newly installed system, or refilling a system which has been partly disconnected, all air should be evaluated in the manner prescribed in the relevant Maintenance Manual.

(c)   While Refilling is in progress, care should be taken to ensure that refrigerant used is of the specified type, and quantity, and that all precautions recommended by the manufacturer are observed.

Temperature control system components

The temperature control of complex air conditioning system is usually accomplished either electrically or electronically.

Consequently the following precautions are normally adopted when installing such equipment are applicable.

As temperature-sensing elements are positioned, so that it will be directly affected by the changes in duct and cabin air temperatures. Care should be taken that element sensing cabin air temperature are not shielded by loose upholstery, and are protected, if paint spraying or similar operations are performed in their vicinity.

The damping effect of shock absorbers and anti-vibration mountings which may provide support for electronic amplifiers and similar sensitive equipment, should be checked by hand after installation.

Cables interconnecting components must be of the rating specified by the manufacturer and all connection must be clean and secured properly.

When installing control units, care should be taken that such controls are preset potentiometers and fine adjustment resistors are not disturbed.

On completion of the installation of a component, sensitivity tests and final balance adjustments should be carried out in accordance with the procedure laid down for the specific aircraft system. Tests of the overall controlling function should be made by selecting various temperature settings and noting that the actuators controlling such components as heat exchanger cooling air flaps, bypass valves, etc., move in the appropriate directions.

Valves

Mechanically and electrically operated valves are employed in the various types of heating, ventilating and air conditioning systems and therefore Maintenance Manuals should always be referred to for the appropriate installation procedures. The details given in the following paragraph are of a general nature.

All valves should be inspected before installation for cleanliness, signs of damage and freedom of movement. Functional checks should be made on electrically-operated valves, e.g. spill valves bypass valves and choke valves to ensure that limit switches are correctly adjusted at the extremes of valve travel.

Valves are often marked with arrows to indicate the direction of flow and particular care is necessary to ensure that the valve is installed in correct relation to flow.

The attachment of valves to their respective mountings and duct section must be secure and torque loadings strictly observed.

Electrical connections to actuators and to position indicators where fitted, should be checked against the relevant wiring diagrams and plugs, sockets and terminal screws checked for security.

On completion of the installation of a valve, an in-situ functional test should be carried out in accordance with the procedure specified in the relevant Component and Aircraft Maintenance Manual.

Distribution systems

The methods of installing ducting and other components of distribution systems depend on the type of air conditioning system and reference must, therefore, always be made to the relevant Aircraft Maintenance Manual and the procedures specified carried out.

The following summary serves a guide to some important aspects common to installation procedures:

(a) Ducting should be inspected externally and internally for cleanliness, signs of damage and security of end fittings.
(b) Lagging, where fitted, should be inspected to ensure freedom from tears, damage and evidence of deterioration.
(c) When fitting ring clamps, the sealing rings must be correctly positioned between duct and fittings squarely before the clamps are tightened.
(d) Ring clamps should be torque-tightened to the loads specified, the loadings should be rechecked after the engine run following installation.
(e) Ducts made from fibreglass, plastic and reinforced plastic should not be subjected to any weight or load during installation, and the straps or clamps attaching the ducts to support brackets should not be over tightened.
(f) After replacement of a duct, the disturbed joints should be checked for leakage.
(g) Where specified, ducts must carry identification labels.
(h) When assembled, on ducts rubber sleeves should be in a free condition, i.e. they should not be twisted, stepped or collapsed.
(i) Bedding tape or metal clips must be fitted between rubber sleeves and adjustable clamps to prevent damage to the sleeves when tightening the clamps. Expansion bellows, sliding clamps or gimbal mountings where installed, should be checked for full and free movement.
(j) Electrical bonding leads must be properly secured.

MAINTENANCE

The information given in the following paragraphs on maintenance periodic inspection and testing, is of a general nature and should be read in conjunction with the Maintenance Manuals and Schedules for the components and aircraft concerned.

Compressors and blowers

Units should be inspected for damage and for security of mountings attachment to engine drives and accessory gearboxes, and also duct attachments.

Oil transfer pipes should be examined for security of attachment, signs of chafing and other damage, and for leaks. At the periods specified in the Maintenance Manual oil filters should be removed for examination and cleaning or renewed as appropriate. If it is suspected that dirt is present in the lubrication system, all pipes and oil passages should be cleaned in the manner prescribed in the Maintenance Manual for the relevant unit. In units having an internal

lubricating system, the oil level in the sump should be checked and replenished as necessary taking care that the equipment for dispensing the oil is scrupulously clean.

Where magnetic chip detectors are fitted to the lubrication system they should be removed and inspected for metal particles. If no particles are found, the chip detector, together with a new sealing ring, should be refitted and wire locked. If metal particles are present the unit should be replaced with a serviceable item.

NOTE: When refitting bayonet type chip detectors extreme care should be taken to ensure positive engagement.

Combustion heaters

Heaters should be examined for security of attachment and signs of malfunctioning, the fuel system should be carefully checked for signs of leakage and drain pipes should be checked, ensure freedom from obstruction. At the specified inspection periods igniter plugs should be cleaned, and heaters should be subjected to pressure test in accordance with the procedure laid down by the manufacturer.

Electrical wiring and associated components should be checked for security of attachment, loose connections, chafing of insulation etc. The sheath of the igniter plug cable should be examined for any possible indications of arcing, which would be evidenced by burning or discoloration of the sheath.

Filters, air and fuel regulating devices, safety devices (e.g. overheat switches, fuel cutoff valves, etc.), and all controls should be inspected, adjusted and tested as required by the approved Maintenance Schedule.

System operation should be checked in accordance with the procedure laid down in the relevant Aircraft Maintenance Manual.

NOTE: In order to reduce the risk of the cabin air supply becoming contaminated by high concentrations of carbon monoxide from the exhaust system, it is imperative that the procedures for inspection, servicing and overhaul of combustion heaters and their associated exhaust systems are maintained to a high level.

Engine exhaust heating

Careful examination of heater muffs is necessary to ensure that no leakage of exhaust gases into the air delivered to the cabin can occur. Unless damage can be rectified within the scope of an approved repair scheme, exhaust pipes or muffs which show signs of cracking, corrosion or excessive high temperature scaling should be renewed. All muffs should be pressure-tested when specified in the Maintenance Schedule.

Hot and cold air ducts associated with the heating system should be free from obstruction and all controllable shutters, valves etc., should be checked for correct functioning. The operation of the complete system should be checked during engine running.

Heat exchangers

Heat exchangers should be inspected for security of attachment to the aircraft structure, security of air duct connection and freedom from damage.

The external surfaces of a heat exchanger matrix must be clean and the cooling air passages free from obstruction. If dirt or other forms of contamination are found the surface and air passages should be cleaned by means of a clean dry air blast.

If a matrix has not been satisfactorily cleaned due to the contamination being excessive or hardened on to the surfaces, or if internal contamination or leakage from the charge air passages is suspected, the heat exchanger should be removed for cleaning and repair and replaced by a serviceable unit.

Cooling air shutters or flaps, linkages and actuators should be examined for freedom of movement and should be lubricated when necessary. Linkages and hinges an shutters or flaps should be checked for excessive play and lost motion.

During functional testing of a complete air conditioning system, a check should be made at all joints for air leakage.

Cold air units

Cold air units should be inspected for security of mountings and external locking devices, cleanliness, freedom from damage, oil leaks, and leakage of air from duct connections. In some units a magnetic chip detector is fitted to the oil sump drain plug; this should be removed and inspected for metal particles. If particles are present, the cold air unit should be replaced by a serviceable. If no particles are present, the chip detector refitted together with new sealing ring and wire-locked.

The oil level must be checked and replenished if necessary taking care that the oil is to the specification approved for the unit, that the equipment for dispensing the oil is scrupulously clean, and that the system is not overfilled.

Refrigeration systems

Refrigeration packs and associated components should be checked for security of mountings, security of pipe line connections between components and level of refrigerant. If the level is low the system should be checked for leaks and, after rectification, recharged with the refrigerant specified for the system taking care that all precautions are observed.

Temperature and control system

All components should be inspected for security of mounting and electrical connection , signs of damage, deterioration of electrical cables etc.

The operation of individual components should be checked during specified ground tests to ensure that they respond correctly whenever different heating and cooling and conditions are selected, and also that, in combination,

they maintain cabin temperature conditions within a comfortable range. It should be borne in mind that, apart from consideration control of comfort, cabin temperature control limits the misting and icing of windscreens and windows and therefore affects the safe operation of aircraft. The operation of components, systems and circuits, designed specifically for emergency operating conditions, must also be checked during ground test procedures.

The test procedures vary and the extent to which a system can be tested may be limited, particularly in relation to ram air methods of cooling. On the other hand, full-range temperature control of a system in some aircraft may be checked on the ground. Reference must therefore always be made to the relevant Aircraft Maintenance Manual and Maintenance Schedule for the procedure to be adopted and precautions to be observed.

Valves

The maintenance of valves associated with air temperature control is usually confined to; inspection for cleanliness, security of mounting ducting attachments and, where applicable, security of electrical connections, functioning tests and light lubrication specified by the manufacturer of the component.

Sliding or rotating parts of valve assemblies should be free from scores, damage or excess static friction. The maximum effort required to move a valve should be checked when necessary and should not exceed the figure recommended by the manufacturer. However some electric-mechanically operated valves are not designed to operate without the application of an electrical supply. Therefore reference should be made to the specific Maintenance Manual for test instruction, before manual operation.

Lubricants should be of the type specified for the component and should be applied sparing taking care to prevent oil entering air supply ducts.

Valve seats and valves faces should be kept free of dust or traces of lubricant.

Checks on the operation of valves should normally be carried out during ground testing of temperature control systems since their functions are integrated.

Distribution systems

All ducting and associated air distribution components should be inspected for security and general condition, particular attention being given to joints between duct section and components.

Lagging should always be properly secured and free from oil hydraulic fluids etc. It should be remembered that duct sections in some parts of a system often become heated to a degree sufficient to make oil-soaked lagging flammable.

When specified, ducts should be proof-tested at the pressure recommended by the manufacturer. Pressure tests are however, more often made with the object of detecting leaks, in which case the test pressure is not critical provided it does not exceed a value which might damage the duct.

It is usually more convenient to test a complete distribution system by dividing it into section and applying a recommended pressure separately and in sequence. The sections should be selected so that all critical joints are subjected to the test pressure; advantage being taken of shut-off valves, non-return valves, etc., where these provide convenient boundaries between sections.

Leaks can be detected by ear although these are sometimes revealed by discoloration and holes blown in the lagging. If there is difficulty in locating leaks, the soap and water method can be used.

NOTE: Because of the high operating temperatures and pressures involved, it is recommended that care should be taken when carrying out a physical check for air leaks.

CHAPTER: 6
PRESSURIZATION SYSTEMS

PRESSURISATION SYSTEMS

These systems are designed to automatically maintain a selected altitude relationship between cabin and aircraft by controlling the pressure of the air normally derived from an associated air conditioning system.

GENERAL

In order to protect the occupants of an aircraft from the discomfort and dangers arising from the effects of reduced atmospheric pressure encountered at altitude, it is necessary to pressurise the cabin. To overcome the problems associated with these effects, the actual pressure in the cabin is controlled by regulating the rate at which the air supplied from the air conditioning system is discharged overboard. In general this is achieved by a pressure controller passing a signal to one or more discharge valves (which impose a restriction on the discharged air) to establish, and then subsequently to maintain, the required cabin pressure.

In addition to the basic units that control cabin pressure during flight, pressure limiting and inward relief valves are also provided to safeguard the cabin in the event of failure of a controlling unit. Indication of cabin pressure, selected altitude, and prevailing altitude conditions is provided by a differential pressure gauge, a dial and pointer system in pressure controllers, and a separate altimeter and vertical speed indicator.

Cabin Altitude

With an increase in altitude there is a decrease in atmospheric pressure (see Fig.1).
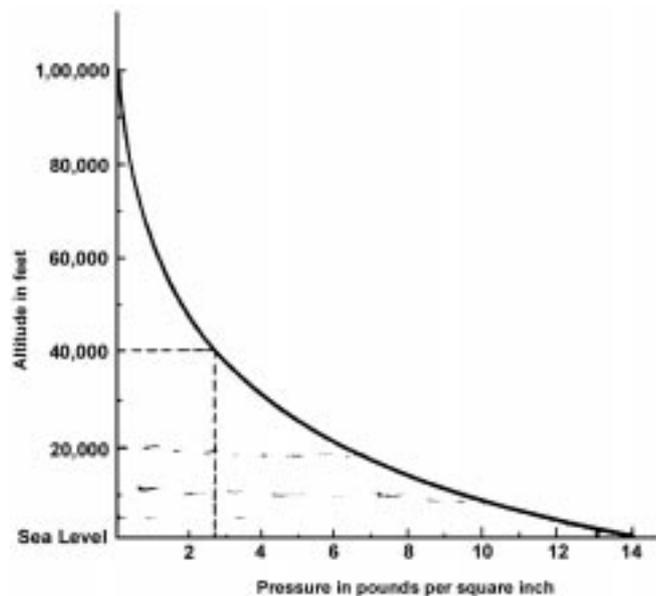
Fig. 1. Atmospheric Pressure.

From sea level to 7000 ft the oxygen content and pressure of the atmosphere is so sufficient as to maintain all mental and physical functions. At approximately 10,000 ft above sea level, oxygen saturation of the blood is lowered to approximately 90%, and any prolonged exposure to this level of cabin altitude could result in the occupants suffering headaches and fatigue. If the cabin altitude is allowed to rise further to approximately 15,000 ft, disorientation, impaired vision and physical changes may occur. Therefore, the purpose of the pressurisation system is to artificially create a lower altitude within the cabin (cabin altitude) relative to the aircraft altitude using pressurised air (Fig.2). Design of the pressurisation system will, however, require certain devices to ensure the comfort and safety of the passengers and the structural integrity of the aircraft. These devices are described in the following paragraphs.

The cabin pressure (relative altitude) is controlled by regulating the rate at which air, normally supplied by the air conditioning system, is discharged to atmosphere by one or more discharge valves. In general this is achieved by the pressure controller passing a pneumatic or electrical command signal to the discharge valves (outflow valves) which respond by increasing or decreasing restriction to the flow of air from the cabin to atmosphere (see Fig.3)

In addition to the basic units which control cabin pressure, pressure limiting valves, inward relief valves, ground depressurisation valves, (of either automatic or manual control), and associated warning systems are provided as a part
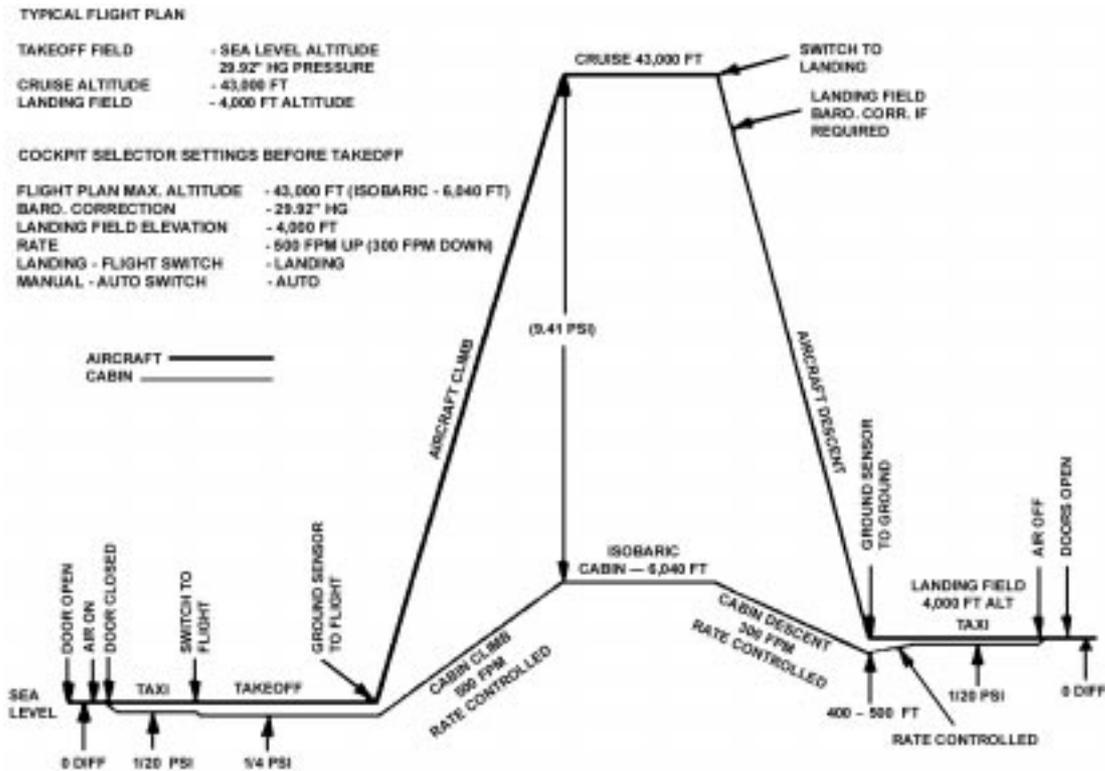
Fig. 2. Typical Pressurisation Schedule.

of the pressurisation system to safeguard the occupants and airframe, in the event of a system or component failure.

Flight deck instrumentation systems and controls include indications of: cabin altitude, differential pressure, and cabin altitude rate of change. These indications can be of either, analogue or digital form, using instruments or cathode ray tube (CRT) displays.

Normally, visual warning systems also include additional simultaneous audible alarms to alert the crew members of any significant changes taking place, which may require immediate crew action.

Brief descriptions of some principal units, controls and instruments which form a typical pressurisation system are given in the relevant paragraphs of this Leaflet. For precise details of specific systems, reference should be made to the relevant Aircraft Maintenance Manual.

PRESSURISED AIR

The source of pressurised air is normally dependent upon the aircraft and engine type. Piston engine aircraft in general, use superchargers or turbochargers which may be part of the induction system or specifically incorporated for the purpose of pressurisation, for further information see Leaflet EL/1-3.

Where aircraft are powered by a turbo-jet engine(s), bleed(s) air from the compressor section of the main engine core is utilised (see Fig.4). However, on smaller aircraft, a system of ram air, supplemented by a small amount of high temperature bleed air for temperature control, may be adopted for air conditioning and pressurisation purposes.

Where fitted, the auxiliary power unit (APU) is another alternative source of pressurised air for the purpose of pressurisation. However operation is subject to certain operational limitations, for further information see Leaflet AL/3-26.

THE PRESSURISATION CONTROL SYSTEM
General

The principal requirements of the pressurisation control system are:-
a. To control, maintain and monitor the cabin altitude relative to the aircraft altitude within the specified parameters.
b. To safeguard the occupants and airframe from 'pressure bumps' when ascending to or descending from altitude, by providing a controlled rate of altitude change.
c. To provide safeguards against total system failure.

Pressure Controllers

These units control the cabin differential pressure, i.e. the difference between the pressure in the cabin and external pressure, to selected values and they operate in conjunction with discharge or outflow valves. The maximum differential pressure values vary between types of aircraft but, in general, they are such that the cabin pressure does not fall below that equivalent to an altitude of 8000 feet. The rate of pressure or cabin altitude change can also be controlled and within a small pre-determined range, the values which are selected on typical pressure controllers for normal operation are between 300 and 500 feet per minute.
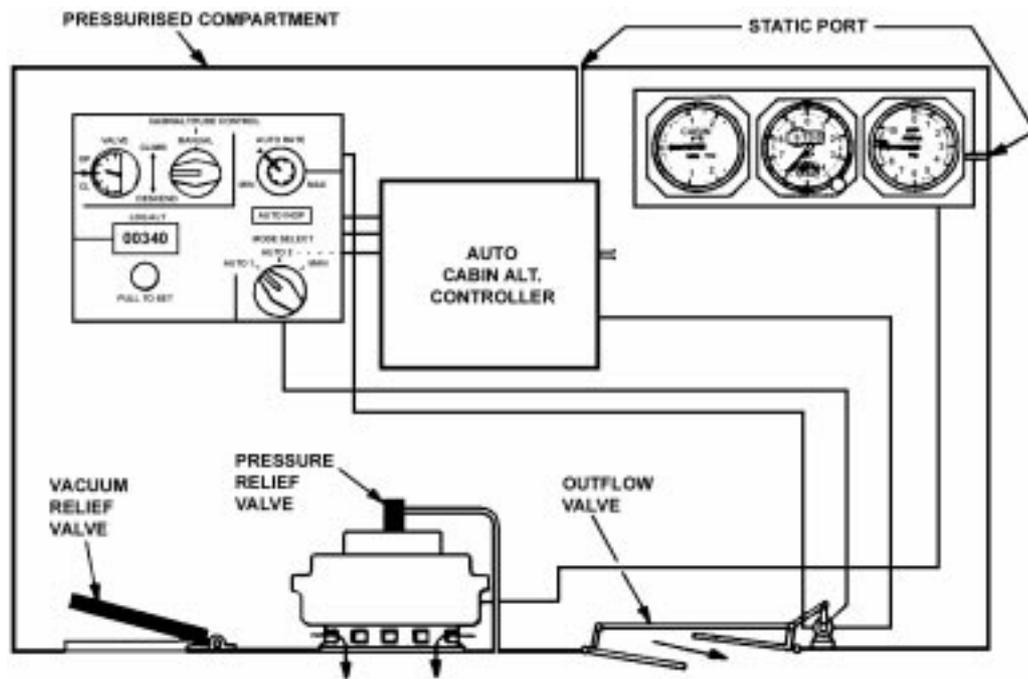
Fig. 3. Pressurisation System Schematic (Electronic).

Pressure controllers vary in their construction, but basically they comprise pressure sensing capsules and diaphragms which are subjected to both cabin and external pressures, metering valves, and controls for selecting the required cabin altitude and rate of pressure change. When the controls are preset, the capsules, diaphragms and metering valves are adjusted to datum positions which ultimately establish the appropriate cabin differential pressure. As the cabin pressure changes, the controller automatically senses the change relative to the external pressure and transmits a pressure signal via a pressure sensing line connected to the discharge valves. The pressure signal then positions the valve to regulate the release of air from the cabin at the preselected rate of change thus stabilizing the required maximum differential pressure. In some type of controller the datum positions and resultant pressure signals are converted to electrical signals which, after amplification, position discharge valves by means of electric actuators.

Pneumatic Pressure Controllers

Pneumatic pressure control systems comprise; pressure-sensing capsules and diaphragms which are subjected to both cabin and external pressures, metering valves, and controls for selecting the required cabin altitude and rate of change. With the controls preset prior to flight, the capsules, diaphragms and metering valves assume a datum position which will ultimately establish and maintain the appropriate cabin differential pressure. As the cabin pressure changes, the controller automatically senses the change relative to the external ambient pressure and transmits a pressure signal via a pressure sensing line connected to the discharge valves (outflow valves). The transmitted pressure signal will then open or close the valve to regulate the release of air from the cabin at the pre-selected rate of change, subject to the maximum differential pressure. The following paragraphs describe the function of a typical pressurisation controller and discharge valve of pneumatic operation (see Fig.5).

Preflight Set-up

Prior to take off, control knobs (A) and (B) respectively, are set for the required cabin altitude and rate of change. The effect of this, will impose a load on capsule (E) by the spring (L) through the beam (C). The combination of the spring and capsule will then position the main valve (F) through beam (H). The main valve (F) will now open to allow atmospheric pressure into the master unit control chamber and the lower chamber of the No.2 unit of the discharge valve through the interconnecting pipework. Atmospheric pressure will also enter the altitude chamber through the rate of change needle valve (J), to equalise pressure either side of the diaphragm (G).

Aircraft Climb

As the aircraft continues to climb (with the main valve (F) open), the atmospheric pressure within the master unit control chamber will decrease. Pressure within the altitude chamber will also decrease but to a lesser degree because of the restriction imposed by the needle valve (J) on the rate of change control. As a result, pressure below the diaphragm (G) will be greater than the altitude chamber causing the diaphragm to move upwards to close the main control valve (F). As a consequence of the rising cabin pressure entering inlet orifice (K) and the closing of the main control valve (F), pressure within the master unit control chamber will rise. This rise in cabin pressure is also communicated through pipework to the lower chamber of the No.2 unit. The upper chamber of the No.2 unit is also subjected to cabin pressure, and between it, and the lower chamber is an additional chamber subjected to atmospheric pressure. However, with the greater effective area of the lower chamber diaphragm and the increase in cabin pressure, the diaphragm assembly moves
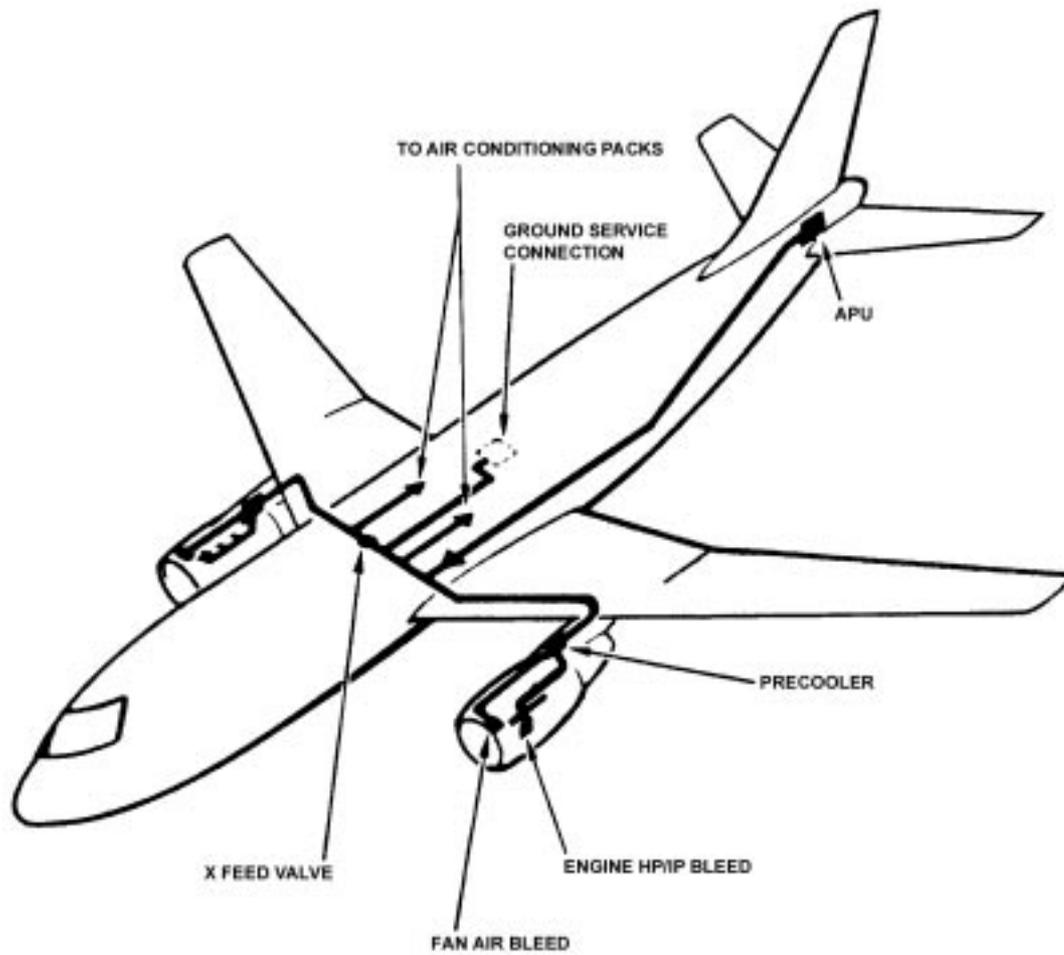
Fig. 4. Pressurisation System Schematic (Electronic).

upwards. As a result of this upward movement, duct inlet valve (R) will open to allow duct air from the air conditioning system to enter the interior of the bellows, which expand and consequentially restrict the outflow of cabin air and pressurisation of the fuselage will commence.

Cruise

Once the aircraft achieves level flight, any pressure difference on either side of diaphragm (G) will soon equalise. Any further change in cabin pressure, will be sensed by the capsule pack (E), which is sensitive to both static and altitude chamber pressure. The resultant movement of the capsule pack (E) will be transposed through the control beam (H) to open or close the main control valve (F). Movement of the control valve will again create pressure changes within the master control chamber which will be transmitted to the lower surge chamber of the No. 2 unit. These pressure movement will then act upon the diaphragms within the No. 2 unit to either open the duct inlet valve (R), allowing duct pressure into the inner bellows and closing the discharge valve or to open the static outlet valve (S) which will vent duct pressure to atmosphere and subsequently open the bellows of the discharge valve.

Should the aircraft climb to the maximum differential pressure, the differential capsule pack (N) will contract to open the differential limiting valve (P). This will reduce pressure within the master control unit chamber and lower the surge diaphragm of No.2 unit, subsequently closing the duct inlet valve (R) and opening the static outlet valve (S) allowing the discharge valve to contract and reducing cabin pressure to a safe level. With a reducing cabin pressure the differential capsule pack (N) will expand closing the differential limiting valve (P) returning the control chamber to the conditions of normal operation.

Aircraft Descent

Prior to descent, selection of a suitable rate of change, and cabin altitude equal to a landing field height, is required. These selections will reduce the compression load on the altitude capsule pack (E), the result of which, closes the main control valve (F). Therefore, assuming the aircraft cabin is now at the maximum differential pressure because of the low cabin altitude selection, the differential capsule (N) will be in control, as described in paragraph 4.3.5.

As the aircraft descends, the increasing atmospheric pressure, will expand the differential capsule (N) and progressively close the limiting valve (P). This produces a stronger pressure signal to the close discharge valve, subsequently lowering the cabin altitude. When the limiting valve finally closes, the pressure within the altitude
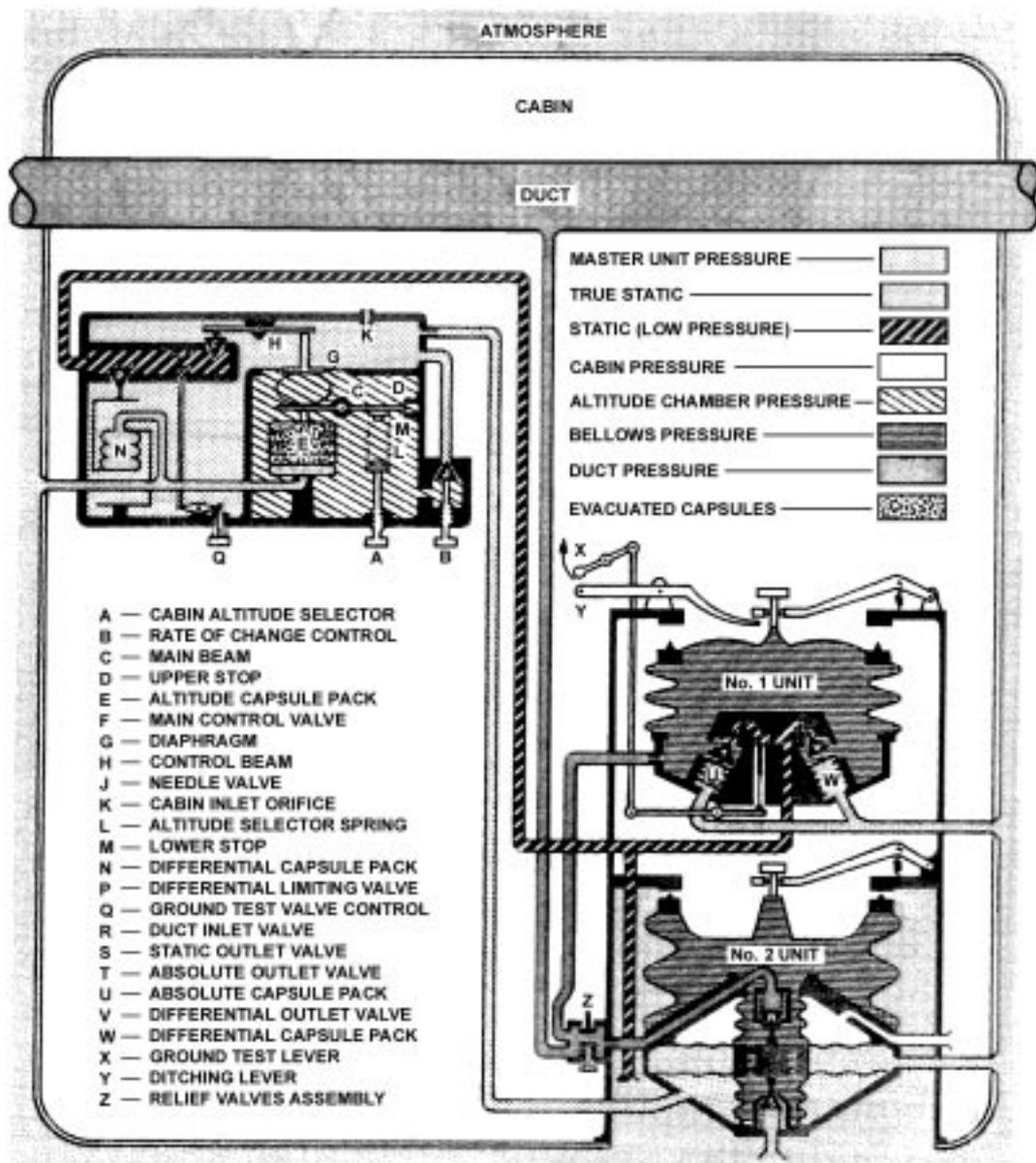
Fig. 5. Pressurisation System Schematic (Electronic).

chamber rises sharply creating a pressure differential across the diaphragm (G), causing it to deflect and, through the control beam (H), opening the main control valve (F) thus preventing a pressure surge on the lower surge control chamber. The rate of change mechanism will now take control, progressively closing the main control valve (F) and increasing the pressure signal to the discharge valve, at the selected rate of change unit the point of cabin altitude and aircraft altitude are of the same value.

NOTE: If in practice the rate of descent of the aircraft is such that it attains the selected altitude before the cabin altitude has reached the same value, the landing of the aircraft must be delayed.

Emergency Operation

Under the circumstances of normal operation, the discharge valve No. 1 unit is non-effective in respect of pressurisation control, except to provide a free passage for air to flow into the No. 2 unit.

Whilst the No. 2 unit is in control, the absolute outlet valve (T) vents air from within the bellows of the No. 1 unit to atmosphere. As a consequence, the bellows collapse due to the impingement of cabin pressure on the outer surfaces.

However, should the No. 2 unit fail (open), the consequential decrease in cabin pressure allows the bellows to extend, thereby restricting the flow of air to atmosphere through the failed No. 2 unit.

Pressurisation control is now the responsibility of the absolute capsule pack (U); which is in two parts, and the differential capsule pack (W) with their respective valves, absolute outlet valve (T) and differential outlet valve (V).

As the aircraft altitude climbs or descends, the differential capsule of absolute capsule pack (U) reacts correspondingly, opening or closing absolute outlet valve (T). This results in changing the bellows pressure and the position of the bellows thereby modulating the flow of air and cabin pressure. The changing bellows pressure also effects the absolute
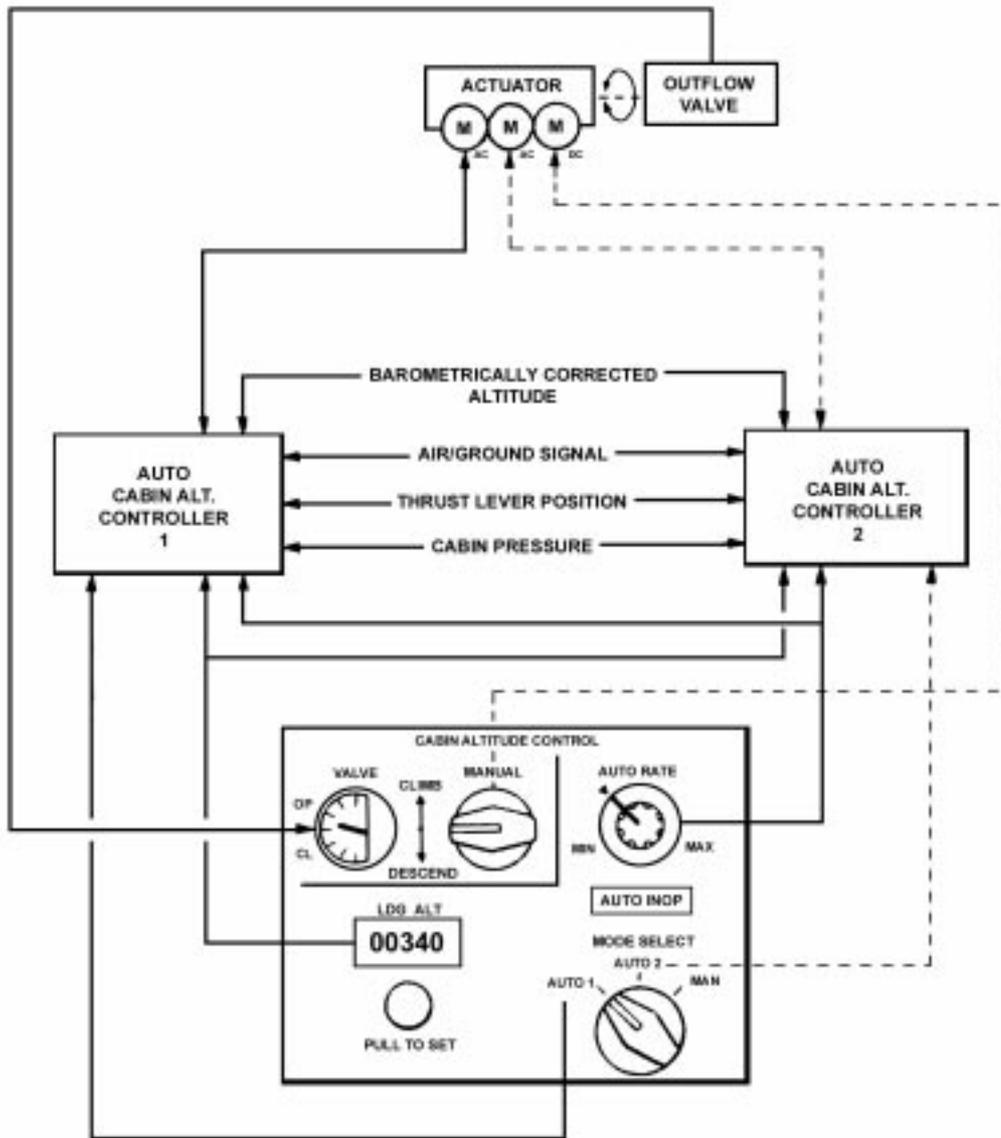
Fig. 6. Pressurisation System Schematic (Electronic).

portion of the capsule pack (U), which expands or contracts whereby the outlet valve (T) returns to a controlling position.

If there is any tendency for the cabin pressure altitude to exceed that of the preset calibration of absolute capsule pack (W) to open differential outlet valve (V). As a consequence the bellows will compress, discharging the overpressure condition of the bellows and the cabin to atmosphere.

NOTE: With the No. 1 unit in control it is not possible to control the rate of cabin altitude change. However, under normal operational conditions, the change in cabin altitude relative to aircraft altitude should be satisfactory.

Electronic Pressurisation Control

The operational parameters and requirements of the electronic pressure controller are identical to those of the Pneumatic Controller.

The basic differences between, pneumatic and electronic pressurisation control (with reference to Fig.5 and 6), are as follows:-

a. The automatic cabin altitude controllers are duplicated (Auto 1 and Auto 2), with additional inputs from the landing gear (air/ground signal) and thrust lever positions.

b. The signal between the automatic cabin altitude controller and the outflow valve (discharge valve) is electrical as opposed to a pneumatic signal.

c. The cabin altitude control panel is remote from the cabin altitude controller (normally located within the avionics equipment bay) and not an integral part of the controller.

d. The outflow valve (discharge valve in this description) can be actuated by: either of the two A.C. motors, or for manual or emergency control the D.C. motor.

The electronic pressurisation controller (the cabin altitude controller in Fig.6) is, in basic terms, a shaping and summing network. With information derived from the air data computer, cabin altitude control and various systems within the aircraft, a reference signal is produced by the controller. This reference signal will then be compared by the cabin altitude controller, to the signal produced by the cabin altitude monitor. If a disagreement exists between the two signals, a correcting error signal is produced, which when applied, modulates the outflow valve (s).

As a safeguard against the cabin altitude or rate of change exceeding defined limits within the pressurisation schedule, override circuits constantly monitor the performance of the system in control. If any deviation from the schedule exists, the override circuits will either: automatically transfer control to the standby system, (Auto 1 to Auto 2) or de-activate the system completely with the appropriate flight deck indications and aural warnings. The following paragraphs describe the operation of a typical electronic controller.

Preflight Set-up

Automatic electronically controlled cabin pressurisation systems in general terms require the following action prior to take-off:-
a. Provision of pressurised air from the air conditioning system.
b. The setting of landing field height (QFE).
c. Rate of cabin altitude change.

Prepressurisation

Where prepressurisation of the cabin prior to take-off is part of the pressurisation schedule, control inputs will be required of the: landing gear (air/ground signal), engine oil pressure, forward throttle position, and the door warning system. The cabin pressure within this part of the schedule is normally only marginally above the ambient atmospheric pressure (i.e. a cabin altitude just below airfield altitude).

Climb

Prepressurisation ceases when the aircraft leaves the ground and the landing gear and oleo fully extends (air/ground signal). The cabin altitude climb sequence of the pressurisation schedule will now commence with the cabin altitude rate of change limited to approximately 500 ft per minute.

Cruise

With the aircraft maintaining a constant height, the cruise sequence of the pressurisation schedule will commence. Simultaneously, the cabin altitude controller will, for the purpose of originating a datum point for a scheduled descent, and any correction of the cabin cruise altitude, compare the theoretical cabin altitude to that of the selected landing altitude. Any variation to aircraft altitude, in climb, or descent of less than 500 ft, the corresponding cabin altitude will remain unchanged. If, however, the aircraft altitude climbs or descends by more than 500 ft, the cabin altitude controller will enter into an appropriate auto schedule subject to the various controlling parameters i.e. take-off height, landing field height and selected auto rate of change.

Descent

The descent sequence of the pressurisation schedule is normally initiated by a descending aircraft altitude of approximately 500 ft and subject to the following criteria:-
a. The relative aircraft altitude.
b. The auto rate selected.
c. The landing field height (QFE).
d. The maximum cabin to ambient differential pressure limit.

Landing

For those aircraft which are designed to land in a pressurised condition, the cabin altitude controller will normally automatically lower the selected landing field by approximately 100 ft height. As a result the cabin will remain pressurised marginally above atmospheric pressure until touch down, where the landing gear air/ground signal takes precedence for controlled depressurisation of the aircraft.

Emergency Operation

Protection against system failure is provided for by duplication of the control system. In the event of a system or power failure, control will be automatically transferred to the standby system which is electrically supplied from an alternate source. If total system failure does occur, a reversion to manual control will be required.

OUTFLOW VALVES (DISCHARGE VALVES)

DISCHARGE VALVES

The primary function of discharge or outflow valves is to regulate the discharge of cabin air in response to the pressure signals received from the controller. They also vary in design and construction but, in general, they are of two main types. In one type the valves are operated by diaphragms and in the other by electric actuators. The size and number of valves required for a particular type of aircraft is governed by the amount of air necessary for pressurizing, heating and cooling purposes. In some types of discharge valve, safety valves and inward relief valves are incorporated.
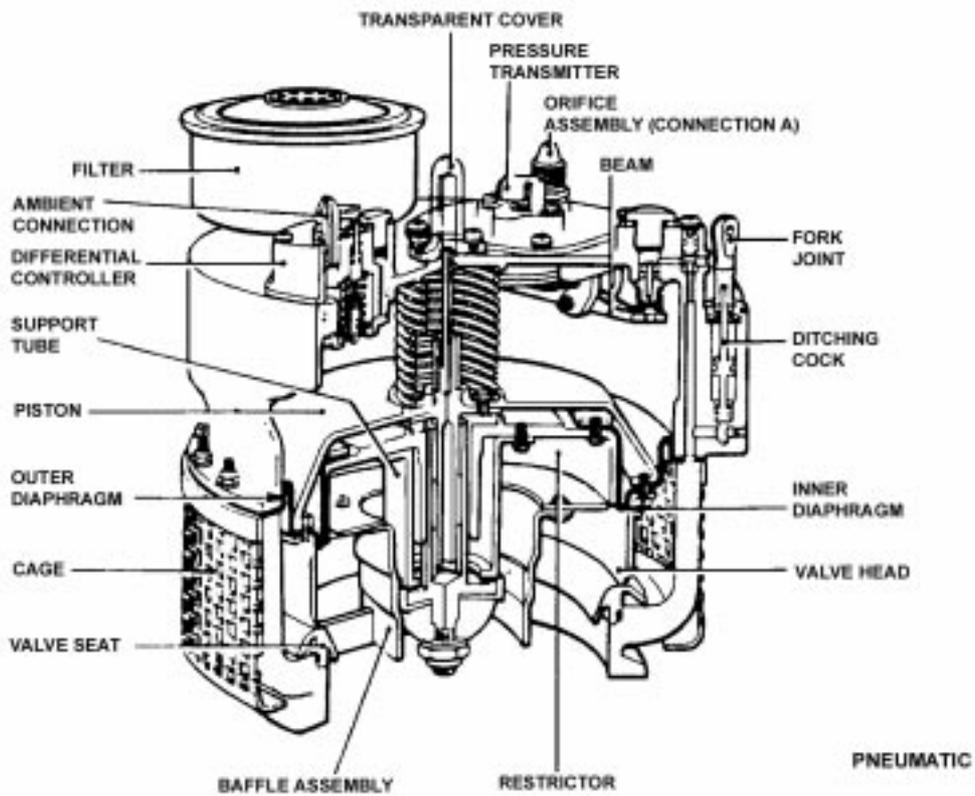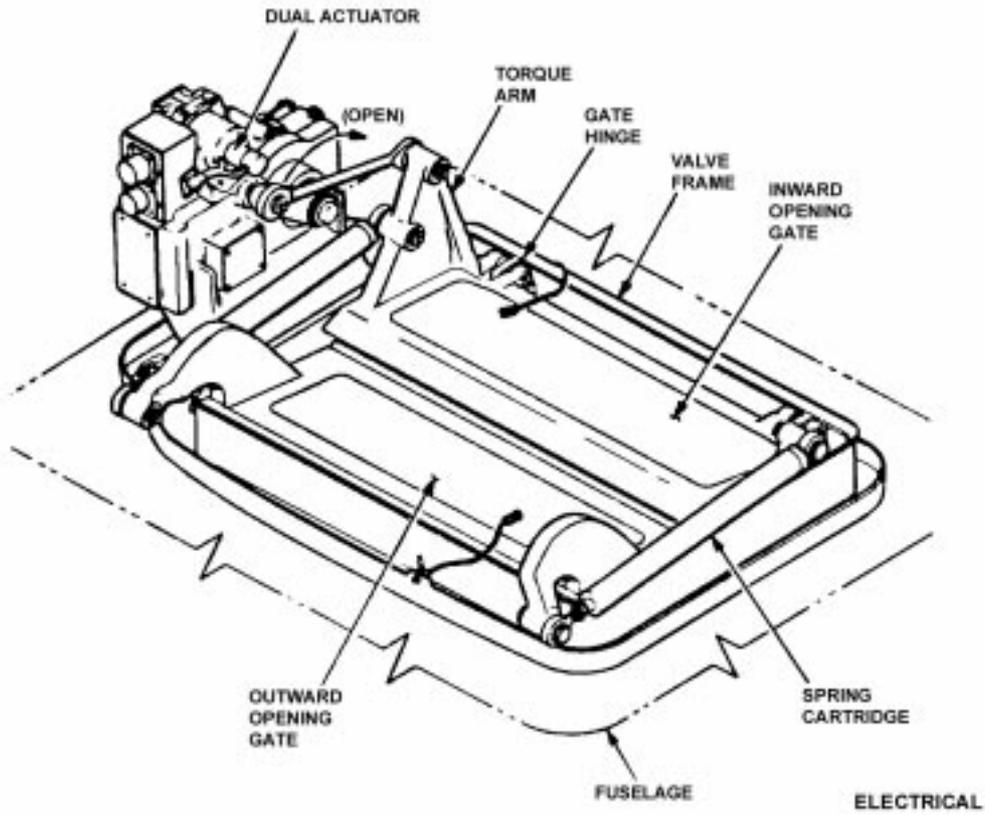
Fig. 7. Pressurisation System Schematic (Electronic).

A means of locking the valve to the closed position in the event of a forced descent on water (ditching) is also a feature of some discharge valves.

SAFETY VALVES AND INWARD RELIEF VALVES

Safety Valves

Safety valves are provided to relieve excess cabin pressure in the event of a failure of the pressure controller and/or discharge valves. In ward relief valves are provided to limit any possible negative differential pressure to a safe value. Depending on the system adopted for a particular type of aircraft, the valves installed may either be in the form of separate units, single integrated units, or they may be combined with the discharge valves. The valves vary in construction and operation but those most commonly used are either of the type utilizing diaphragm control similar to a discharge valve, or of the spring-loaded hinged flap type.
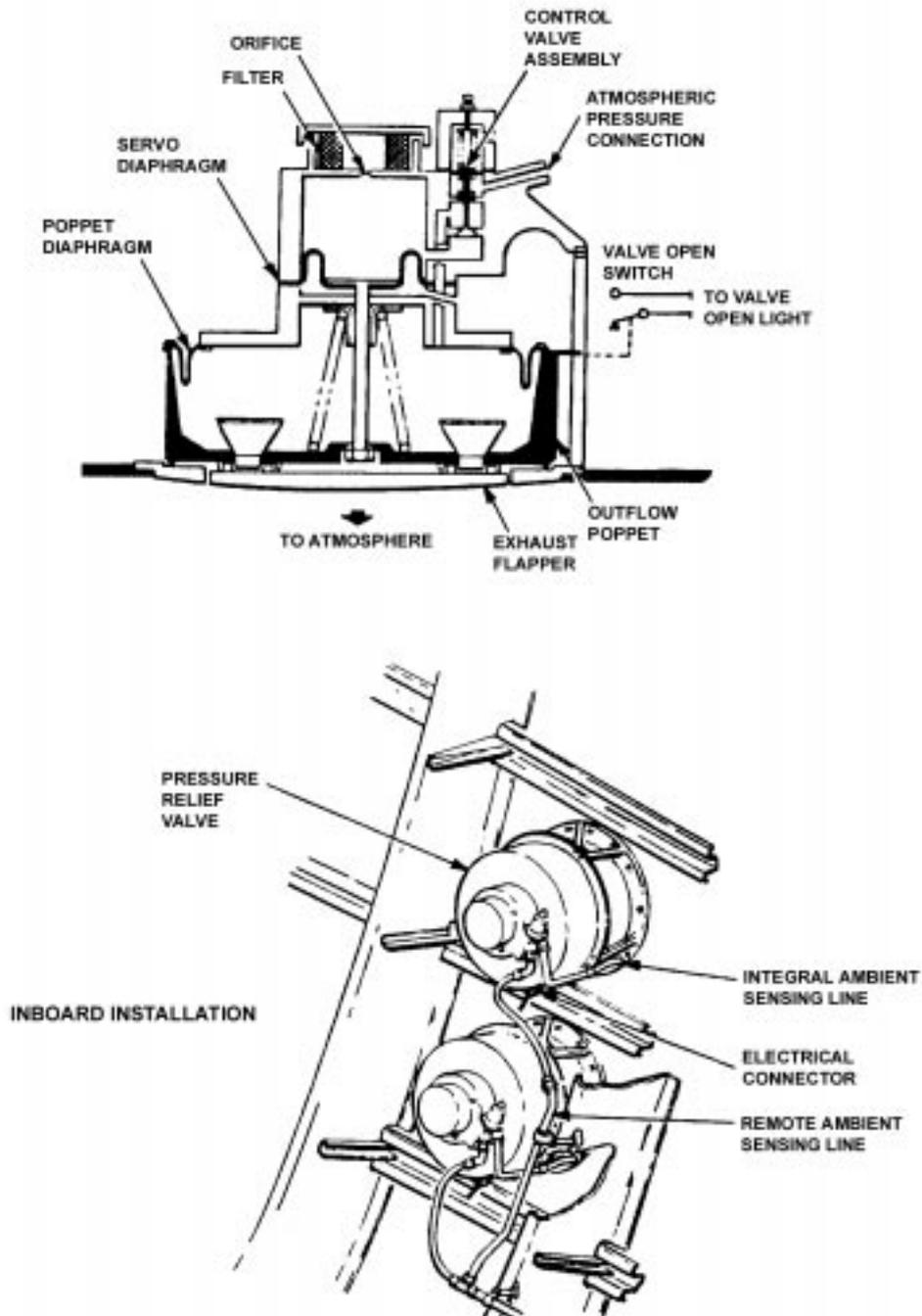
Fig. 8. Typical Pressure Relief Safety Valves.

Inward Relief Valves

Inward relief valves are provided to limit any possible negative differential pressure to a safe value. Depending on the system adopted for the particular aircraft type, the valves installed may either be in the form of separate units, single integrated units, or combined with the discharge valves. The valves vary in construction and operation but those most commonly used are of the type utilising diaphragm control (similar to a discharge valve).

GROUND AUTOMATIC RELIEF VALVES

The ground automatic relief valve is a form of discharge valve used on some aircraft types which is additional to those discharge valves which form part of the pressurisation system. The valve as its title implies, is effectual whilst the aircraft is in a ground mode (i.e. ground/air signal) with the following primary functions:-

a. To maintain a free flow of ventilating air within the aircraft when parked.

b. To prevent cabin pressurisation and pressure surges whilst the aircraft is taxiing.

c. To transmit ground/air signals derived from the landing gear and engine thrust levers, to the cabin altitude controller for controlled prepressurisation and depressurisation of the cabin when respectively the aircraft is taking off or landing.

INSTRUMENTS AND INDICATORS

General

The presentation of instrumentation forming part of the pressurisation control system, is largely dependent upon the method of pressurisation control. Pneumatic pressure controllers; as described in paragraph 4.3, have the principal instruments as an integral part of the control panel. Electronic pressure controllers; as described in paragraph 4.4, have instruments which are remote from the controller and generally form part of the cabin altitude control panel.

Instruments

The principal instruments in respect of pressurisation control are, Cabin altitude, Differential pressure, and Rate of Change (vertical speed). These are generally positioned as described in paragraph 8.1, or as a cathode ray tube (CRT) generated display in either digital or analogue (dial and pointer) form in the main instrument panel. Instruments may also be provided to indicate the position of certain valves, e.g. discharge valves.

Indicators

Crew compartment indications, are in general, presented in visual and audio form, i.e. warning light or CRT image with an accompanying sound (bell, chime or horn etc). The factors which will activate those indications, in respect of the cabin altitude control are:-

a. Excessive cabin altitude.

b. Discharge valve failure or disagreement.

c. Inward relief valve operation.

d. An automatic system changeover.

e. Excessive differential pressure.

f. Positive pressure relief valve operation.

EMERGENCY CONTROLS

In addition to the normal devices which control pressure to the required values, provision is made for the normal operating cabin pressure to be reduced rapidly in the event of, emergency landings, clearing the cabin of smoke or other contaminations, and the rapid reduction of cabin pressure. In all such cases cabin pressure is reduced by the 'dumping' of air. This may be achieved in a number of ways and the methods most commonly adopted include, separate manually operated dump valves, manual override control of a discharge valve or a safety valve, and in some cases manual control of a pressure controller.

FILTERS AND AIR DRIERS

Filters are connected in the cabin air pressure sensing lines to the pressure controllers and discharge valves and normally consist of a casing housing a replaceable filter cartridge and fitted with appropriate inlet and outlet connections. In some aircraft installations, air driers are provided to eliminate the possibility sensing lines to discharge valves, safety valves and inward relief valves. Two types of driers are in common use; one utilizing the properties of a silica gel drying agent, and the other consisting of a baffle box mounted on the inside of the fuselage skin and utilizing the skin temperature to condense any water vapour present in the cabin air. The moisture deposited in the box eventually drains away through an outlet in the box and aircraft skin.

CHAPTER: 7
OXYGEN SYSTEM

PURPOSE OF OXYGEN SYSTEMS

With increase in altitude the pressure of the atmosphere and the partial pressure of its oxygen content decreases, resulting in a deficiency of oxygen in the blood and tissues of individuals subjected to such pressures. This condition, known as "anoxia", seriously impairs physical and mental abilities and prolonged exposure to it can prove fatal. The purpose, therefore, of oxygen systems in aircraft, is to offset the varying effects of anoxia by supplying oxygen through a breathing mask at a controlled rate of flow.

"Unless oxygen is administered at high cabin altitude unconsciousness and finally death will occur, the time of one set of unconsciousness depending on the cabin altitude, for example, without added oxygen the time of useful consciousness at 25,000 feet is approximately three minutes and at 40,000 feet it is twenty seconds."

TABLE 1

Physiological Effects of Altitude	Feet
Maximum altitude without oxygen at which flying efficiency is not seriously impaired.	8000
Altitude at which the incidence of decompression sickness increases rapidly with exposure exceeding ten minutes.	25000
Maximum altitude at which sea level conditions can be maintained by breathing 100 per cent oxygen.	33000
Maximum allowable altitude without pressure breathing	44000

OXYGEN SYSTEMS

Civil transport aircraft cruise at altitudes where cabin pressurisation is necessary to maintain conditions inside the cabin approximately equal to a maximum altitude of 8,000 feet, regardless of the actual altitude of the aircraft. Under such conditions oxygen is not normally needed for the comfort of the passengers and crew. However, as a precaution, oxygen equipment is installed for use in the event of a cabin pressurisation system failure. In addition, portable oxygen sets are also provided for therapeutic purposes, and for cabin attendants' use while moving about the passenger cabin during low cabin pressure emergencies.

In some of the smaller and medium size aircraft designed without a cabin pressurisation system, oxygen equipment may be installed for use by passengers and crew when the aircraft is flown above 10,000 feet. In other cases where there is no oxygen system installation, passengers and crew depend on portable oxygen sets stowed in convenient positions.

The design of the various oxygen systems used in aircraft depends largely on the type of aircraft, its operational requirements and, where applicable, the pressurisation system. In some aircraft the continuous flow oxygen system is installed for both passengers and crew but the diluter demand system is widely used as a crew system, especially on the larger types of transport aircraft. Many aircraft have a combination of both systems which may be augmented by portable sets.

The oxygen is normally stored in gaseous form but, in some cases, systems may be used in which oxygen is produced when required, by special oxygen generators operating on a chemical reaction principle. Gaseous oxygen is stored at approximately 1,800 1b/in^2 and is reduced to the low pressure required for breathing purposes by pressure regulator valves or reducer valves. In oxygen generator systems the gas is produced directly at low pressure.

Continuous Flow Oxygen Systems

A typical continuous flow oxygen system is illustrated in simplified form in Fig. 1. When the line valve and cylinder valve are turned "on" oxygen will flow from the charged cylinder through the high pressure pipe to the pressure reducing valve which reduces the pressure to that required at the mask connection points. Reducing valves my be fitted directly to cylinders together with shut-off valves, or they may be separate units designed for "in-line" coupling. A calibrated orifice is normally provided in the sockets to control the flow of oxygen delivered to the mask.

The passenger system may consist of a series of supply sockets with mask plug-in connections at each passenger seat group, or it may be the "drop-out" mask arrangement where, in the event of pressurisation system failure, individual masks are presented automatically to each passenger from service units. When the masks are pulled to the usable position, valves are opened to permit oxygen to flow to the masks, the flow being indicated by a simple flow indicator within each mask hose. Any automatic control (e.g. barometric control valve) in the ring main supply can be overridden manually by a member of the crew. Service units are also provided with a plug-in receptacle for attaching a separate mask for the rate mask for therapeutic use.

Fig. 2. illustrates a continuous flow system commonly used in some types of light aircraft carrying a pilot and five passengers. The cylinder contains gaseous oxygen at 1,800 1b/in^2 and has the pressure regulator and pressure gauge fitted directly to it. The shut-off valve is also on the regulator and is opened and closed by a mechanical linkage
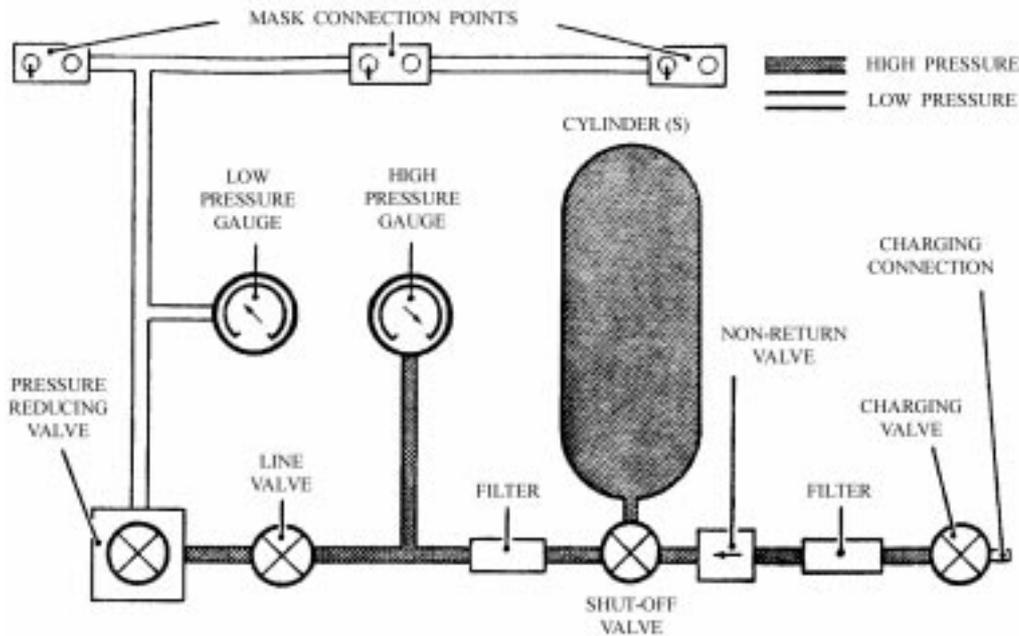
Fig. 1. Typical Continuous Flow System.

connected to a control knob in the cockpit. Mask connections are of the plug-in type and each mask hose contains a simple device which indicates that oxygen is flowing. A cylinder charge valve is incorporated in the system and is usually of the self-sealing, automatic opening and closing type.

Diluter Demand System

A diluter demand system is one in which the oxygen is diluted with air and the mixture is supplied only when the user inhales, i.e. as demanded by an individual respiration cycle. The interconnection of a typical system is illustrated in simplified form in Fig. 3. It will be noted that there is a regulator for each crew member who can control the regulator according to his requirements.

Chemical Oxygen Generator Systems

In these systems, oxygen is produced by chemical generator and dispenser units which are contained within service panels at each group of passenger seats and other essential locations.

In the basic form, a unit consists of a generator, a "drop-out" mask and hose. The generator is comprised of a corrosion resistant steel cylinder containing a thermal insulating liner, a compressed block of sodium chlorate and iron powder, a filter, and an electrically operated firing mechanism mechanically connected to the mask by a lanyard. The power supply required for electrical operation is 28 volts d.c. The mask is ejected automatically from the service panel by a release mechanism controlled by an aneroid switch, the contacts of which are set to make at the appropriate cabin altitude, e.g. 14,000 feet.

When the mask is pulled towards the user, the lanyard trips the generator firing mechanism which then ignites the sodium chlorate charge block. As the temperature of the block is raised a chemical reaction is created, thereby producing a supply of low pressure oxygen which flows through the filter to the mask. This process continues until the charge block is expended. Oxygen normally flows for a period of 15 minutes, and although extremely high temperatures are generated, the temperature of the oxygen delivered at the mask does not exceed 10^0C above ambient.

Oxygen generators are made in three sizes depending on the number of passenger masks to be supplied. A valve to relieve any excess pressure is incorporated, and an indication of an expended generator is also provided by the change in colour of a band of thermal paint around the outside of the case.

Portable Oxygen Sets

A typical portable oxygen set consists of an alloy steel lightweight oxygen cylinder fitted with a combined flow control/reducing valve and a pressure gauge. A breathing mask, with connecting flexible tube and a fabric carrying bag with the necessary straps for attachment to the wearer completes the set. The charged cylinder pressure is usually 1,800 lb/in². The capacities of sets vary, a size most commonly used being 120 liters.

Depending on the type of set, it is normally possible to select at least two rates of flow, "Normal" and "High". with some sets three flow rate selections are possible, i.e. "Normal", "High", and "Emergency" which would correspond to 2,4 and 10 litres per minute with an endurance under these flow rates of 60, 30 and 12 minutes respectively for a cylinder of 120 liter capacity.

COMPONENTS

Brief details of some of the components commonly used in oxygen systems are given in the following paragraphs. Full descriptive details of the components installed in specific types of aircraft are contained in the relevant Maintenance Manuals and reference should be made to these documents.

HIGH PRESSURE
LOW PRESSURE
CHARGING LINE

CYLINDER & PRESSURE REGULATOR

CYLINDER PRESSURE GAUGE

PASSENGERS MASK CONNECTIONS

OXYGEN CONTROL KNOB

CHARGING CONNECTION

PILOT AND PASSENGER MASK CONNECTIONS
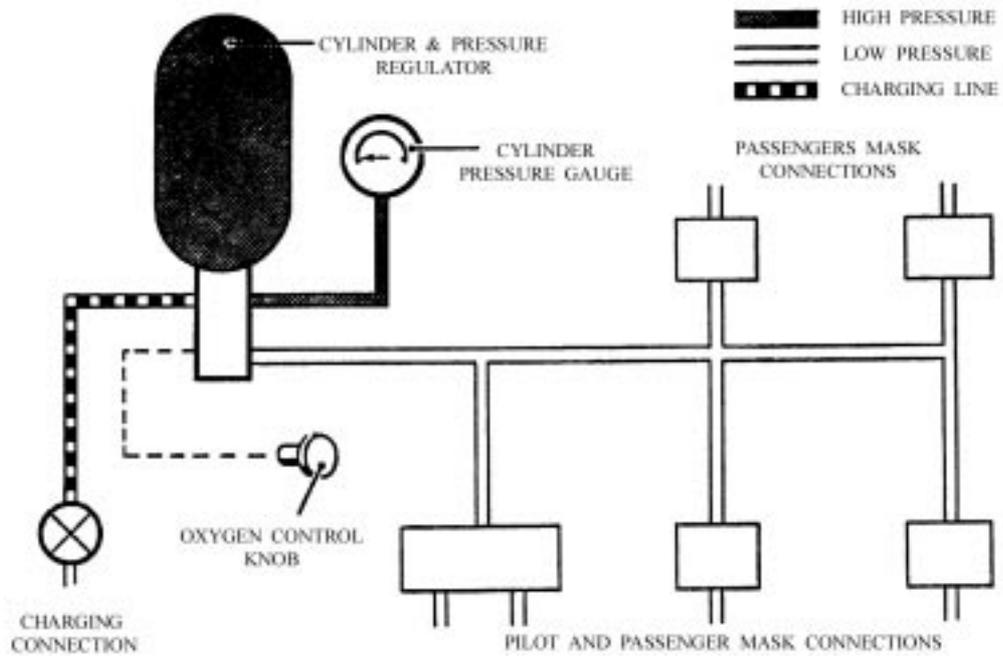
Fig. 2. Typical Light Aircraft System.

DISCHARGE INDICATOR

CYLINDER PRESSURE GAUGE

CYLINDER SHUT-OFF VALVE

SYSTEM SHUT-OFF VALVE

LOW PRESSURE GAUGE

MASK CONNECTION POINTS

SAFETY DISC

NON-RETURN VALVE

PRESSURE REGULATOR

FILTER

DEMAND REGULATORS

FUSELAGE

CHARGING VALVE

HIGH PRESSURE
**LOW PRESSURE**
CHARGING LINE
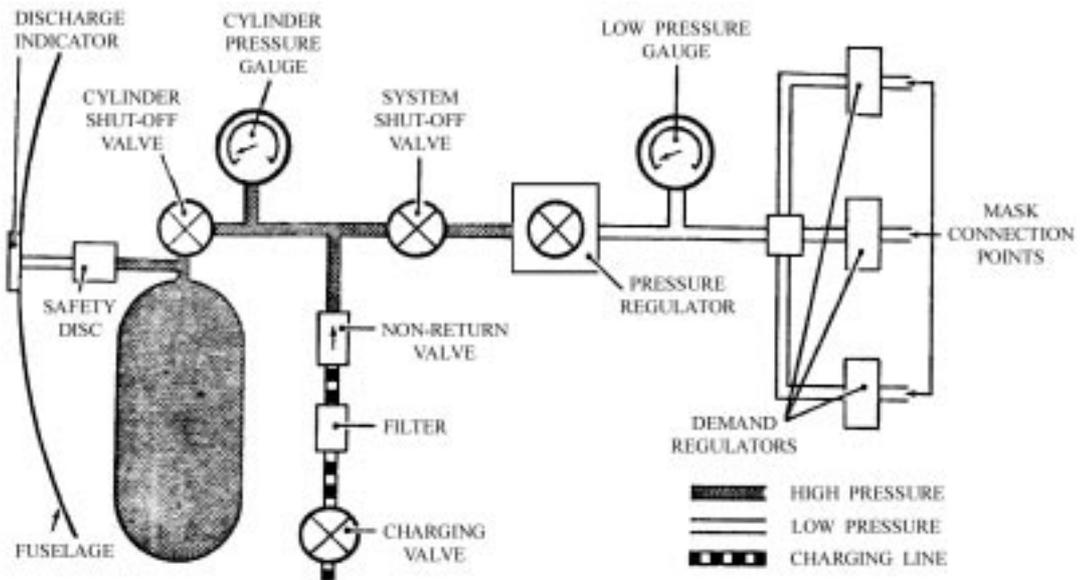
*Fig. 3.Typical Diluter Demand System.*
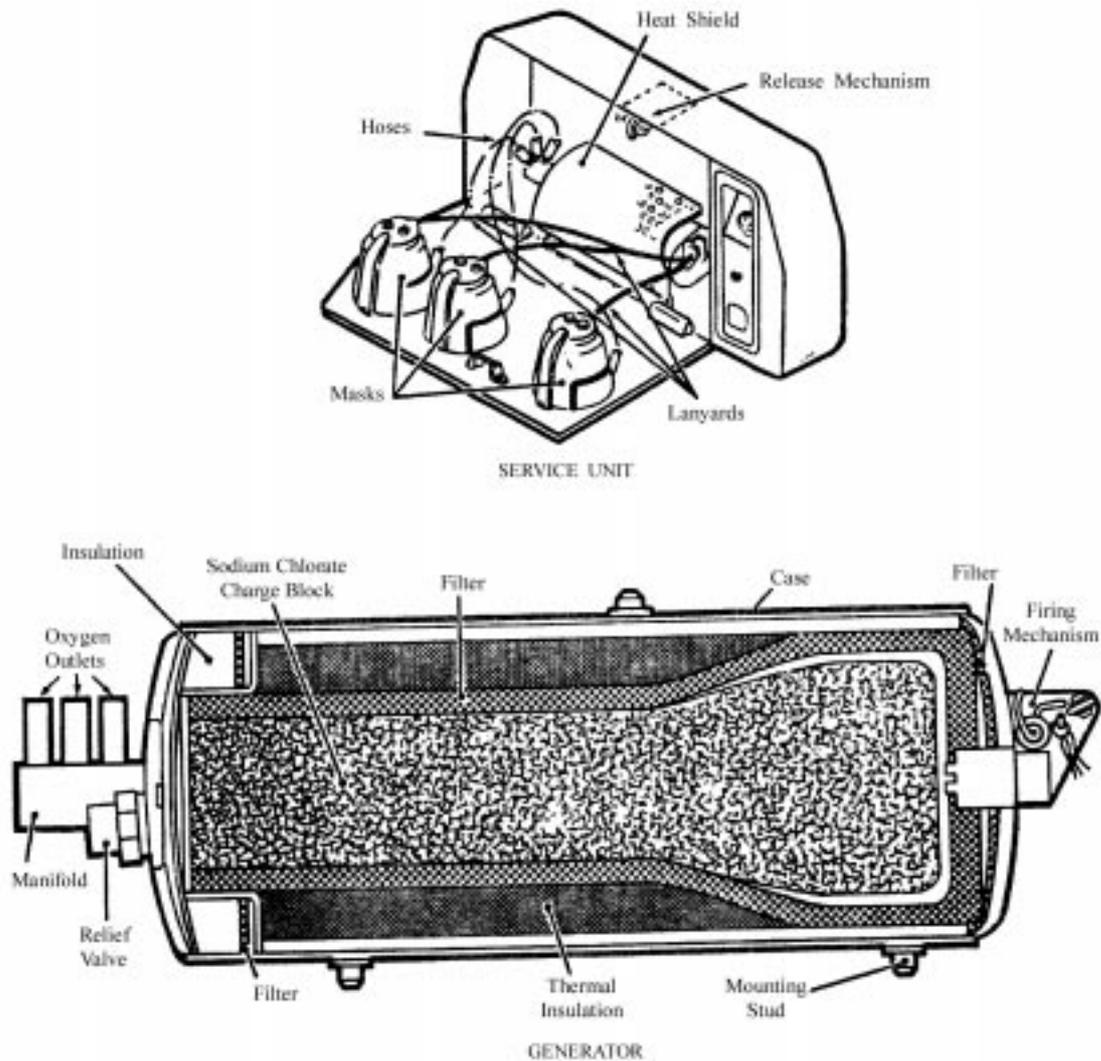
Fig.4. Chemical Oxygen Generator System.

Oxygen Storage Cylinders

Cylinders designed for the storage of gaseous oxygen are made from drawn high tensile alloy steel and normally have a manual stop valve and, in many instances, a pressure regulator and a pressure gauge threaded into the neck of the cylinder. The charged pressure is usually 1,800 lb/in^2 and capacities vary from 80 litres for portable sets to 2250 litres for large installations.

Cylinders are often provided with an excess pressure rupture disc, usually fitted in the valve body, which vents the cylinder contents to the outside of the aircraft in the event of a dangerous pressure rise. An indicator is provided in some aircraft to indicate discharge resulting from pressure relief.

Cylinders for use in aircraft oxygen systems are colour coded for identification purposes, and there are two codes presently adopted: (i) black for the main body and white for the top hemispherical portion (the valve end) and (ii) green for cylinders of American origin. As a means of further identification of cylinder contents, it is also necessary for the name of the gas and its chemical formula to be marked at the valve ends of cylinders in accordance with British Standard 2N 100 and International Organization for Standardisation recommendation ISOR448. In addition, the following information is painted or stencilled on the bodies of the cylinders :-

(i)   In red letters on a white background : "Use No Oil".

(ii)   In white letters on the black cylindrical portion :

         Name of manufacturer
         Drawing assembly No.
         Capacity .... litres
         Test Pressure ....
         Working pressure .....
         Test date ....

Pipe Lines

The characteristics of the pipe systems vary widely between different types of aircraft and the particular oxygen system installed and reference should be made to the relevant manuals for full details. High pressure pipes are usually

made of either stainless steel or copper-based alloys, while pipes for low pressure areas of systems are made of aluminium-based alloys. Pipe also vary in size and some typical values are 3/16 to 1/4 inch outside diameter for high pressure pipes, and 5/16 inch outside diameter for low pressure pipes.

The types of couplings normally used for pipe joints are of the standard AGS type and MS flareless tube type. Because of the difficulty of ensuring the complete removal of flux and scale, silver soldered connections are, generally, not used.

Identification of pipes in the system by symbols and colour coding is widely used and should comply with BS 3M. 23. Tie-on metal tags or metal identification rings should not be used as they may cause damage through vibration, or become detached and foul moving parts of control systems.

Non-Return Valves

These components are designed to prevent flow reversal and are installed in a pipe line or at a connector adaptor. Of the two basic types commonly used, one consists of a housing containing a spring-loaded valve which is forced against the spring when pressure is applied to the inlet side, thus breaking the seal and allowing oxygen to flow. When pressure is equalised the spring returns the valve onto its seating, so preventing any reversal of oxygen flow. The other type is a bell-mouthed hollow cylinder fitted with a captive ball in its bore. When pressure is applied at the bell-mouthed (i.e. inlet) end, the ball is forced onto the seating of a port at the opposite end and at the same time, its displacement uncovers holes in the wall of the valve to allow oxygen to flow into the pipe or connection. Any tendency for the flow to be reversed is prevented by the oxygen forcing the ball back onto its seating at the inlet end. The normal direction of flow for both types of valve is indicated by an arrow on the valve body.

Filters

Filters, generally of the gauze or sintered bronze type, are provided at points downstream of oxygen cylinders and in some cases, immediately after the ground charging connection. In most systems in current use a filter, usually of the sintered bronze type, is normally embodied in the supply connection of a particular component, e.g. a regulator or a reducing valve. In some instances the charging connection is counter-bored to house a slug-type sintered bronze filter which also acts as a restrictor to guard against too rapid charging of the system.

Pressure Reducing Valves

These valves reduce the high pressure oxygen from the storage cylinders to the pressure required in the low pressure part of the system. In a continuous flow system the reduced pressure is supplied to the mask connection points. In a pressure demand system the pressure from the reducing valve is comparatively higher than that for a continuous flow system and further pressure regulation is necessary at each regulator.

Design features vary considerably, but in general, reducing valves comprise a pressure reducing pre-set spring and valve control mechanism with a relief valve to safeguard against overloads. Pressures can be reduced to the pressure required for a particular system.

Oxygen Diluter Demand Regulators

These regulators are used in crew oxygen systems and are designed to adjust the output ratio of oxygen and air in accordance with cabin pressure and to supply, on demand, the correct air/oxygen mixture. A typical diluter demand regulator operates as follows :-

(i)   With the oxygen supply "on" and "normal oxygen" selected by the appropriate control lever on the regulator, diluted oxygen in accordance with cabin altitude will be supplied to the crew member's mask when the user inhales. The amount of air mixed with oxygen is controlled by the regulator and the air decreases with increase in cabin altitude until a cabin altitude of 32,000 feet is reached when approximately 100 per cent oxygen is supplied.

(ii)   If the crew member selects "100% oxygen" the regulator air valve is closed and 100 per cent oxygen is supplied when the user inhales, irrespective of cabin altitude.

(iii)   If "Emergency" is selected, e.g. to provide protection against smoke and other harmful gases, a flow of 100 per cent oxygen is supplied at a positive pressure to avoid any inward leakage into the mask. Depending on the type of regulator, the oxygen may either flow only when the user inhales, or continuously and irrespective of the user's respiration cycle.

(iv)   When "Test mask" is selected oxygen is supplied at a higher pressure than that provided for the "Emergency" condition and is used for testing the masks and equipment for fit and leakage.

Supply Sockets

These components provide connections between the aircraft system and individual oxygen mask connecting tubes. Some embody two socket points for "Normal" or "High" flow and others may have only one socket point with a flow selector lever. Calibrated orifices in the socket points of continuous flow systems control the flow rate to the masks. Socket points are made with self closing shut-off valves, spring loaded in the closed position, and open when the mask tube connecting plug is inserted in the socket.

Pressure and Contents Indicators

Pressure indicators are provided to indicate cylinder pressure and, where necessary, medium and low pressure in the supply lines. The indicators are normally of the direct-reading Burden tube type calibrated in lb/in^2, and may be located on cylinders, pressure regulators and at oxygen system servicing panels. In aircraft requiring monitoring of system high pressure at a flight engineer's station, electrical indicating systems are also employed. These consist of a transducer which senses high pressure and converts it to a variable electrical signal for controlling an indicator at the flight engineer's panel. The power supply required for operation is 28 volts d.c. and a regulating circuit is incorporated to ensure that pressure indicators are not affected by fluctuations in supply voltage.

Pressure switches are installed in the low pressure sections of some passenger oxygen systems to illuminate warning lights, thereby indicating that a system is in use. The lights are located on a cockpit overhead panel and on cabin attendants' panels.

Contents indicators, as opposed to pressure indicators, are fitted to some types of cylinders and they are normally marked with coloured sectors to indicate contents in terms of "FULL", "3/4 FULL", etc.

Oxygen Masks

There are numerous types of oxygen masks in use which vary widely in design and detailed information is outside the scope of this Leaflet. It is important that the masks used are suitable for the particular oxygen system concerned.

In general, crew masks can be fitted to the wearer's face with minimum leakage and may be of the self-contained re-breather type. Crew masks also contain a microphone cord and jack plug for connection into the aircraft communications system. In some instances there is a requirement for pressurised aircraft to carry oxygen masks designed for the protection of crew members in a smoke or fume laden atmosphere. These masks are of the full-face type consisting of a transparent visor, oxygen supply hose and adjustable head straps, or of the "sweep-on" type with pre-set head straps and/or elasticated sides. A demand regulator may also be fitted to some masks to control the flow. The hose connections are of the plug-in type designed for insertion into the supply sockets of a ring main system or, alternatively, a portable cylinder.

The masks provided in automatic drop-out systems for passengers are normally simple cup-shaped rubber mouldings sufficiently flexible to obviate individual fitting. They may be held in position by a simple elastic head strap, or may require holding to the face by the passenger. In non-automatic systems, the masks are usually plastic bags fitted with a simple elastic head strap.

Flow Indicators

Oxygen flow is often indicated by a direct type of flow indicator, e.g. a float inside the transparent hose of a mask, or by a pressure-operated blinker type of instrument.

Thermal Compensators

Thermal compensator assemblies are installed in the charging lines of some oxygen systems for the purpose of minimising temperature build-up when oxygen, at charging pressure, flows through. A compensator consists of a brush-like wire element approximately 5 inches long, inserted into a stainless steel tube provided with connectors at each end.

There are two types of thermal compensators in use, one for connection to oxygen cylinders and the other for connection to shut-off valves or regulators. Those fitted to oxygen cylinders have a coupling nut fitting that attaches direct to a cylinder and the downstream end has a flare less tube connection. The second type of compensator is attached to the component by means of a corrosion-resistant steel union through which the wire element extends. A flareless tube connection is fitted to the upstream end.

Discharge Indicators

In some aircraft, discharge indicators are mounted flush to the fuselage skin in an area adjacent to the oxygen system servicing panels. They are connected to the pressure relief lines from the oxygen cylinders and consist of a green plastic disc which is normally retained within its holder by a circlip. In the event of an excess pressure within a cylinder the safety valve opens and escaping oxygen will blow out the indicator disc, thereby providing a visual indication that discharge has occurred.

Ground Charging Valves

Oxygen systems are provided with valves to permit "in-situ" charging of the cylinders from special ground servicing units. The charging connections to the valves are normally sealed off by blanking cap nuts. A short length of chain between a cap nut and an adjacent part of the structure, ensures retention of the nut at the charging point location when removed for charging purposes.

In some systems, the charging valve incorporates manual temperature and pressure compensation adjustments which allow the system cylinder to be charged to optimum pressure at the ambient temperature in the vicinity of the cylinder. The charging rate is automatically controlled by the valve to a safe value thereby minimising the hazard of heat build-up. A pressure/temperature correction chart is normally displayed near the charging valve for reference purposes.

CHAPTER: 8
ANTIICING AND DEICING SYSTEMS
[PNEUMATIC DE-ICING SYSTEMS]

GENERAL

A schedule of the Air Navigation Order requires that public transport aircraft shall be provided with certain protective equipment for flights in which the weather reports available at the time of departure indicate the probability that conditions predisposing to ice formation will be encountered.

Airfoil surfaces are included in those features of the aircraft which are required to be so protected. Certain basic standards have to be met by all aircraft whether or not they are required to be protected by the requirements of the Air Navigation Order and these are intended to provide a reasonable protection if the aircraft is flown unintentionally for short periods in icing conditions. The requirements specified in BCAR and JAR cover such considerations as the stability and control balance characteristics, jamming of controls and the ability of the engine to continue to function in icing conditions.

COMPONENTS AND APPLICATION OF SYSTEMS

Pneumatic dicing systems are employed in certain types of piston-engined aircraft and twin turbo-propeller aircraft. The number of components comprising a system vary together with the method of applying the operating principle. The arrangement of a typical system is illustrated schematically in Figure 1.
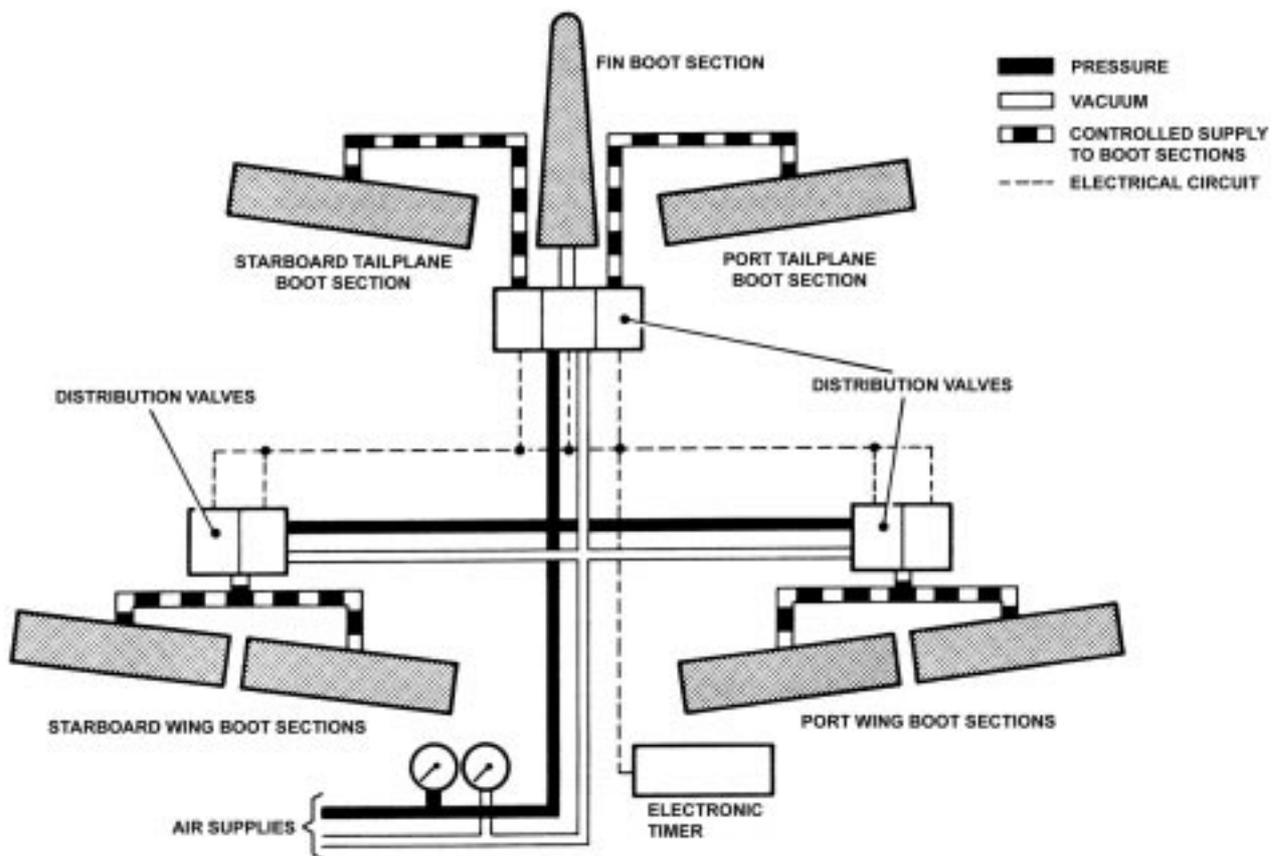

Fig.1. Schematic Diagram Of A Pneumatic De-Icing System.

De-icer Boots

The de-icer boots, or overshoes, consist of layers of natural rubber and rubberised fabric between which are disposed flat inflatable tubes closed at the ends. The tubes are made of rubberised fabric and are vulcanised inside the rubber layers. In some boots the tubes are so arranged that when the boots are in position on a wing or tail plane leading edge the tubes run parallel to the span; in others they run parallel to the chord. The tubes are connected to the air supply pipelines from the distribution valves system by short lengths of flexible hose secured to connectors on the boots and to the pipelines by hose clips. The external surfaces of boots are coated with a film of conductive material to bleed off accumulations of static electricity. Depending on the type specified, a boot may be attached to a leading edge either by screw fasteners (rivnuts) or by cementing them directly to the leading edge.

Metal fairing strips are fitted to cover the edges of screw-fastened type boots, both on the upper and lower surfaces of an airfoil, and also at the ends of the boots. These latter strips serve to secure the ends of the boots and prevent inward 'creep'. The strips are secured by the same screws used for securing the edges of the boots to the rivnuts.

Air Supplies and Distribution

The tubes in the boot sections are inflated by air from the pressure side of an engine-driven vacuum pump, from a high-pressure reservoir or in the case of some types of turbo-propeller aircraft, from a tapping at an engine compressor stage. At the end of an inflation stage of the operating sequence, and whenever the system is switched off, the boots are deflated by vacuum derived from the vacuum pump or, in systems utilizing an engine compressor tapping, from the venturi section or an ejector nozzle.

The method of distributing air supplies to the boots depends on the de-icing systems required for a particular type of aircraft but, in general, three methods are in use. One method employs shuttle valves which are controlled by a separate solenoid valve; in the second method air is distributed to each boot by individual solenoid-controlled valves; in the second method air is distributed to each boot by individual solenoid-controlled valves; in the third method distribution is effected by a motor-driven valve.

Controls and Indicators

The controls and indicators required for the operation of a de-icing system depend on the type of aircraft and on the particular arrangement of its de-icing system. In the basic arrangement, a main on-off switch, pressure and vacuum gauges or indicating lights form part of the controlling section. Pressure and vacuum is applied to the boots in an alternating timed sequence and the methods adopted usually vary with the methods or air distribution. In most installations, however, timing control is effected by means of an electronic device. Reference should always be made to the relevant aircraft Maintenance Manual for details of the appropriate controlling system and time cycles.

OPERATION

When the system is switched on, pressure is admitted to the boot sections to inflate the tubes. The inflation weakens the bond between ice and the boot surfaces, causing the ice to break away. At the end of the inflation stage of the operating sequence, the air in the tubes is dumped to atmosphere through automatic opening valves and the tubes are fully deflated by the vacuum supply. This inflation and deflation cycle is repeated during the period the system is in operation. When the system is switched off vacuum is supplied continually to all tubes of the boot sections to hold the sections flat against the wing and tail unit leading edges thus minimising aerodynamic drag.

CHAPTER: 9
THERMAL (HOT GAS) DE-ICING SYSTEMS

GENERAL

In systems of this type, the leading edge sections of wings and tail units are usually provided with a second inner skin positioned to form a small gap between and the inside of the leading edge section. Heated air is ducted to the wings and tail units and passes into the gap, providing sufficient heat in the outer skin of the leading edge to melt ice already formed and prevent further ice formation. The air is exhausted to atmosphere through outlets in the skin surfaces and also, in some cases, in the tips of wings and tail units. The temperature of the air within the ducting and leading edge sections is controlled by a shutter or butterfly type valve system the operation of which depends on the type of heating system employed.

AIR SUPPLIES

There are several methods by which the heated air can be supplied and these include bleeding of air from a turbine engine compressor, heating of ram air by passing it through a heat exchanger located in an engine exhaust gas system and combustion heating of ram air.

In a compressor bleed system the hot air is tapped directly from a compressor stage and after mixing with a supply of cool air in a mixing chamber it passes into the main ducting. In some systems, equipment, e.g. safety shut-off valves, is provided to ensure that an air mass flow sufficient for all de-icing requirements is supplied within pressure limits acceptable to duct and structural limitations.

The heat exchanger method of supplying warm air is employed in some types of aircraft powered by turbo-propeller engines. The heat exchanger unit is positioned so that exhaust gases can be diverted to pass between tubes through which outside air enters the main supply ducts. The supply of exhaust gases is usually regulated by a device such as a thermostatically controlled flap fitted in the ducting between the exhaust unit and the heat exchanger.

In a combustion heating system ram air is passed through a cylindrical jacket enclosing a sealed chamber in which a fuel/air mixture is burned, and is heated by contact with the chamber walls. Air for combustion is derived from a separate air intake and is supplied to the chamber by means of a blower.

DUCTING

The type of ducting, materials used, methods of inter connection and disposition in an aircraft vary between de-icing systems, and reference should therefore always be made to the relevant Aircraft Maintenance Manual for details.

Light alloy and stainless steel are materials normally used in construction, stainless steel being adopted principally in compressor bleed systems. Flanged and bolted end fittings, or band-type vee-clamps with interposed sealing rings are common methods of connecting duct sections together, and in some cases an additional means of sliding duct sections one end into the other and securing by adjustable clamps may be adopted.

In some installations in which ducting passes through the fuselage, joints between duct sections are sealed to prevent loss of cabin air pressure. Fuselage ducting may, in some types of aircraft, comprise an inner stainless steel duct surrounded by an outer fibreglass duct. The two ducts are approximately 13 mm ($1/2$ in) apart and the interspace is filled with glass wool to provide thermal insulation. The purpose of this ducting arrangement is to serve as a leak warning system by venting interspace air through venturis which operate pressure switches and a warning light.

Expansion and contraction of ducting is catered for by bellows or gimbal type expansion joints and in aircraft having variable incidence tailplanes and other moveable aerofoil surfaces such as leading edge slats and Kruger flaps, swivel joints and telescopic joints are fitted in the ducts supplying air to these surfaces.

In some installations, ducting in certain areas is lagged with a fire-resisting, heat-insulating material, normally fibreglass held in place by glass-cloth bound with glass cord.

TEMPERATURE CONTROL

The control of the air temperature within ducting and leading edge sections is an important aspect of thermal de-icing system operation and the methods adopted depend on the type of system.

In a typical compressor bleed system, control is effected by temperature sensing units which are located at various points in the leading edge ducting and by valves in the main air supply ducting. The sensing units and valves are electrically interconnected so that the valves are automatically positioned to regulate the flow of heated air to the system thus maintaining the temperature within a predetermined range. Indications of air temperature conditions are provided by resistance type temperature sensing elements and indicators, temperature sensitive switches and overheat warning lights. On some aircraft the electrical supplies to the valves are interrupted by landing gear controlled relays when the aircraft is on the ground. Under these conditions, valve operation is accomplished by holding the system control switch to a 'TEST' position.

When heat exchangers are employed, temperature control is usually obtained by the use of adjustable flaps and valves to decrease or increase the supply of heating and cooling air passed across the exchangers. The method of controlling the flaps and valves varies with different aircraft but a typical system incorporates an electric actuator, which is operated automatically by an inching device controlled by a temperature sensing element fitted in the duct on the warm air outlet side of the heat exchanger. In some systems, actuators are directly controlled by thermal switches,

so that the flaps or valves are automatically closed when a predetermined temperature is reached. Indications of air temperature conditions are provided by resistance type temperature sensing elements and indicators, temperature sensitive switches and overheat warning lights.

In systems incorporating combustion heaters, the temperature is usually controlled by thermal cyclic switches located in the heater outlet ducts, so that when the temperature reaches a predetermined maximum the fuel supply to the heaters is automatically switched off.

CHAPTER: 10
GROUND DE-ICING OF AIRCRAFT

GENERAL

The presence of frozen deposits on an aircraft may be the result of direct precipitation (rain, snow, frost etc.,) or accretion of frost or ice on external surfaces of integral fuel tanks after prolonged flight at high altitude, or accumulations on the landing gear and forward surfaces or undersurfaces following taxying through snow or slush.

Any deposits of ice, snow or frost on the external surfaces of an aircraft may drastically affect its performance. This can be due to reduced aerodynamic lift and increased aerodynamic drag resulting from the disturbed airflow over the aerofoil surfaces, or due to the weight of the deposit over the whole aircraft. The operation of an aircraft may also be seriously affected by the freezing of moisture in controls, hinges and microswitches, or by the ingestion of ice into the engine. Furthermore, since the in-flight de-icing system may not become effective until the aircraft is established in the climbout, the measures taken to remove frozen deposits on the ground must also be such as to provide adequate protection during the initial stages of flight.

Neither the use of currently available Freezing Point Depressant (FPD) types of de-icing/anti-icing compounds, nor the use of manual techniques of de-icing with such compounds should be thought of as producing reliable anti-icing qualities for a define period of time because the number of variables involved make it impractical to estimate that time. Only in the sense that under certain conditions FPD anti-icing compounds are known to be effective in retarding the formation of frost, snow or ice may they be considered to have anti-icing qualities for a period of time thus making the process of de-icing simpler and in many cases obviating the need for further de-icing or treatment during that period. It is emphasised, however, that the need for a close inspection of an aircraft prior to take-off still remains.

The aircraft de-icing systems are designed to remove or prevent the accretion of ice on a specific area of the wings, tail and engine nacelles in flight and would not normally be effective in removing deposits which have accumulated while the aircraft is stationary. Their use on the ground may, in some instances, also cause a different type of stationary. Their use on the ground may, in some instances, also cause a different type of unsatisfactory situation by melting parts of the deposit which would then freeze elsewhere. The use of cabin heating to remove deposits from the fuselage is also not recommended for the same reason.

When aircraft are moved so as to be under cover during inclement weather, any melted snow or ice may freeze again when the aircraft is subsequently moved into sub-zero temperatures. Complete protection could be provided by placing aircraft in heated hangers, but due to the size of modern transport aircraft and the need to meet schedules involving quick turnround times this is not often practicable. Removal of frost, ice and snow from aircraft is therefore often necessary and maintenance crews need to be familiar with the methods of ground de-icing in current use.

There are two main types of de-icing/anti-icing fluids:-

(a) **Type I fluids (unthickened).** These fluids have a high glycol content and a low viscosity. The de-icing performance is good, however, the provide only limited protection against refreezing.

(b) **Type II fluids (thickened).** These fluids have a minimum glycol content of approximately 50% and due to the thickening agent have special properties which enable the fluid to remain on the aircraft surfaces until take-off. The de-icing performance is good and, in addition, protection is provided against refreezing and/or build-up of further accretions, when exposed to freezing precipitation.

CHAPTER: 11
WIND SCREEN DE-ICING
AND ANTI-ICING SYSTEMS

There are two methods of De-icing and Anti-icing system of wind screen, they are: Fluid De-icing system and Electrical Anti-icing system.

FLUID DE-ICING SYSTEM

The method employed in this system is to spray the windscreen panel with a methyl-alcohol based fluid. The principal components of the system are a fluid storage tank, a pump which may be a hand-operated or electrically-operated type, supply pipe lines and spray tube unit. Figure 1 illustrates the interconnection of components based on a typical aircraft system in which fluid is supplied to the spray tubes by two electrically-operated pumps. The system may be operated using either of the pumps or both, according to the severity of icing.

ELECTRICAL ANTI-ICING SYSTEM

This system employs a windscreen of special laminated construction heated electrically to prevent, not only the formation of ice and mist, but also to improve the impact resistance of the windscreen at low temperatures.

The film-type resistance element is heated by alternating current supplied from the aircraft's electrical system. The power required for heating varies according to the size of the panel and the heat required to suit the operating conditions. Details of these requirements are given in the relevant aircraft Maintenance Manual.
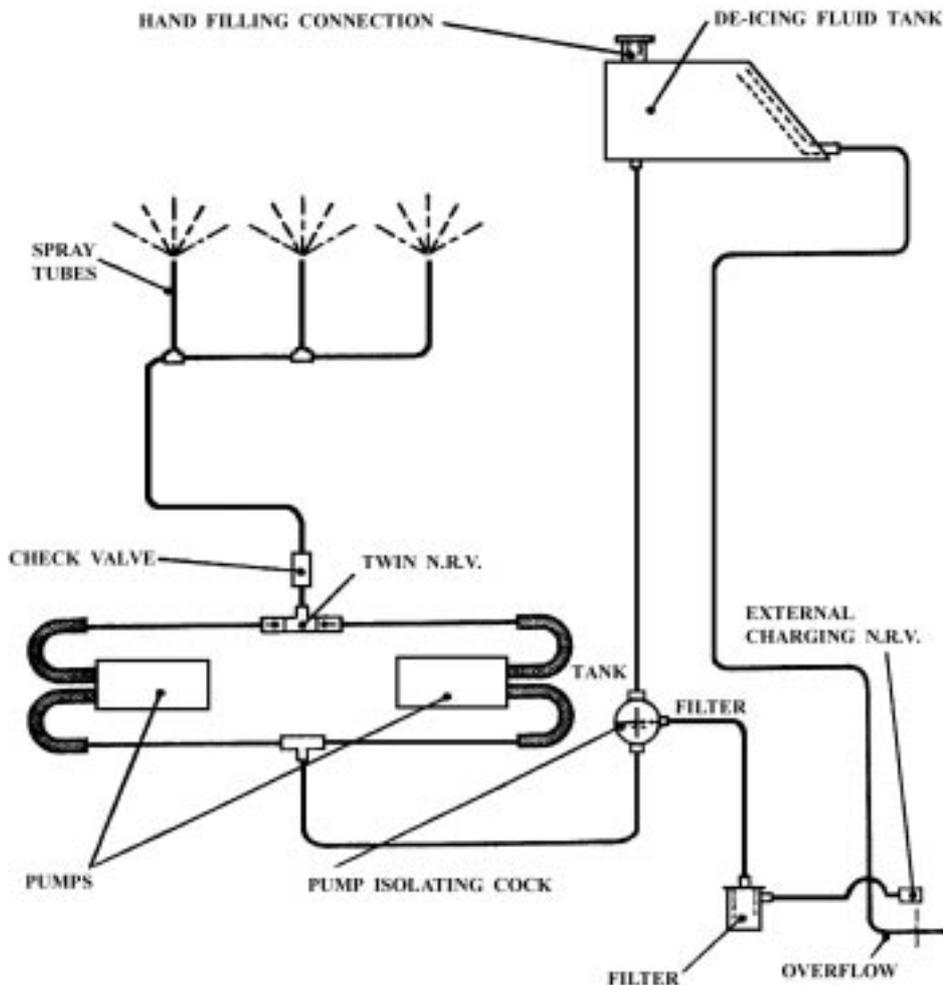

*Fig.1. Typical Fluid De-Icing System.*
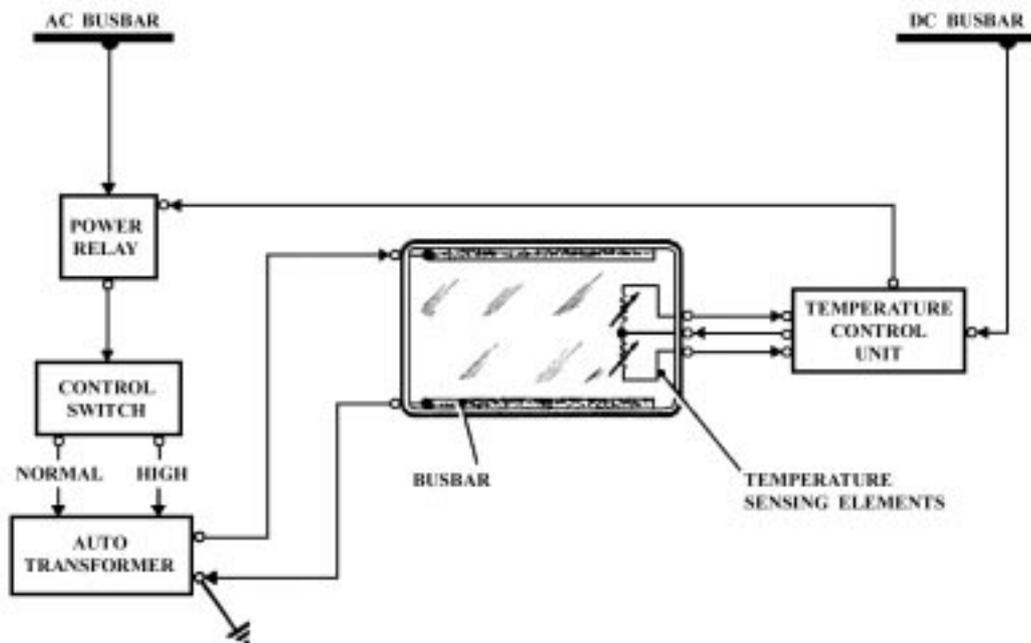
Fig.2. Typical Electric Anti Icing System.

The circuit embodies a controlling device, the function of which is to maintain a constant temperature at the windscreen and also to prevent overheating of the vinyl inter layer which would cause such permanent damage is vinyl 'bubbling' and discoloration. In a typical anti-icing system shown schematically in Figure2, the controlling device is connected to two temperature sensing elements laminated into the windscreen. The elements are usually in the form of a fine wire grid, the electrical resistance of which varies directly with the windscreen temperature. One sensing element is used for controlling the temperature at a normal setting and the other is used for overheat protection. A system of warning lights and, in some cases, magnetic indicators, also forms part of the control circuit and provides visual indications of circuit operating conditions, e.g. 'normal', 'off' or 'overheat'.

When the power is applied via the system control switch and power relay, the resistance element heats the glass. When it attains a temperature pre-determined for normal operation the change in resistance of the control element causes the control device or circuit to isolate, or in some cases to reduce, the power supply to the heater element. When the glass has cooled through a certain range of temperature, power is again applied and the cycle is repeated. In the event of a failure of the controller, the glass temperature will rise until the setting of the overheat sensing element is attained. At this setting an overheat control circuit cuts off the heating power supply and illuminates a warning light. The power is restored and the warning light extinguished when the glass has cooled through a specific temperature range. In some systems a lock out circuit may be incorporated, in which case the warning light will remain illuminated and power will only be re-applied by cycling the system control switch to 'OFF' and back to 'ON'.

(a)   In addition to the normal temperature control circuit it is usual to incorporate a circuit which supplies more heating power under severe icing conditions when heat losses are high. When the high power setting is selected, the supply is switched to higher voltage output tappings of an auto transformer which also forms part of an anti-icing system circuit thus maintaining the normal operating temperature. The temperature is controlled in a manner similar to that of the normal control temperature circuit.

(b)   For ground testing purposes, the heating power supply circuit may also be controlled by landing gear shock-strut microswitches in such a way that the voltage applied to the resistance elements is lower than that normally available in flight.

CHAPTER: 12
FLUID DE-ICING SYSTEM

GENERAL

In systems of this type, a de-icing fluid is drawn from a storage tank by an electrically driven pump and fed through micro filters to a number of porous metal distributor panels. The panels are formed to the profiles of the wing and tail unit leading edges into which they are fitted. At each panel the fluid passes into a cavity, and then through a porous plastic sheet to a porous stainless steel outer skin. As the fluid escapes it breaks the bond between ice and the outer skin and the fluid and ice together are directed rearward, by the airflow, over the airfoil.

The interconnection of components of a typical fluid de-icing system is shown in Figure1. The head compensating
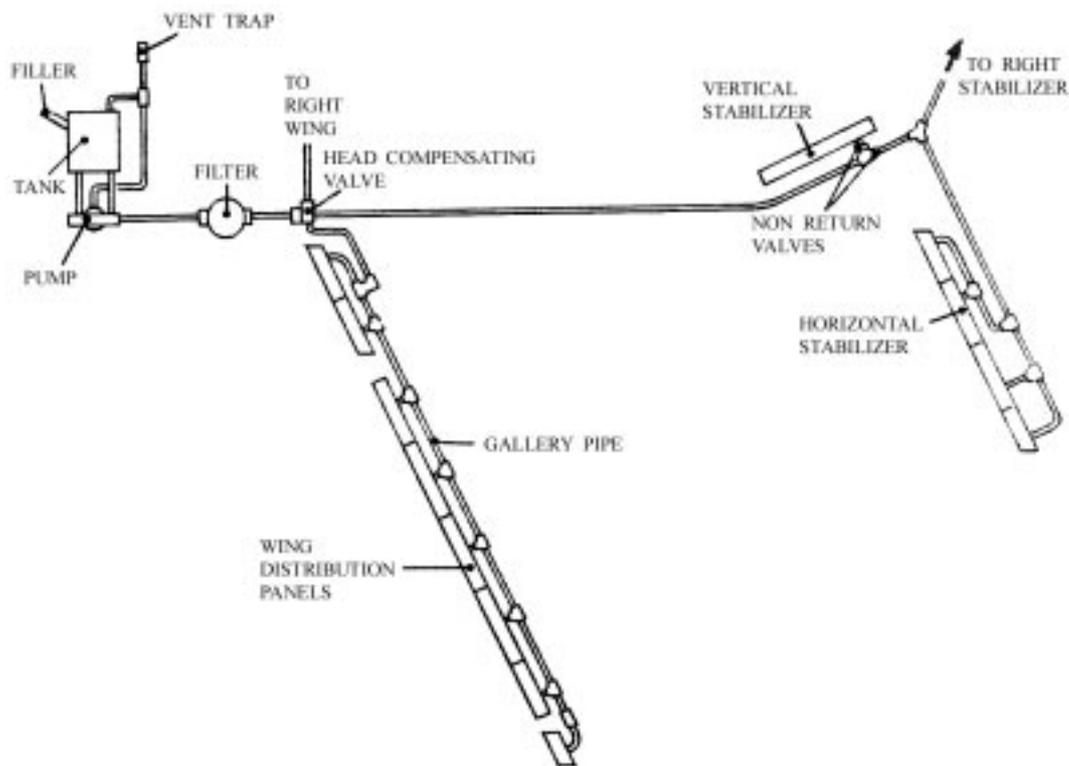
Fig. 1.Typical Fluid De-Icing System.

valve is fitted in some types of aircraft to correct for variations in system pressure (head effect) due to differences in level between the wings, horizontal and vertical stabilisers. The non-return valves prevent back flow when the system is inoperative. Nylon pipelines are usually used throughout the system; those for the main fluid supply being of 8mm (5/16 in) inch outside diameter and those for connections to individual distributor panels of 4.7 mm (3/16 in) outside diameter.

A sectional view of a typical distributor panel is shown in Figure2. The connector contains a metering tube which is accurately calibrated to provide the required rate of fluid flow through the distributor. In some aircraft the metering of fluid to the distributor panels is done via proportioning units containing the corresponding number of metering tubes.

To prevent electrolytic corrosion, plastic sealing strips are interposed between the stainless steel panel and the metal used in the airfoil structure. In some installations an epoxy resin sealing compound is used, and to facilitate the removal of a panel it is sprayed along its edges with a thin coating of polytetrafluourethylene (p.t.f.e.) to act as a release agent. In addition, a strip of p.t.f.e. tape may be laid along the mating surfaces of the aerofoil structure.
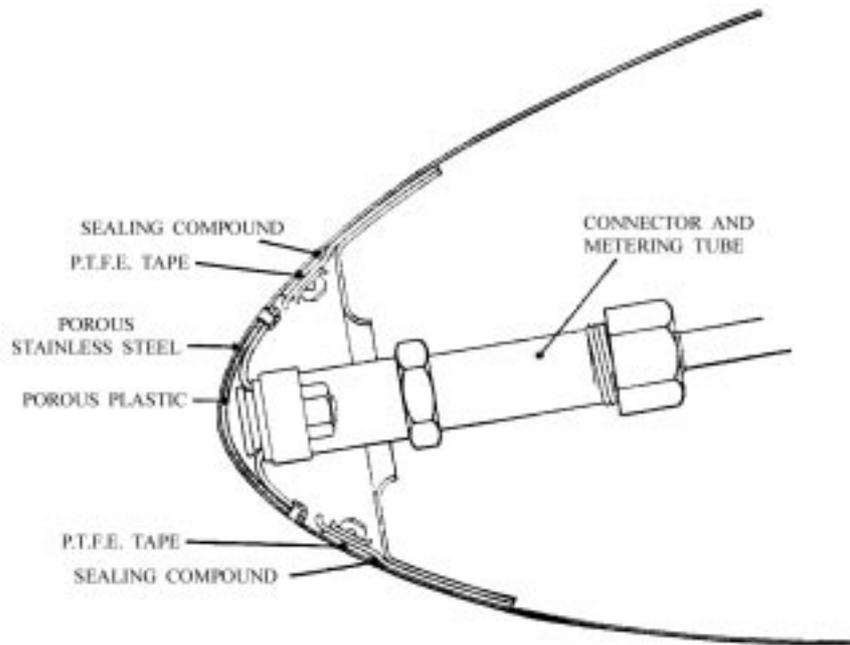
Fig.2. Section Of A Typical Distributor Panel.

CHAPTER: 13
LANDING GEAR

GENERAL

The functions of a landing gear are to support an aircraft during ground manoeuvres, dampen vibration, and absorb landing shocks; when required, it also performs the functions of steering and braking. These objectives are achieved by many different designs, depending on the type of aircraft to which the landing gear is fitted and the degree of sophistication required. A landing gear usually takes the form of two or more main undercarriage units in the wings or fuselage, and an auxiliary undercarriage unit at the nose or tail which carries only a small proportion of the total load and is used for steering purposes.

With slow, light aircraft, and some larger aircraft on which simplicity is of prime importance, a fixed (non-retractable) landing gear is often fitted; the reduced performance caused by the drag of the landing gear during flight is offset by the simplicity, reduced maintenance and low initial cost. With higher performance aircraft, drag becomes progressively more important, and the landing gear is retracted into the wings or fuselage during flight; there are however, penalties of increased weight, greater complication and additional maintenance.

The landing gear of an aircraft may receive harsh treatment throughout its installed life, being subject to frequent landing shocks and in regular contact with spray, ice, dirt, and abrasive grit. Regular servicing and lubrication are required, therefore, to guard against corrosion, seizure of mechanical parts and failure of electrical components.

FIXED LANDING GEAR

There are three main types of fixed landing gear; those which have a spring steel leg, those which employ rubber cord to absorb shocks, and those which have an oleo-pneumatic strut to absorb shocks. Exceptions include aircraft with rubber in compression, spring coil, and liquid spring struts.

Spring Steel Legs

Spring steel legs are usually employed at the main undercarriage positions. The leg consists of a tube, or strip of tapered spring steel, the upper end being attached by bolts to the fuselage and the lower end terminating in an axle on which the wheel and brake are assembled.

Maintenance

Spring steel under carriages should be inspected regularly for damage and corrosion. The aircraft should be jacked up periodically, so that all load is taken off the wheels, and the security of each undercarriage checked by attempting to move it against the restraint of its attachments to the airframe structure. If there are signs of looseness, the bolts should be removed for detailed inspection and the bolt holes should be checked for cracks or fretting. Axle fittings should be similarly inspected, and all nuts and bolts should be tightened to the specified torque.

Rubber Cord

When rubber cord is used as a shock-absorber, the undercarriage is usually in the form of tubular struts, designed and installed so that the landing force is directed against a number of turns of rubber in the form of a grommet or loop.

Rubber cord is colour coded to indicate the date of manufacture and the specification to which it conforms, by replacing some of the fibres in the outer cotton covering with coloured threads wound in a spiral.

Maintenance

The undercarriage should be examined for damage, corrosion, wear or cracks at the pivot points, and bent pivot bolts, and should be lubricated as specified in the approved Maintenance Schedule. The rubber cord should be inspected for Chafing, necking, or other deterioration, and it is advisable to replace if it is more than five years old, regardless of its external condition.

Oleo-Pneumatic Struts

Some fixed main under carriages, and most fixed nose under carriages, are fitted with an oleo-pneumatic shock-absorber strut. The design of individual struts varies considerably, and reference should be made to the appropriate Maintenance Manual for a particular type, but operation and maintenance procedures for a typical design are covered in the following paragraphs.

Construction

Fig. 1 shows the construction of a simple oleo-pneumatic strut, in this instance a nose undercarriage which also includes a steering mechanism. The outer cylinder is fixed rigidly to the airframe structure by two mounting brackets, and houses an inner cylinder and a piston assembly, the interior space being partially filled with hydraulic fluid and inflated with compressed gas (air or nitrogen). The inner cylinder is free to rotate and move up and down within the outer cylinder, but these movements are limited by the torque links, which connect the inner cylinder to the steering collar. The steering collar arms are connected through spring struts to the rudder pedals, and a shimmy damper is attached to the steering collar.

Operation

i) Under static conditions the weight of the aircraft is balanced by the strut gas pressure and the inner cylinder takes up a position approximately midway up its stroke.

COMBINED FILLER PLUG
AND INFLATION VALVE

UPPER MOUNTING
BRACKET

OUTER CYLINDER

PISTON SUPPORT

OIL LEVEL

INNER CYLINDER

SPRING-LOADED
STEERING ROD

LOWER MOUNTING BRACKET

BEARING

SHIMMY DAMPER
BRACKET

STEERING COLLAR

ORIFICE

METERING VALVE

NOSEWHEEL FORK

TORQUE LINKS
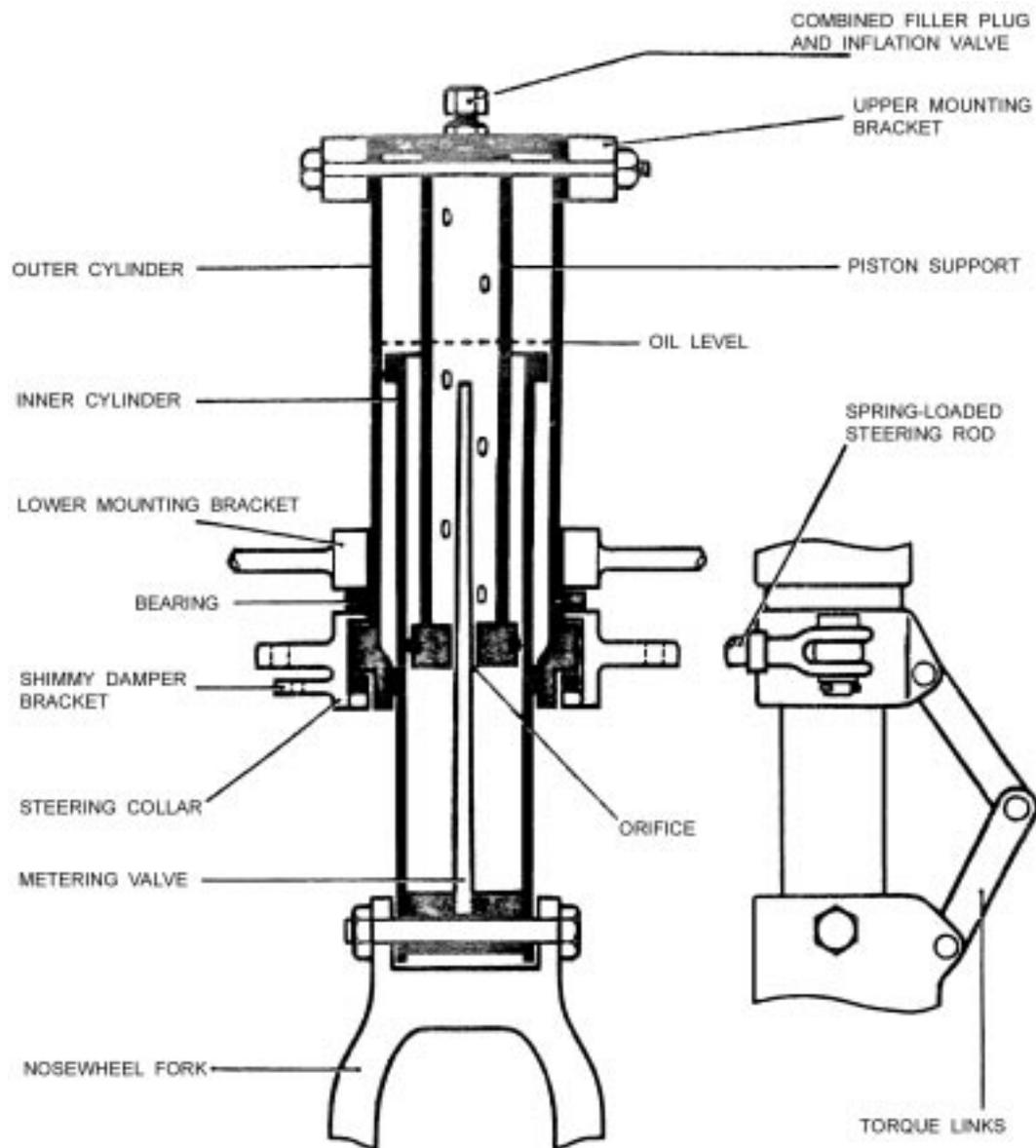
Fig.1. Oleo-Pneumatic Strut.

ii) Under compression (e.g. when landing), the strut shortens and fluid is forced through the gap between the piston orifice and the metering rod, this restriction limiting the speed of upward movement of the inner cylinder.

iii) As the internal volume of the cylinders decreases, the gas pressure rises until it balances the upward force.

iv) As the upward force decreases, the gas pressure acts as a spring and extends the inner cylinder. The speed of extension is limited by the restricted flow of fluid through the orifice.

Note: On some struts an additional valve is fitted to the piston or inner cylinder, to further restrict the flow of fluid during extension, and prevent violent extension of the strut if upward force is suddenly released, such as when a bounce occurs.

v) Normal taxying bumps are cushioned by the gas pressure and dampened by the limited flow of fluid through the orifice.

vi) Movement of the rudder pedals turns the nose wheel to facilitate ground manoeuvres, the spring struts being provided to allow for vertical movement of the nose wheel, and prevent shocks from being transmitted through the rudder control system.

Shimmy Dampers

Most of the nose and tail wheels are fitted with shimmy dampers to prevent rapid oscillation during ground manoeuvres.

A simple damper consists of two friction discs, one connected to a fixed part of the undercarriage and the other connected to the oscillating part. The discs are held in contact by spring pressure and resist relative movement between the parts to which they are connected.

A type of damper commonly found on light aircraft is illustrated in Fig. 2; the piston rod is connected to the steering collar and the cylinder attached to a fixed part of the strut. The cylinder is completely filled with fluid, and small holes in the piston allow a restricted flow of fluid when force is applied to the piston rod. Movement of the nose undercarriage is therefore slowed down, and oscillations damped.
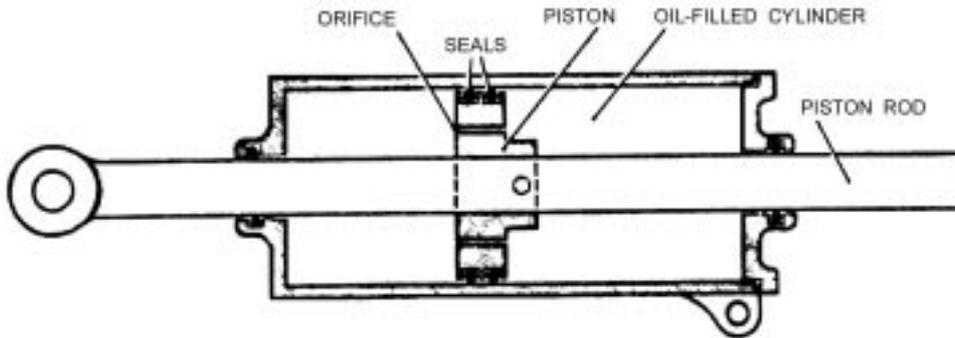
Fig.2. Damper Strut.
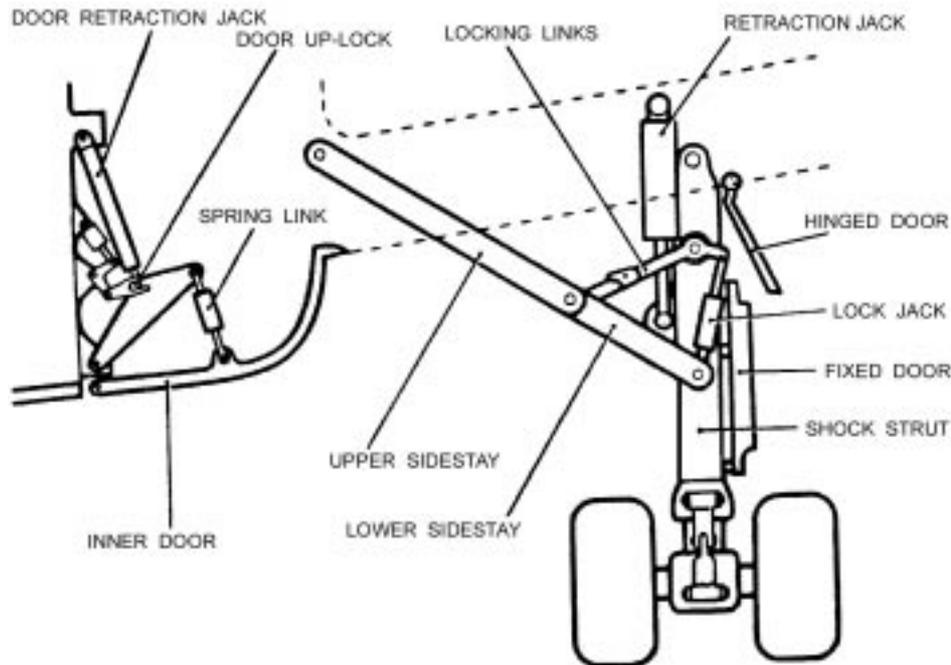
Fig.3. Typical Undercarriage Unit.

RETRACTABLE LANDING GEAR

The majority of modern transport aircraft, and an increasing number of light aircraft, are fitted with a retractable landing gear, for the purpose of improving aircraft performance. Retraction is normally effected by a hydraulic system, but pneumatic or electrical systems are also used. In some instances power is used for retraction only, extension being effected by gravity and slipstream. Retractable landing gear is also provided with mechanical locks to ensure that each undercarriage is locked securely in the retracted and extended positions; devices to indicate to the crew the position of each undercarriage; and means by which the landing gear can be extended in the event of failure of the power source. In addition, means are provided to prevent retraction with the aircraft on the ground, and to guard against landing with the landing gear retracted. Undercarriage wells are normally sealed by doors for aerodynamic reasons, but one particular aircraft type employs inflatable rubber bags to seal the main undercarriage wells.

Retractable under carriages normally consist of an oleo-pneumatic shock-absorber strut, similar to the one shown in Fig. 1 but supported in a trunnion bearing which is fixed to a spar or strengthened box section in the wings or fuselage; the strut is braced longitudinally by drag struts, and laterally by side stays. In some designs the drag strut or side stay is in two parts, and hinges about the centre point to provide a means of retraction, while in others the retraction jack operates on an extension of the shock-absorber strut housing. Fig. 3 shows a typical retractable undercarriage unit which is hydraulically operated in both directions and locked by means of a geometric (over centre) lock.

Hydraulic Retraction system

A hydraulic system for retracting and extending a landing gear normally takes its power from engine driven pumps, alternative systems being available in case of pump failure. On some light aircraft a self-contained 'power pack' is used, which houses a reservoir and selector valves for the landing gear and flap systems; an electrically driven pump may also be included, or the system may be powered by engine driven pumps. This type of system normally provides for powered retraction of the landing gear, extension being by 'free-fall', with the assistance of spring struts.

Fig. 4 is a schematic diagram of a simple hydraulic retraction system. The various components shown illustrate operation of this system, but are not intended to represent a typical design; actual components often operate in a different manner, but their purpose is the same.

Operation of the system illustrated in Figure below is as follows :

(i) Retraction

When the landing gear selector is moved to the 'up' position, fluid under pressure is directed to the 'up' line and fluid from the 'down' line is directed back to the hydraulic reservoir. Fluid flows to the sequence valves (SV3, SV4), retraction jacks (MJ1, MJ2, NJ1), main undercarriage down-lock jacks (LJ1, LJ2), and nose undercarriage down-lock (NL2); it cannot pass the sequence valves, which are closed, but operates the retraction jacks and down locks. The locks operate first, releasing the landing gear and allowing the retraction jacks to raise each undercarriage, the nose undercarriage engaging its spring-loaded up-lock (NL1) first, because of the jack's smaller size. At the end of upward travel of the main undercarriage units, a striker on each leg contacts the plunger of its associated sequence valve (SV3, SV4), and opens the valve, allowing fluid to flow to the door jacks (DJ1, DJ2). The main undercarriage engages the up-locks (ML1, ML2) and the doors close, engaging locks DL1, DL2. Fluid in the 'down' lines returns to the reservoir, flowing unrestricted through the restrictor valves (R1,R2) and overcoming the small restriction of the spring loading of the sequence valves (SV1, SV2).

Note : The nose undercarriage doors are operated mechanically by linkage to the nose shock-absorber housing.

(ii) Extension

When the landing gear selector is moved to the 'down' position, fluid under pressure is directed to the 'down' line, and fluid from the 'up' line is directed back to the reservoir. Fluid flows to the sequence valves (SV1, SV2), door jacks (DJ1, DJ2), door locks (DL1, DL2), nose undercarriage retraction jack (NJ1) and the nose undercarriage up-lock (NL1). The sequence valves are closed, so fluid pressure releases all the door locks and the nose undercarriage up-lock, and the doors and nose undercarriage extend, the nose undercarriage engaging its down-lock (NL2) at the end of its travel. When the doors are fully open, the door jacks strike the plungers of their associated sequence valves (SV1, SV2) and open the valves, allowing fluid to flow through the restrictor valves (R1, R2) to the main undercarriage up-locks (ML1, ML2) and retraction jacks (MJ1, MJ2). These locks are released, and the retraction jacks lower the main undercarriage fully, the spring-loaded lock-jacks (LJ1, LJ2) imposing a geometric lock on the side stays. Main undercarriage doors are held open by fluid pressure.

Note: Restrictor valves are normally fitted to limit the speed of lowering of the main undercarriage units, which are influenced in this direction by gravity. The nose undercarriage often lowers against the slipstream and does not need the protection of a restrictor valve.

Pneumatic Retraction System

Operation of a pneumatic retraction system is similar to that of a hydraulic system, except that pressure in the return lines is exhausted to atmosphere through the selector valve. Pressure is built up in a main storage cylinder by engine driven air pumps, and passes through a pressure reducing valve to the landing gear selector valve. Operation of the selector valve to the 'up' position directs pneumatic pressure through the 'up' lines to the retraction rams, and opens the down line to atmosphere. Operation of the selector valve to the 'down' position directs pneumatic pressure through a second pressure reducing valve and the down lines, to the up-lock rams and retraction rams. A simple pneumatic system is illustrated in Fig. 5.

Note: A low pressure is used for landing gear extension, for the same reason that restrictor valves are used in hydraulic systems, which is to prevent damage occurring through too-rapid extension of the undercarriage units.

Retraction rams are usually damped to prevent violent movement. The hollow piston rod is filled with oil or grease, which is forced through the angular space between the inner surface of the piston rod and a stationary damper piston whenever the ram extends or retracts, thus slowing movement.

Up-locks and down-locks are similar to those used with hydraulic systems, the geometric down-locks being imposed by over-centering of the drag strut at the end of retraction ram stroke, and the up-locks by spring-ram operated locks. Down-locks are released by initial movement of the retraction rams during retraction, and up-locks are released by pneumatic pressure in the spring-rams during extension.

Undercarriage doors are operated mechanically, by linkage on the shock-absorber housing.
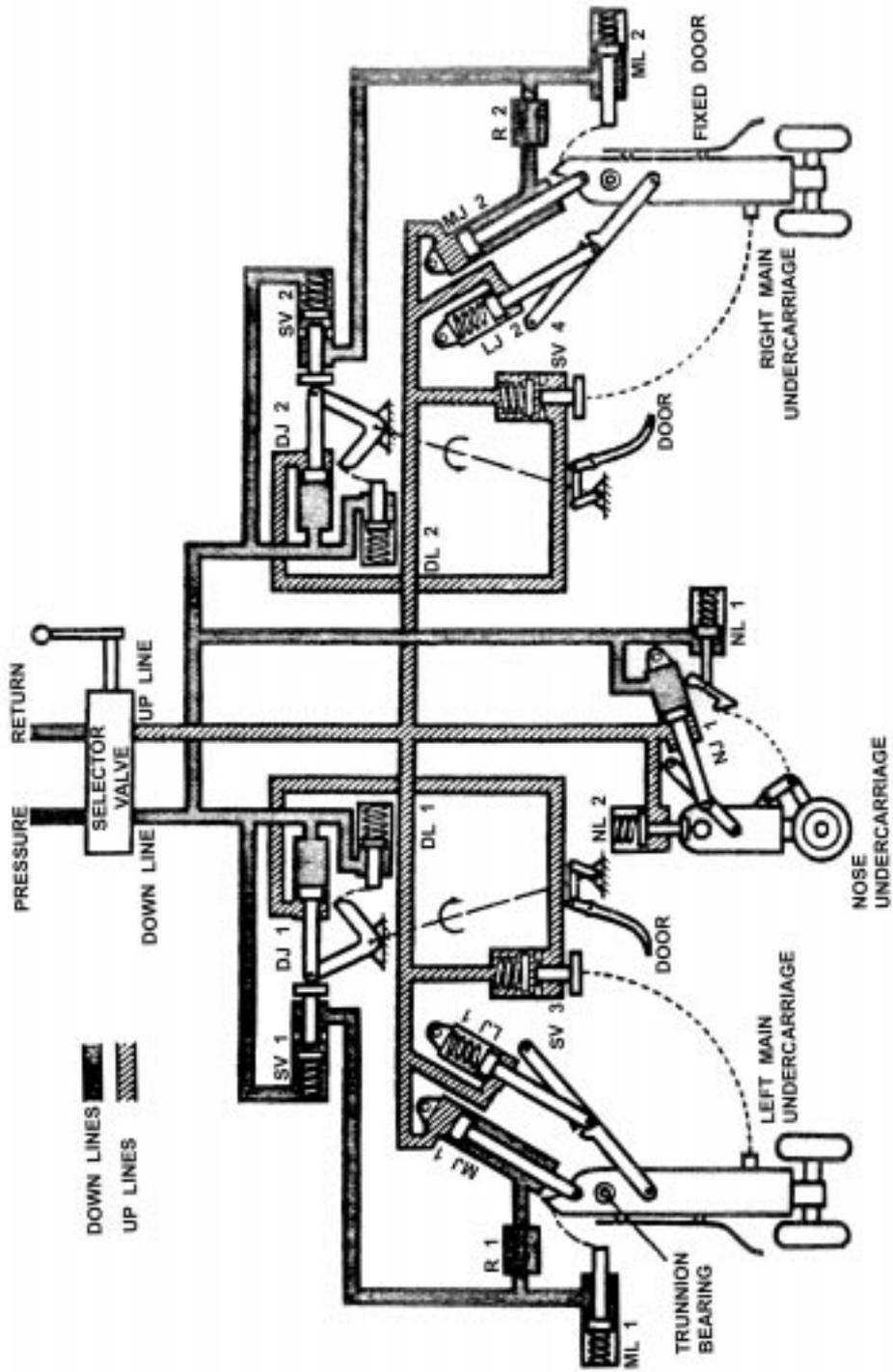
Fig.4. Simple Hydraulic Retraction System.

Electrical Retraction System

An electrical retraction system is often fitted to light aircraft which do not otherwise require the use of a high pressure fluid system. The main and nose undercarriage units are similar to those used in fluid retraction systems, but push and pull forces on the retraction mechanism are obtained by an electric motor and suitable gearing. Fig. 6 illustrates a typical system, in which a single reversible electric motor provides the power to retract and extend the landing gear.

The motor operates a screw jack, which provides angular movement to a torque tube; a push-pull rod from the torque tube acts on the drag strut of the nose undercarriage, and cables and rods from the torque tube act on the main undercarriage side stays, rubber cord being used to assist extension of the main undercarriage units.

Down-locks are imposed by over-centering of the drag strut and side stays during final movement of the operating
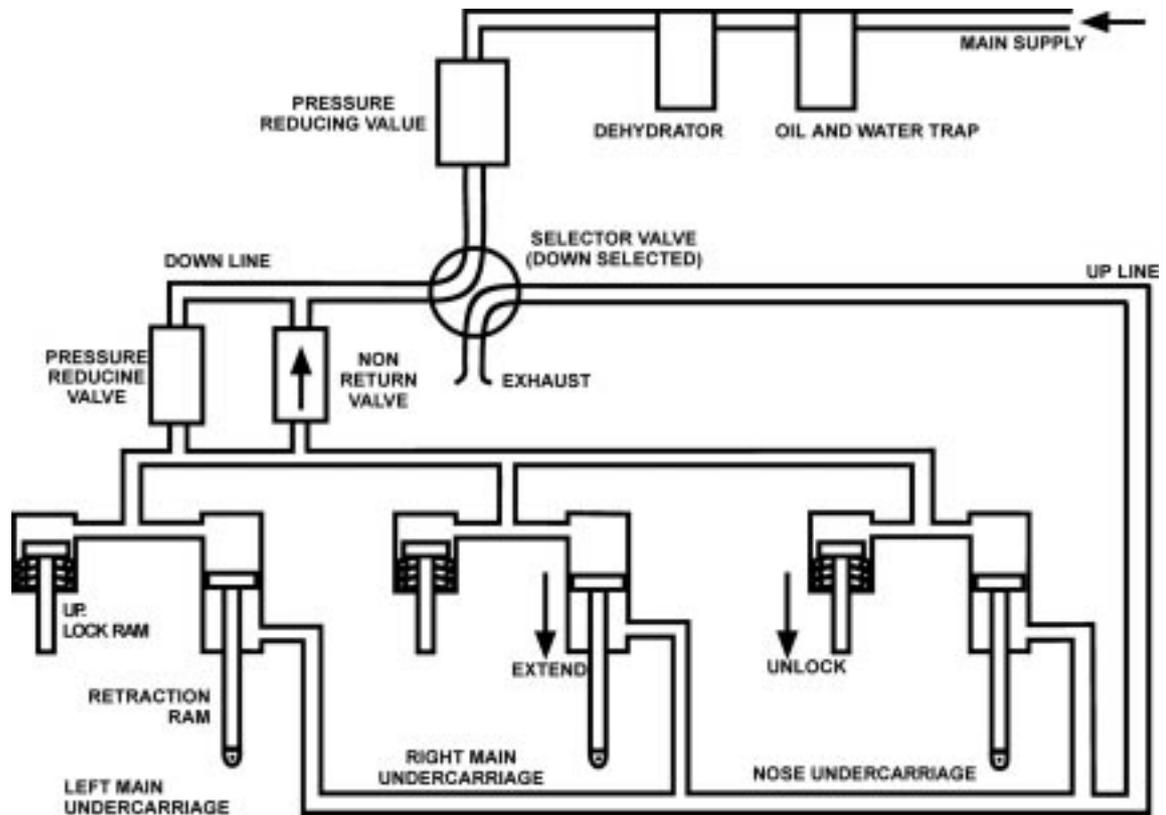

*Fig.5. Simple Pneumatic Retraction System.*
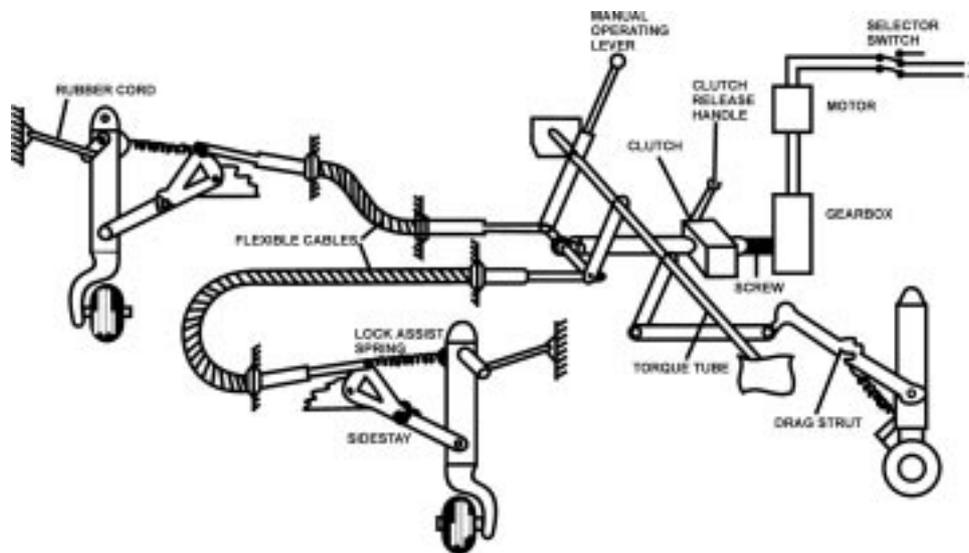
Fig. 6.Simple Electric Retraction System.

mechanism, with the assistance of springs. Limit switches on the drag strut and side stays cut off electrical power and brake the motor switches on the drag strut and side stays cut off electrical power and brake the motor when the down-locks have engaged, while a limit switch on the torque tube stops and brakes the motor when the landing gear is fully retracted.

Undercarriage doors are operated by linkage go the shock-absorber housings.

Position Indication

Although the landing gear, when selected down, may be visible from the crew compartment, it is not usually possible to be certain that each undercarriage is securely locked. An electrical indicating system is used to provide a positive indication to the crew of the operation of the locks and of the position of the landing gear. The system usually consists of micro switches on the up-locks and down-locks, which make or break when the locks operate, and which are connected to a landing gear position indicator on the instrument panel. A mechanical indicator may also be provided, to show that the landing gear is down and locked when the electrical system is inoperative. On British manufactured aircraft, the electrical undercarriage indicating system operates in such a manner that a green light is displayed when the undercarriage is locked down, a red light is displayed when the undercarriage is in transit, and no lights are visible when the undercarriage is locked up; bulbs are usually duplicated to avoid the possibility of false indications as a result of bulb failures. On other aircraft, similar indications may be obtained by the use of magnetic indicators or lights, but on some light aircraft a single green light indicates that all under carriages are locked down, and an amber light indicates that all under carriages are locked up. On some transport aircraft, provision is also made for the crew to examine the locks during flight in the event of failure or incorrect operation of the indicating system. Whichever indicating system is used, it is important that the micro switches are adjusted so that operation of the lights coincides with the corresponding position of the landing gear.

Safety Features

Since the correct operation of the landing gear is of the utmost importance, a number of safety features are included in the retraction system to ensure its correct operation under all conditions.

Nose-wheel Centering

To avoid damage to the airframe structure, the nose wheel must always be aligned in a fore and aft direction during retraction, and a number of methods are used to ensure that this happens automatically. One method utilizes a cam and cam track between the inner and outer cylinders on the shock-absorber. The cam is fixed to the top of the inner cylinder, and the track to the bottom of the outer cylinder. As the strut extends under internal gas pressure after take-off, the cam engages the track and centres the nose undercarriage before it retracts. A second method is the use of a peg located at the top of the shock-absorber strut, which engages a track fixed to the strut housing or in the wheel bay, and this device centres the undercarriage as it retracts. Hydraulic nose wheel centering on aircraft with powered steering will be discussed later in this chapter.

Selector Lock

To prevent inadvertent retraction of the landing gear when the aircraft is resting on its wheels, a safety device is incorporated which prevents movement of the selector lever; mechanical ground locks are also provided for servicing purposes. The safety lock consists of a spring-loaded plunger which retains the selector in the down position land is released by the operation of a solenoid. Electrical power to the solenoid is controlled by a switch mounted on the shock-absorber strut; when the strut is compressed the switch is open, but as the strut extends after take-off, the switch contacts close and the electrical supply to the solenoid is completed, thus releasing the selector lever lock and allowing the landing gear to be selected up. A means of overriding the lock, such as a separate gated switch to complete the circuit, or a mechanical means of avoiding the locking plunger, is provided for emergency use and for maintenance purposes.

Warning Devices

To guard against landing with the landing gear retracted or unlocked, a warning horn is incorporated in the system and connected to a throttle-operated switch. If one or more throttle levers are less than approximately one third open, as would be the case during approach to land, the horn sounds and the red warning lamp illuminates if the landing gear is in any position other than down and locked. A horn isolation switch is often provided to allow certain flight exercises and ground servicing operations to be carried out without hindrance.

Emergency Extension

A means of extending the landing gear and locking it in the down position is provided to cater for the eventuality of main system failure. On some aircraft the up-locks are released manually or by means of an emergency pneumatic system; the landing gear 'free-falls' under its own weight and the down locks are engaged by spring jacks. On other aircraft the landing gear is extended by an emergency pressure system which often uses alternative pipelines to the jacks. Pressure for the emergency system may be supplied by a hydraulic accumulator, a hand pump, a pneumatic storage cylinder, or an electrically powered pump.

POWERED STEERING

Light aircraft generally employ a simple steering system, in which the nose wheel is mechanically linked to the rudder pedals. Larger aircraft require powered steering arrangements, in which the nose wheel is turned by hydraulic,

HYDRAULIC SYSTEM

MECHANICAL LINKAGE (IN CASTORING POSITION)
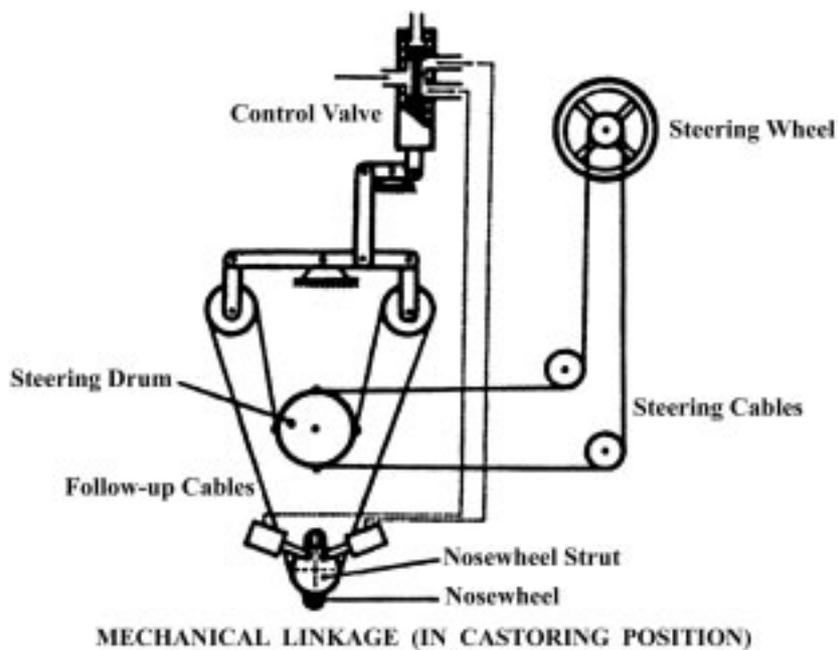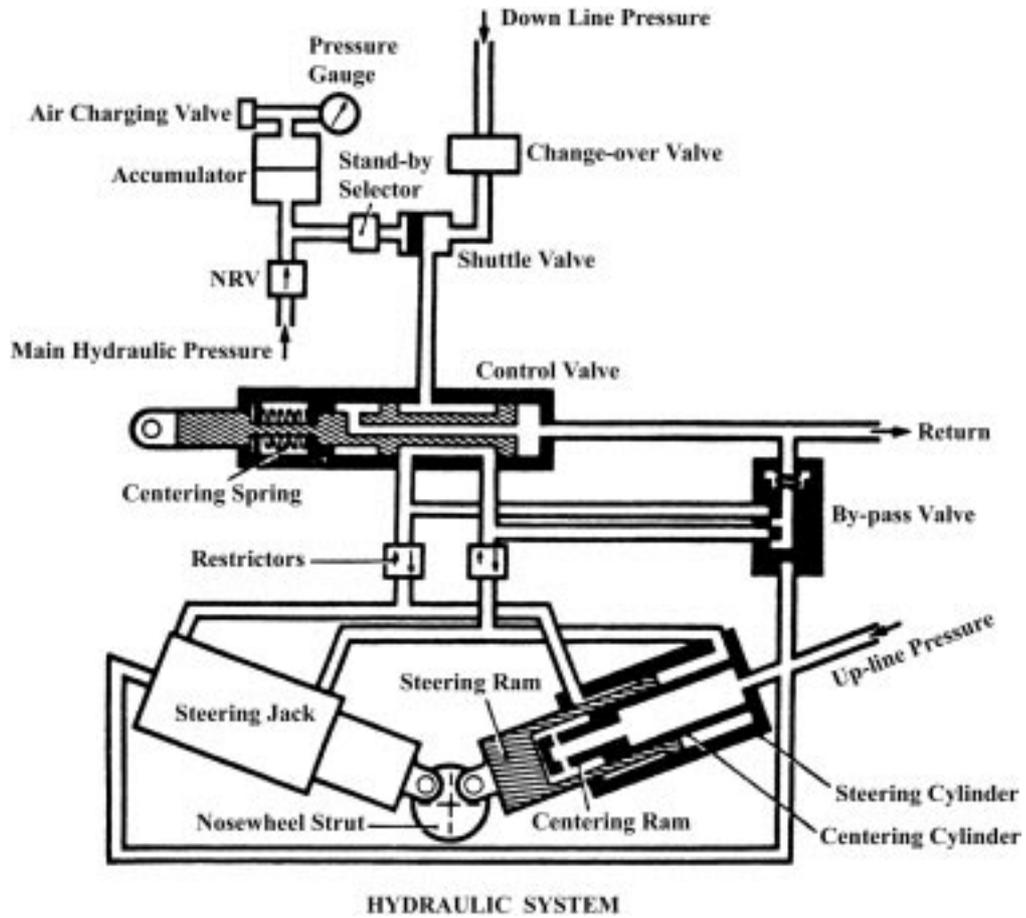
Fig. 7.Powered Steering System.

pneumatic, or electrical power. A powered steering system generally includes a cockpit steering wheel or tiller, a control valve, steering cylinders to actuate the nose undercarriage, a follow-up device to hold the nose wheel at the correct angle, and a power source. A typical hydraulically operated system is described below, and illustrated in figure7.

Hydraulic Steering System

Main operating pressure is derived from the undercarriage 'down' line' and a limited emergency supply is provided by a hydraulic accumulator. In the system shown in Figure below, hydraulic pressure passes through a change over valve, which ensures that the steering system is only in operation when the nose undercarriage is down.

Steering Operation

Pressure is directed through the control valve to the steering jacks, which retract or extend to rotate the nose shock-absorber strut within its housing. Movement of the steering wheel is transmitted through mechanical linkage to the control valve, in accordance with the amount and direction of turn required. Follow-up linkage from the nose undercarriage gradually resets the control valve as the nose wheel turns, and when the selected angle is reached a hydraulic lock is formed between the control valve and the steering jacks, preventing further movement. When the steering wheel is released, the control valve returns to neutral under the action of its centering springs, and the nose wheel is free to castor.

An inner cylinder in each steering jack is connected to the landing gear 'up' line and is supplied with fluid under pressure when the landing gear is selected up. The steering jacks extend equally to centralize the nose wheel before pressure is applied to the nose retraction jack, and the bypass valve allows fluid from the steering jacks to flow to the return line.

Castoring

Whenever the control valve is in its neutral position, fluid is free to flow between the steering jacks, thus allowing the aircraft to be towed, or the nose wheel to return to the central position after a turn has been initiated with the steering wheel. Angular movement of the nose wheel during towing will be transmitted through the follow-up linkage to the steering wheel. Some form of quick-release pin is often provided to enable the steering jacks to be disconnected so that the nose wheel may be turned through large angles during ground servicing.

Damping

Restrictors in the pipelines between the control valve and the steering jacks, provide damping for the nose undercarriage.
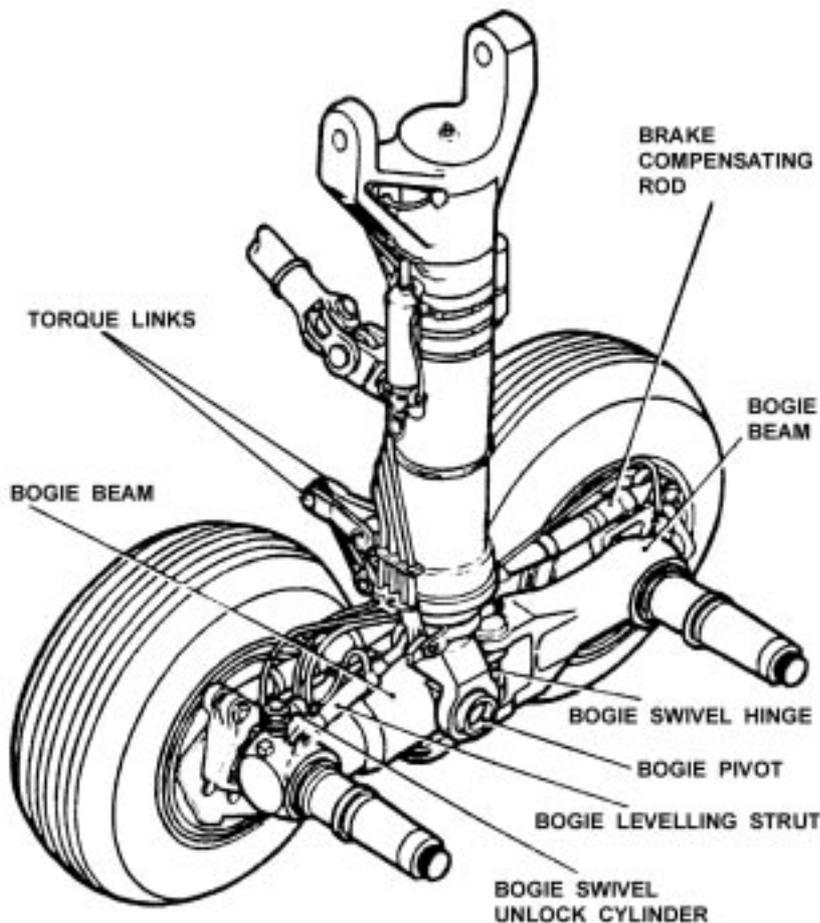

Fig.8. Typical Bogie Under Carriage.

BOGIE UNDER CARRIAGES

On heavy aircraft, the need to spread the weight over a large area has resulted in the use of multiple wheel under carriages. A typical four-wheeled bogie is illustrated in Fig. 8, but a larger number of wheels are used on some under carriages.

The undercarriage unit normally consists of a shock-absorber strut, at the lower end of which a bogie beam is pivoted, and the axles are attached to each end of the beam. On some aircraft the rear pair of wheels swivels on the bogie beam, and castors when the nose wheel is turned through a large angle; on others, the upper torque link member is replaced by a pair of hydraulic jacks, which, when nose wheel steering is applied, rotates the whole bogie. Castoring or steering prevents excessive torque on the undercarriage leg and minimizes tyre scrubbing during turns. For normal operation, the swivelling pair of wheels is locked in line with the fixed pair. Brake torque at each wheel is transmitted through compensating rods to the shock-absorber strut, thus preventing excessive loads on the bogie beam.

On retractable landing gear a levelling strut or 'hop damper' provides a means of positioning the bogie beam at suitable angles for retraction and landing; this strut is usually connected into the hydraulic system to prevent retraction if the bogie is not at a suitable angle, and combines the functions of hydraulic ram and damper unit.

CHAPTER: 14
TANKS

GENERAL

There are three types of tanks in use; rigid or shell tanks, flexible tanks, and integral tanks (tanks which are formed by sealing part of the structure). Rigid tanks are generally used for oil, de-icing fluid, hydraulic fluid, water, and, in some cases, fuel, whilst flexible and integral tanks are used almost exclusively for fuel, so as to make full use of the available space, and to save weight.

RIGID TANKS

Rigid tanks are normally used in engine oil systems, water systems, and the fuel systems of some light aircraft. Tanks which are contained within the airframe structure are generally manufactured from aluminium alloy, and may be either riveted or welded. Some tanks, such as coolant header tanks, may be constructed from sheet brass or similar alloy, and others, which have to withstand high temperatures or corrosive fluids may be made from stainless steel. External fuel tanks are sometimes made from nonmetallic materials such as glass fibre.

Installation

Rigid tanks are often mounted on suitably shaped bearers, and secured by means of padded metal straps, which are joined and tightened by turn buckles. On some wing fuel tanks, however, the lower surface of the tank is also the wing skin, and is secured to the surrounding structure by screws. In instances where the tank skin or the tank bay closing panel provides a load-bearing surface, the wing must be suitably supported before the tank is removed, and the supports must remain in position until the tank is re-installed and secured.

Before a tank is installed, the tank bay should be examined for cleanliness, damage and corrosion, and to ensure that there are no projections such as bolts, screws, or fasteners, which could chafe or damage the tank when it is in position. Any rectification necessary should be carried out, and protective treatment should be applied and allowed to dry. The tank bay area should then be thoroughly cleaned, fuel pipe and vent connections should be prepared to receive the tank, and electrical power to any tank connections should be isolated. Blanks fitted to the pipes should be left in position as long as possible, in order to prevent the ingress of foreign matter and moisture.

The tank which is to be fitted should be inspected for damage, all traces of inhibitor should be removed from it, and any components required for the tank, such as contents transmitters and booster pumps, should be installed in accordance with the appropriate Maintenance Manual. Any filters should be inspected for cleanliness and security and the filler cap, where fitted, should be checked for effective sealing. Vents should be checked to ensure they are properly connected and unblocked. All fittings should be locked in the appropriate manner.

Care is necessary when installing a tank, since there is often very little clearance between the tank and tank bay, and access holes may permit only a limited view. Careless installation could result in damage to the tank, which may lead to subsequent leakage.

Connections should be made without bending or stretching the pipes, and, when required by the manufacturer, installation alignment tolerances should be checked . The introduction of a low point in a feed or vent pipe run could result in the collection of water at that point, which could lead to a blockage if the water freezes.

Straps should be tightened sufficiently to prevent the tank from moving, but over-tightening must be avoided. It is important that all straps are tightened equally, to permit even distribution of strain.

Overboard drain and vent pipes should be checked after tank installation, to ensure they do not discharge in such a manner that combustible fluids could leak into the structure or passenger compartments, and create a fire hazard.

The bonding of tanks which are not connected directly to the structure is most important, and all bonding strips and cords should be securely attached. After installation of the tank, bonding should be checked.

The tank should then be filled, while the contents gauge is checked.

INSPECTION
Installed tanks

All applicable panels in he aircraft skin adjacent to the tank should be removed, and the tank should be inspected for security correct adjustment of straps and slings, contamination, corrosion, superficial damage, cleanliness, distortion, and evidence of leakage form pipe connections, drains and the tanks itself. Leakage form connections may often be corrected in situ, by draining the tank and remaking the connection, but a damaged tank must, in most cases, be removed for repair.

Removed Tanks

Tanks must be drained before being removed for inspection, and other associated tanks should be isolated by means of their supply cocks, so that only the tank being removed is drained. Vent pipes must be clear, to prevent the tank from collapsing as the fuel drains out. When necessary the wing structure should be supported, access covers should be removed, pipes and vents should be disconnected and blanked, and electrical services should be isolated and disconnected. The tank should be released from its mountings, then carefully removed, and laid in a suitable cradle. The tank should then be thoroughly flushed and cleaned to remove all traces of fluid, sediment and gummy substances,

and the following inspections should be carried out as appropriate:
a. The external surfaces of the tank should be examined for evidence of leakage and corrosion, and for any other damage which may have resulted from factors such as chafing, vibration, and incorrect adjustment of mounting straps.
b. The condition and security of all pipe adaptors, anchor nuts, and external fittings should be checked.
c. The internal surfaces of the tank should be examined for defects such as corrosion, contamination, and where applicable, the looseness or flaking of the internal protective treatment. All internal fittings, such as pumps, baffles, and de-aerating devices, should be examined for security, damage and corrosion.

FLEXIBLE TANK

Flexible tanks are manufactured from rubber or plastics sheet, which is reinforced with nylon or fabric. They are tailored to fit a particular location in the wing or fuselage, and are supported by means of buttons or cords, to ensure that they maintain their shape and enable accurate contents indications to be obtained. Filler necks, pumps, vents, feed pipes and contents units, are each connected to the tank by means of a moulding at the tank aperture; the moulding being squeezed between an internal and external fitting. A controlled compression joint is often used, to prevent damage to the moulding through over tightening of the attachment bolts.

Installation

Tank bays for flexible tanks are designed with smooth, flat surfaces, to provide maximum support for the tank. Any projections, such as rivet heads or skin joints, are covered with tape or rubber strip, to prevent chafing of the outer surface of the tank. Before a tank is installed, the tank bay should be inspected to ensure that the protective strips are secure, that the tank bay is free from foreign objects, rags, etc., and that there are no projections or loose swarf likely to damage the tank.

A flexible tank should always be inspected before installation, to ensure that no damage has been sustained during transit, or through faulty storage . If damage is found, it must be repaired in accordance with the appropriate Manual, before the tank is installed. It is important also to check any life limitations before installation.

The tank must, generally, be folded in the manner prescribed in the appropriate Maintenance Manual, and inserted into the tank bay through an access hole; in some cases, a manhole large enough to permit entry into the tank is provided, to facilitate both installation and internal repairs. The edges of the access hole should be padded, in order to prevent damage to the tank, and after the tank has been inserted, it should be carefully unfolded and slid into position. The use of french chalk is often recommended to assist in moving the tank into position.

When the tank fittings have been positioned, the tank securing studs or cord should be attached, using and approved lubricant to ease installation, and the tank walls should be smoothed out to eliminate creases. Where entry into the tank is necessary, soft, rubber-soled canvas shoes must be worn, and a protective rubber mat should be laid on the floor of the tank.

All internal fittings should then be attached, and the access hole covers and manhole cover should be replaced.

When the installation of the tank is complete, vent and drain pipes should be carried out as described for rigid tanks. The tank should then be filled while the contents gauge is checked.

Inspection

It is generally only possible to make a superficial examination of a tank after it has been installed in an aircraft since only small parts of the external surface will be visible. With all adjacent skin panels removed all visible parts of the tank and the tank bay should be inspected for damage and damp patches. External connections should be examined for leakage. The inside of the tank should be inspected for damage, corrosion of any metal fittings, contamination, and deterioration of the lining. This inspection should be carried out using a mirror and flameproof lamp inserted through examination is required removal of the tank is usually specified in the approved Maintenance Schedule.

In order to remove the tank for inspections, it should be drained, and all external pipes should be disconnected and blanked. The manholes and hand holes which are attached to the aircraft structure, and any items, such as booster pumps, which may hinder withdrawal of the tank, should be removed. After checking that the tank interior is free from loose articles and debris, the tank fastening should be released, and the tank should be folded in a prescribed manner, and carefully withdrawn through the access hole. Handling straps are sometimes provided to assist in withdrawal, but external fittings must not be used as handles. Some tanks are too inflexible to be folded, and in these cases the access is sufficiently large to permit withdrawal without folding. Any sharp edges or projections should be padded prior to withdrawal of the tank, in order to prevent damage to the exterior surface. When removed, the tank should be laid on a rubber sheet, ready for inspection.

Any fuel which may be on the outside of the tank should be wiped off, and the following external inspections should be carried out:-
a. Examine all metal fittings, for security, corrosion, and evidence of leakage.
b. Examine the tank for cuts, punctures, chafing, lifting of seams, and security of fittings.
c. Examine the tank for stains, and check whether they are the result of fuel leakage.

All inspection covers must be removed, and the tank must be freed from fuel vapour, before an internal inspection is carried out. The safety precautions should be followed and the following inspections should be carried out:-
a. Examine all joints, seams, and reinforcing patches, for lifting , and for signs of bubbles resulting from lack of adhesion of the lining.
b. Examine the lining for creases, and for deterioration resulting form exposure to air.
c. Examine any baffles or supporting pillars which may be fitted, for security and buckling.
d. Examine all internal fittings for security, damage, corrosion and contamination.

Any damage, lack of adhesion, or bubbles, which are likely to result in leakage, should be repaired, and a pressure test should be carried out before the tank is returned to service.

INTEGRAL TANKS

Integral tanks are often formed by sealing the whole of the wing torque box during manufacture. Chordal diaphragms both divide the wing into a number of compartments, or tanks, and also prevent surge; external or internal pipes connect the tanks into the fuel system. A number of methods are used for sealing the structure, including the use of sealant as a flaying compound between mating surfaces, and the use of a filleting compound at the edges. The interior of the tank is then further protected by tank coatings, which may be applied by slushing, brushing or spraying. Any or all of these methods may be used on a particular aircraft, and may be accompanied by special paint schemes, which are designed to minimise microbiological attack. A suitable number of large access panels, hand holes, and tank connections, are included in the structure at strategic positions; the covers are normally made fuel tight by using seals or sealant at the mating surfaces.

In some cases, corrosion inhibitor cartridges are fitted in integral tanks. Typically, these cartridges consist of strontium chromate or calcium chromate tablets contained in a linen bag. It is a requirement with such cartridges that the linen bag should be thoroughly wetted with water before installation, and after tank repair operations.

Inspection

At the periods specified in the approved Maintenance Schedule, the fuel tanks should be inspected for leaks, corrosion or damage to internal components, freedom of operation of non return and anti-surge valves, and microbiological contamination. Particular attention should be paid to areas of stress concentration, and holes which have been formed in the spar webs or structure for the purpose of mounting booster pumps or other heavy components, to ensure that no cracks have developed.

To check for leakage, the tanks should be filled to maximum capacity, and a whitening solution (e.g. dye penetrant developer) should be applied over all joints, rivets, and bolts, which may be likely sources of leaks. After a soaking period (4 to 12 hours), the external surfaces should be inspected for drips, and for any staining of the developer. If leaks are found they should be marked with a soft crayon, and should subsequently be categorized and repaired, as necessary. The developer should be removed with a soft bristle brush, and the tank should be washed off.

Microbiological contamination is more easily visible when it is wet, and, when access is provided in the top skin, the tanks need only be drained sufficiently to permit removal of a suitable hand hole cover. The interior surfaces which are visible through the handhole, should be inspected, using a flame- proof torch, for signs of brown, slimy deposits. This inspection should be carried out, initially, on the tanks which have been found by experience to be the most critical (usually the inboard wing tanks), but, if contamination is found, the remaining tanks must be checked. Any contamination must be removed.

An examination for corrosion of internal metallic parts is best carried out when the tanks are empty, so that entry into the tanks may be effected. The safety precautions must be observed, and particular care must be taken not to damage the tank sealant. In some large aircraft the tanks must be drained in a prescribed order, or the aircraft must be jacked when individual tanks are drained.

PRESSURE TESTS

After repairs have been carried out on rigid and flexible tanks, a pressure test is usually specified to ensure that the leaks have been cured. Pressure testing of integral tanks is not normally required, but flow tests may be specified.

In order to apply pressure to a tank, leak proof blanks must be fitted to all apertures, and one blank must include a fitting suitable for the attachment of a dry air supply. A pressure gauge (normally a water manometer) should be fitted in the pressure line.

Rigid tanks may be pressure tested by filling with a few gallons or kerosene, and applying an mixture of whiting and methylated spirit to all seams, joints and other possible sources of leaks. When the mixture has dried, an air pressure of approximately $10 \, kN/m^2$ ($1.5 \, 1bf/in^2$) is applied to the inside of the tank, which is then rotated to distribute kerosene over the whole surface. Leaks will be indicated by staining of the whiting. After the test, the whiting should be washed off, the kerosene should be drained, and the tank, if not required for kerosene, should be flushed with the appropriate system fluid. As an alternative, the test described below, using dry air pressure and soap solution, may be used.

Flexible tanks may be pressure-tested in a number of ways: by the free test method, by the use of pressure rigs, or by a chemical method.

The free test method is similar to the test used for rigid tanks. The tank is filled with a few gallons of kerosene, and an air pressure of not more than $2kN/m^2$($0.25 \, 1bf/in^2$) is applied in order to shape out the tank. The tank is then rotated in order to distribute the kerosene, and any leaks will be indicated by the presence of kerosene on the exterior surfaces.

The pressure rig method is carried out with the tank contained within a frame, which is designed to support the tank. The frame consists of a welded steel structure inlaid with a wide mesh screen, which permits inspection of all seams and fittings; each frame is designed for use with a particular tank. The tank is carefully located in the frame, and an air pressure of approximately $7 \, kN/m^2$ ($1 \, lbf/in^2$) is applied to the tank. A soap solution is brushed over the tank skin, and if a leak is present, it will be indicated by the appearance of bubbles. After the test, the soap solution should be washed off, the tank should be drained, and, where necessary, the tank should be flushed with system fluid.

In the chemical method, a rag soaked in ammonia is inserted into the tank, which is then sealed and inflated to a pressure of $4kN/m^2$($0.5 \, lbf/cm^2$). A large cloth is then soaked in an indicator solution containing 2.25 litres (0.5 gal) of water, 2.25 litres (0.5 gal) of ethyl alcohol and 40g of phenolhralein crytals, wrung out, and spread over an area of the tank to be checked. Leaks will be indicated by the appearance of red spots on the cloth, and should be marked on the

tank with a silver coloured pencil. The cloth should again be soaked in the indicator solution, and wrung out before checking a different area on the tank.

SAFETY PRECAUTIONS

Whenever it is necessary to enter a tank, in order to make an inspection, or to carry out repairs, certain precautions must be taken because of the flammability and toxicity of fuel and oil vapours. Defuelling and ventilating operations must be carried out in an open area, and no flame or spark producing equipment may be operated in the vicinity of such operations, or when fuel tank covers are open. Adequate and properly manned fire - fighting equipment must be provided, and suitable placards should be prominently displayed. The aircraft, and any ground equipment used, should be electrically earthed to a satisfactory earthing point.

After a tank has been defuelled and drained, it must be ventilated, by removing all access covers and circulating dry, filtered air, through the tank, until all fumes have been removed. The period of ventilation will very according to ambient conditions, but must be continued until the tank walls are completely dry. Interconnecting feed and vent pipes must be blanked or isolated, in order to prevent any liquid or vapour in adjacent tanks, from contaminating the purged tank.

Battery cables should be removed and stowed, to prevent inadvertent sparking of electrical tank units.

Only spark-proof tools and explosion-proof torches may be taken into the tank, and only air-operated vacuum cleaners may be used for removing debris.

All tools required for a particular operation, should be cleaned and placed in a shallow open-topped box, so as to limit the movement of personnel through the access hole, and to minimize the possibility of the tank becoming contaminated with dirt and grit. A check list should be kept of all tools and equipment taken into the tank, and items should be checked off this list as they are removed, before the final inspection of the interior and the replacement of the tank covers.

The edges of holes through which entry is to be made, and the edges of passage ways in internal formers, must be protected from damage, and protective mats must be placed on the bottom of the tank.

Personnel working in a tank must wear an air-fed respirator, and a supply of fresh air should be circulated through the tank. Protective clothing should be worn, and this should include canvas shoes, clean cotton overalls (which should be free from exposed metal buttons, buckles or fasteners), and clean cotton head covering. Goggles and rubber gloves should also be worn when solvents and sealants are to be sealants are to be handled.

Particular care must be taken when working inside water/methanol tanks, since methanol may be absorbed through the skin. For such work the protective clothing should cover the whole body.

A lifeline should be attached to a person who is working inside the tank, and a second person should be stationed outside the tank, to maintain contact with, and to be responsible for, the safety of the first person. Where there is an alternative access hole this should be opened, in case the person inside the tank should require assistance.

CHAPTER: 15
WHEELS AND BRAKES

On light aircraft, where aircraft, weight and landing speed are low, single wheels are fitted at all landing gear positions. Wheel brakes on older types of aircraft are often of the expanding shoe type, similar to conventional automobile practice, and may be operated by cables or by a simple independent hydraulic system. In these systems a single hand brake lever may be used to apply both brakes together, or each brake may be operated individually form a pedal attached to the rudder bar. Modern high performance light aircraft are more usually fitted with hydraulically operated disc brakes.

With larger and modern types of aircraft, where aircraft weight and landing speed are high and aerodynamic drag is low, multiple wheels are generally used at all under carriage positions, to spread the aircraft weight over a greater area and facilitate stowage in the airframe structure. Some older types of medium sized aircraft are fitted with large single wheels and pneumatically actuated drum brakes, but most modern transport aircraft are fitted with twin nose wheels and twin wheels or a four-wheel bogie arrangement at each main undercarriage position. Brakes are of the multiple disc type and are operated from the normal aircraft hydraulic system.

WHEELS
Construction

Wheels are usually made from aluminium or magnesium alloy forgings or castings and are of three main types (Fig below) known as well-base, detachable flange and split hub. Well-base wheels are only fitted on light normally used in conjunction with tubed tyres. Nose wheels which do not house brake units, are usually of simpler construction than main wheels, but in some instances all wheels on an aircraft are interchangeable for ease of provisioning Heat generate by braking action is dissipated by radiation and conduction through the wheel and tyre, and every effort is made to keep heat transference to a minimum. Wheels are designed to permit optimum ventilation, and cylindrical stainless steel heat shields may be installed around the brake unit. On some aircraft, an electric motor mounted within the axle, or a
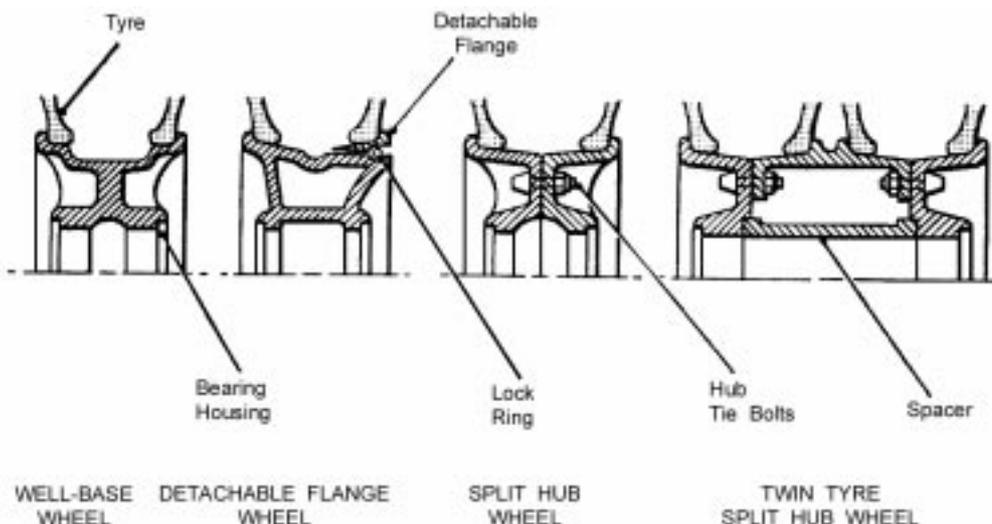

Fig.1. Wheel Types.

series of motors installed in the brake housing drive fans which provide as forced draught through the wheel and relieve the build-up of heat.

To prevent the danger of tyre explosion, the main wheels of many modern aircraft are fitted with fusible plugs which melt at a predetermined temperature (approximately 150°C), allowing a piston to be blown out of the plug bore and thus deflating the tyre.

Some aircraft wheels are also fitted with a pressure relief valve, the purpose of which is to prevent over-inflation of the tyre.

In general wheels are mounted on ball or roller bearings which fit directly on to the axle, or on to a bearing sleeve which is keyed to the axle. In some cases, nose wheels are mounted rigidly on to a "live" axle, which itself rotates within bearings in the nose wheel leg.

REMOVAL

A typical removal procedure is described below:-
i. Prepare aircraft for jacking in accordance with the appropriate aircraft Maintenance Manual.
ii. Raise axle or bogie, as appropriate, until the tyre is clear of the ground.

iii. Deflate tyre or reduce pressure to a low value.
iv. Where applicable, remove cooling fan or hubcap assembly.
v. Remove axle nut locking device.
vi. Remove axle nut install thread protector.
vii. Remove grease seals and bearings.
ix. Install axle protector.
x. Fit protective cover over the brake assembly if the wheel is not to be refitted immediately.

INSTALLATION

Before installing a wheel and tyre, the general condition of the wheel, tyre and bearings should be checked. The axle should also be checked for corrosion, scores and other damage, particularly in the bearing support area and, if an axle sleeve is fitted, this should be checked for allowable wear at the bearing area and correct fit on the axle. Bearings on new or replacement wheels may be packed with storage grease, and this should be cleaned out and replaced by greases specified for service use.

A typical installation procedure is described below:-

i. Grease inner bearing and seal with the specified grease, and install on axle.
ii. Slide wheel into position on axle, using the appropriate aligning fixture as necessary to line up the brake disc driving keys in the wheel hub with the slots in the rotating discs.
iii. Grease and install the outer bearing and seal.
iv. Remove thread protector and lubricate axle threads.
v. Install axle nut and tighten to the recommended initial torque, rotating the wheel as the nut is tightened.
vi. Slacken axle nut then, again rotating the wheel, tighten to the specified final torque and fit the locking device.
vii. Replace cooling fan or hub cap assembly.
viii. Check tyre pressure and tyre growth clearance, retracting landing gear where necessary to facilitate this check, then lower the aircraft and remove the ground locks installed to prevent operation of the steering mechanism or landing gear doors.

DRUM BRAKES

Although used extensively on earlier aircraft, drum brakes have largely been superseded by hydraulically operated disc brakes, on most modern high performance aircraft. Pneumatically operated drum brakes, may still be found in service however, and the construction, operation and maintenance of a typical brake unit of this type is described below.
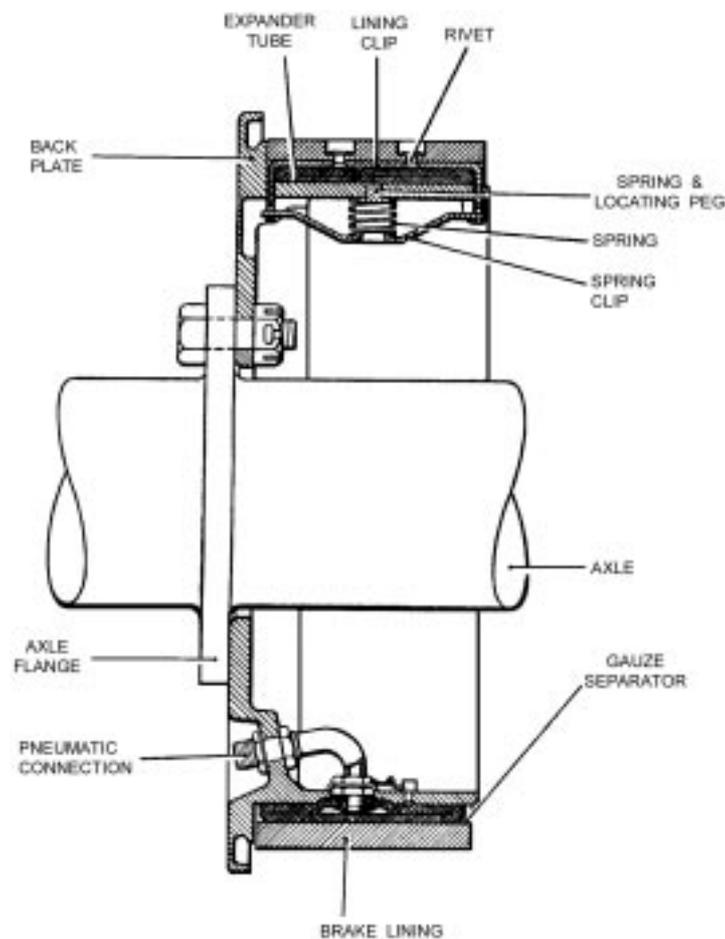

Fig. 2. Drum Brake.

Construction

The main components of the brake unit are the back plate, brake drum, expander tube (pressure bag) and brake linings.

Back Plate: This unit is cylindrical in shape and is attached to a flange at the axle. It houses the expander tube, brake linings and pneumatic connections.

Expander Tube: This is a circular, reinforced rubber tube of flat cross-section, and is fitted around the back plate. It has a pneumatic connection leading through the back plate to the aircraft pneumatic system.

Brake Linings: The complete brake lining assembly is made up of a number of segments of heat-resisting friction material which form a ring around the expander tube and are shaped to conform to the inside radius of the brake drum. Each segment is bonded or riveted to a metal fitting, which protrudes through the back plate and is secured by a spring clip.

Separators: Phosphor-bronze gauze separators are fitted between the ends of the brake lining segments to reduce heat generation to the expander tube and to exclude carbon particles.

Brake Drum: The brake drum is heavy steel cylinder, attached to and rotating with the wheel, and against which the brake lining segments expand to produce the braking action.

Operation: When the pilot's control is operated, air pressure is applied to the inside of the expander tube, which expands and forces the brake linings against the brake drum. When air pressure is released the expander tube collapses and the brake linings are withdrawn from the brake drum by the action of the return springs.

DISC BRAKES

Most modern aircraft are fitted with hydraulically-operated disc brakes (also known as plate brakes). Light aircraft generally have a single-disc type and larger aircraft a multidisc type.

Single Disc Brake Units

A simple single-disc brake unit is shown in Fig. 3 and is of a type found on many light aircraft. A single operating cylinder is shown but two or three are often used for increased braking performance, and larger aircraft may have brakes
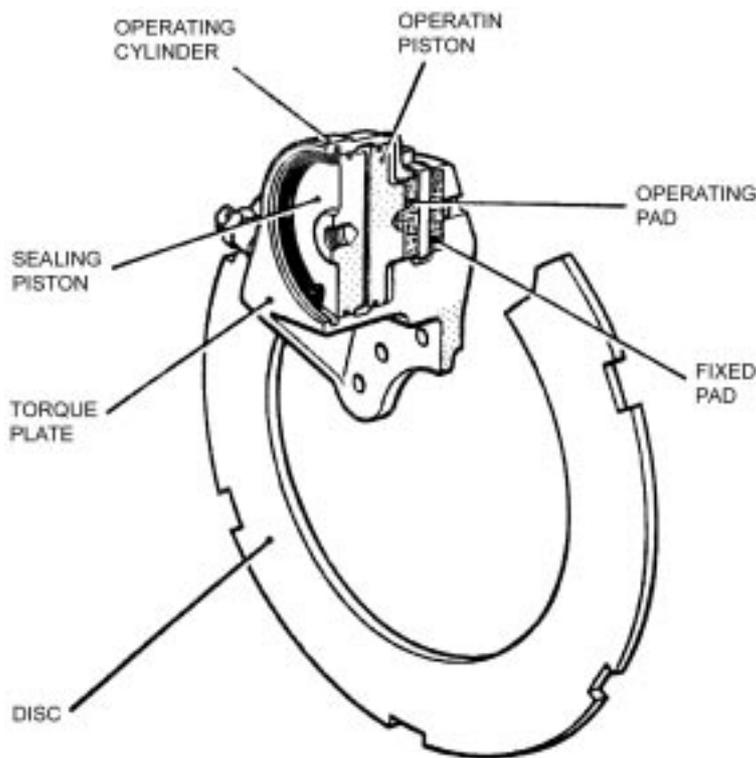

Fig. 3. Single Disc Brake.

using five or six cylinders. The brake unit consists basically of a light alloy torque plate shaped for attachment to the landing gear leg or axle flange, housing a calliper type hydraulic jack unit and a pair of friction pads. A steel disc is slotted into the wheel and rotates between the friction pads. When the brakes are operated, fluid pressure is applied to the cylinder and forces the operating piston towards the disc, thus squeezing the disc between the operating and fixed friction pads and thus resisting wheel rotation. When the brakes are released the disc is free to rotate between the friction pads.

Multi Disc Brake Units

Multi-disc brakes are designed to provide increased friction surfaces for braking purposes. The general arrangement is basically similar to the single-disc brake, but the single disc is replaced by a stack of alternate stationary and rotating

discs, and a number of operating cylinders are equally spaced around the torque rotating discs, and a number of operating cylinders are equally spaced around the torque plate. The friction elements are normally in the form of pads attached to either side of the stationary discs, but on some types the rotating discs have sintered surfaces or pads. This type of brake is operated from the aircraft's main hydraulic system, through valves connected to the pilot's rudder pedals.

Construction

A typical multi-disc brake unit is shown in Fig. 4. In this unit a torque plate and torque tube assembly fits over the axle and is bolted to a flange on the axle; alternative designs are often similarly mounted but prevented form rotating
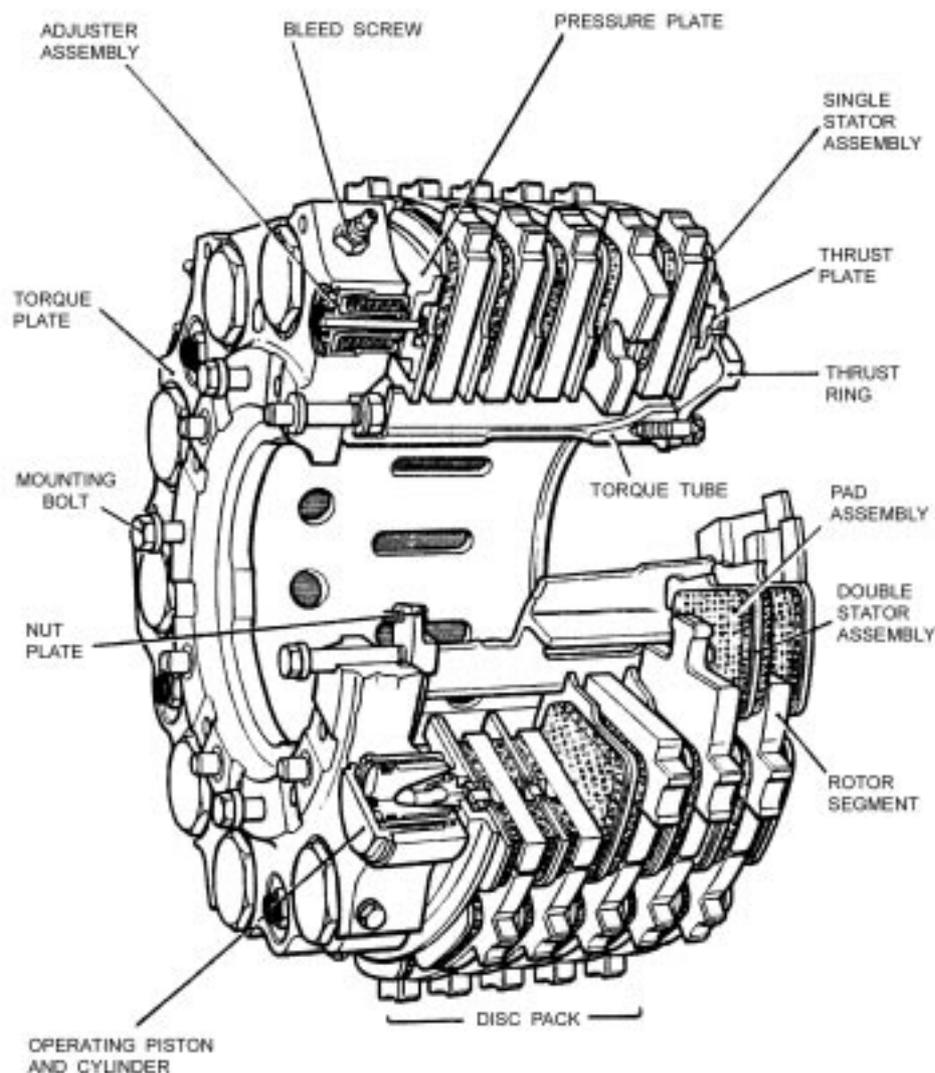
Fig.4. Multi Disc Brake.

by means of a torque arm attached to a suitable fixture on the landing gear leg or bogie. A number or cylinders are spaced around the torque plate, connected to the hydraulic brake system and house a piston which apply load to the pressure plate. The disc pack (also known as the heat pack) contains alternate stationary and rotating discs, the stationary discs being keyed to the torque tube and the rotating discs house the brake pads and the rotating discs are segmented to prevent heat distortion and brake drag. Correct working clearance in the disc pack is maintained by means of adjuster assemblies. Pins attached to the pressure plate and protruding through the torque plate on this brake unit, indicate the amount of wear which has taken place in the disc pack.

A further type of multi-disc brake is known as a trimetallic brake. Construction is similar to the brake described above, except that the rotating discs have as metallic compound sintered to their faces, and steel segments, known as wear pads, are riveted to the faces of the stationary discs. Alternatively, the faces of both sets of discs may be sintered, or the stationary discs may be plain.

Operation

When the brakes are selected "on", hydraulic pressure is admitted to the cylinders and moves the operating pistons against the pressure plate. The disc is clamped between the pressure plate and thrust plate, and the friction loads generated between the stationary and rotating members provide the required braking action. When the brakes are released, springs in the adjuster assemblies move the pressure plate back to maintain a working clearance in the disc pack and permit free rotation of the wheel.
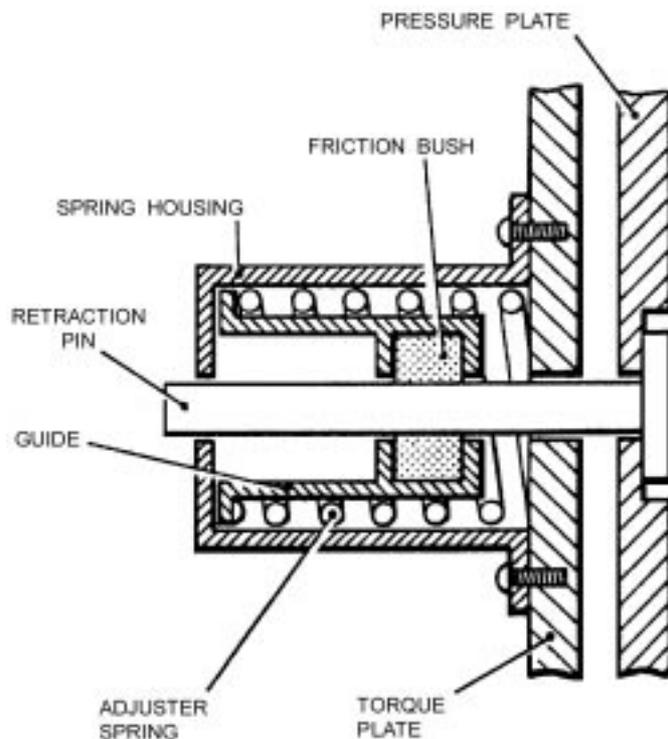
Adjuster Assemblies

The diagrammatic arrangement of a typical adjuster assembly is shown in Fig. 5. At least two adjuster assemblies are fitted to the majority of disc brakes, their purpose being to maintain a suitable running clearance in the brake pack. In a single-disc brake the retraction pins are often attached directly to the operating pistons but on multi-disc brakes they are usually attached to the pressure plate. In operation, movement of the piston or pressure plate is transmitted via the retraction pin and friction bush to compress the adjuster spring and move the guide until it abuts the torque plate. When the brakes are released the adjuster spring pulls the guide back until it contacts the spring housing, the clearance between the guide and torque plate being the designed running clearance. As wear takes place in the discs the pressure plate has to move further forward, thus pulling the retraction pin through the friction bush by amount equal to disc wear, but maintaining the design clearance when brakes are released. On some brake units wear may be assessed by measuring the protrusion of the retraction pin.

Fig.5. Adjuster Assembly.

SKID CONTROL

The braking systems of most modern aircraft are provided with a means of preventing the wheels from skidding on wet or icy surfaces and of ensuring that optimum braking effect can be obtained under all conditions, by modulating the hydraulic pressure to the brakes. Anti-skid units sense the rate of change of wheel deceleration, decreasing the hydraulic pressure applied to the brakes when a high rate of increase in deceleration (i.e. consistent with an impending skid) occurs, and restoring it as the wheel accelerates again. A modulator is often fitted in conjunction with the anti-skid unit, to restrict the flow of fluid to the brakes after initial brake application and to conserve main system pressure. There are basically two types of anti-skid systems in use, the mechanically controlled and the electronically controlled.

Mechanical System or Maxaret System Of Anti Skid

The anti-skid unit is mounted either on the brake unit torque plate or within the axle bore, and is connected into the brake hydraulic circuit at the brake unit. The anti-skid unit consists of a valve assembly connected to a flywheel, which is driven by the associated wheel.

Operation

During normal braking action (i.e. when no skid is present) the flywheel rotates at the same speed as the drive and the valve is closed, allowing maximum hydraulic pressure to be applied to the brake operating pistons. When the rotational speed of the wheel decreases rapidly, as when a skid begins to develop, the inertia of the flywheel alters its angular relationship with the drive shaft and, through the action of a cam and push rod arrangement, the valve opens to relieve the pressure applied to the brake, thus reducing braking action and allowing the wheel to increase its rotational speed. As the wheel accelerates, the angular relationship between flywheel and drive returns to normal, and the valve closes, increasing pressure to the brake. If the wheel bounces clear of the ground after brakes are applied, the adjustment of the anti-skid unit allows the brake to be completely released for a sufficient period of time to ensure that the brake is off when the wheel contacts the ground again.

Electronic System

The system comprises a wheel speed transducer, a control unit and an anti-skid valve in the brake pressure line, together with associated switches, and check-out and warning lamps. The wheel speed unit may supply either d.c. or a.c. depending on the type of system used. Operation is basically similar to the mechanical system but the use of sophisticated logic circuits in the later types of electronic control units enables much finer control to be exercised. Further refinements such as strut oscillation damping circuits, touch-down protection and locked wheel protection,
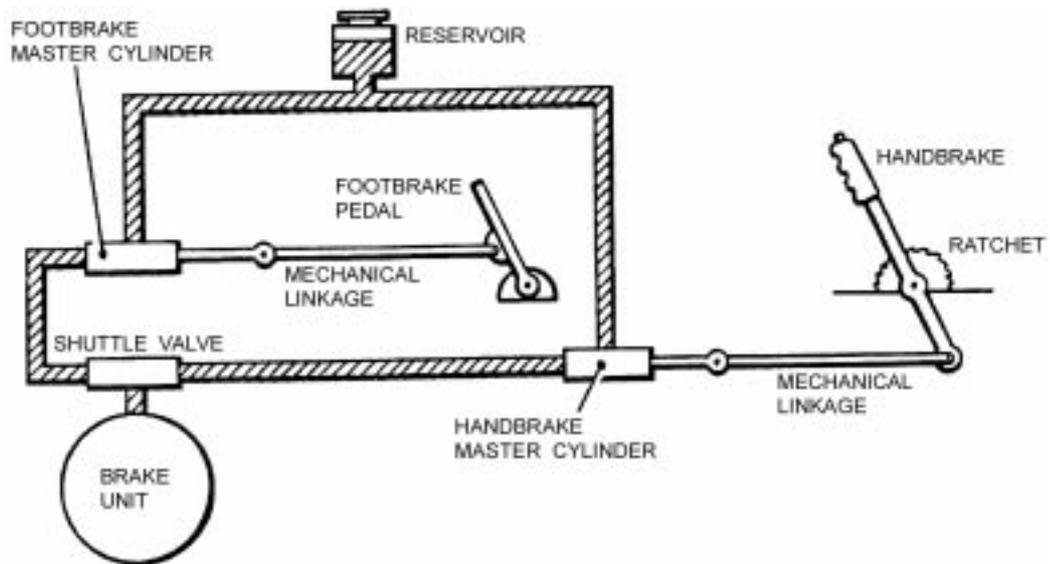
Fig. 6. Simple Low Pressure Brake System.

PT = PRESSURE TRANSMITTER
PRV = PRESSURE REDUCING VALVE
NRV = NON-RETURN VALVE

AIRCRAFT SYSTEM

HANDBRAKE SYSTEM
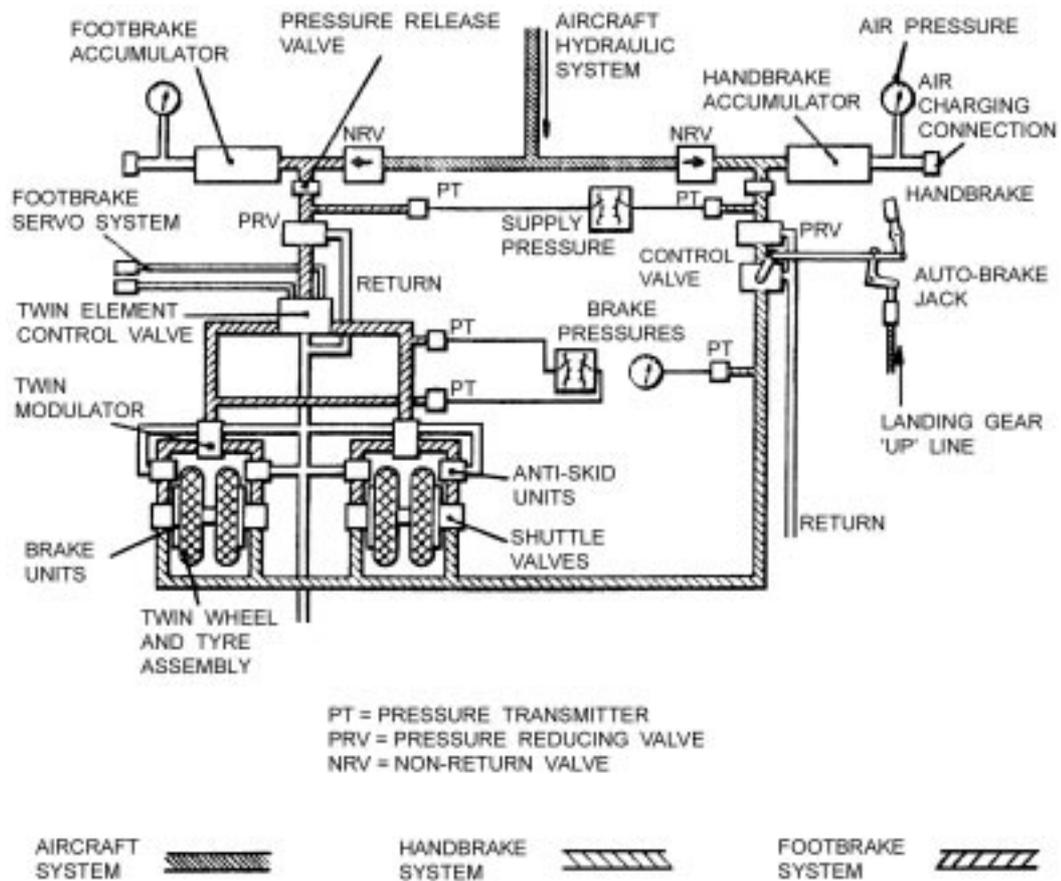
FOOTBRAKE SYSTEM

Fig.7. Simple High Pressure Brake System.

may also be incorporated and some systems automatically de-activate at low speed to prevent interference with normal taxying manoeuvres.

The method by which the wheel speed signal is processed in the control unit varies form type to type, but all operate on the basis that if any brake produces more torque than can be supported by the friction between the tyre and ground for the existing wheel load, the resulting impending skid will produce a smaller rotational velocity signal from the affected wheel. This reduced signal is detected by the anti-skid control circuits, which send a signal to the anti-skid control valve, causing brake pressure to be reduced sufficiently to correct the skid condition. Brake pressure will be re-applied to a level just below that which caused the skid, and will then increase at a controlled rate.

Control units normally circuits which provide warning of failure in the system, and a self-test facility which enables the serviceability of the various components to be checked. Controls for the operation and testing of the anti-skid system are contained in the control unit and in the flight compartment.

Some systems operate by providing a continuous bleed from the brake pressure line, and in these cases the parking brake operates a cut-off valve in the brake return line.

LOW PRESSURE BRAKE SYSTEMS

Most light aircraft are fitted with an independent hydraulic system for each brake, similar to that shown in fig. 6. On some aircraft a handbrake system is connected to each brake through a shuttle valve, while on others a parking brake control applies a mechanical lock to the foot brake linkage when brakes are applied. The main components in each system are a fluid reservoir and master cylinder, connected mechanically to the brake pedals and hydraulically to the brake operating cylinder.

Operation

As the brake pedal is pressed, a piston in the master cylinder forces fluid through the pipelines to the brake operating cylinder, the braking force depending on the force exerted on the brake pedal. When the pedal is released, a return spring in the master cylinder returns the piston to its original position, and pressure is relieved. Handbrake operation is similar except that the shuttle valve moves to allow pressure to the brake unit and close off the port from the foot brake master cylinder; brakes are held on by a ratchet device in the handbrake mounting. With the alternative parking brake system, the brake should be set by applying pressure with the foot brake, then the parking brake operated to lock the foot brake linkage; subsequent foot brake application will release the locking catch.

HIGH PRESSURE BRAKE SYSTEMS

High pressure braking systems use the normal aircraft hydraulic system to provide fluid, under pressure, to the brake units. A brake system accumulator stores energy in the brake system for use in the event of normal system pressure not being available, and an emergency pneumatic system is frequently included to safe guard brake operation in the event of complete hydraulic failure. A simplified system is shown in fig 7.

Operation of the brakes can be controlled from either pilot's position by brake pedals attached to the rudder bar. Application of operation of the associated left or right brakes.

The brake pedals are linked through a system of levers and cables, or a hydraulic servo system, to a control valve (normally located adjacent to the main wheel bays to minimise the length of pipe run) which controls hydraulic pressure according to the position of the brake pedals. This pressure is often reduced through a pressure reducing valve, and modulated by an anti-skid valve, before being applied to the brake cylinders.

Adjustment

The accurate setting-up of the mechanical linkage between the rudder pedals and control valve is very important since it controls the brake pressure in relation to pedal movement and must be identical in both left and right braking systems. Details of the setting-up procedures for a particular aircraft system will be found in the approved maintenance manual, but in a normal system, levers and bell cranks are locked in position by the insertion of rigging pins and the connecting rods and cables adjusted to fit these fixed locations. Alternatively, graduated quadrants may be fitted to show the angular positions of particular levers so that the connecting components may be correctly adjusted. Cables should be tightened to the tension quoted in the Maintenance manual.

CHAPTER: 16
CONTROL SYSTEMS

Three types of control systems commonly used are: (1) The cable, (2) Push-pull, and (3) the torque tube system. The cable system is the most widely used because deflections of the structure to which it is attached do not affect its operation. Many aircraft incorporate control systems that are combination of all three types.

FLIGHT CONTROL SYSTEM HARDWARE, MECHANICAL LINKAGE, AND MECHANISMS

The systems which operate the control surfaces, tabs, and flaps include flight control system hardware, linkage, and mechanisms. These items connect the control surfaces to the cockpit controls. Included in these systems are cable assemblies, cable guides, linkage, adjustable stops, control surface snubber or locking devices, surface control booster units, actuators operated by electric motors, and actuators operated by hydraulic motors.

CABLE ASSEMBLY

The convention cable assembly consists of flexible cable, terminals (end fittings) for attaching to other , and turn buckles.

At each regular inspection period, cables should be inspected for broken wires by passing a cloth along their length and observing points where the cloth snags. To thoroughly inspect the cable, move the surface control to its extreme travel limits. This will reveal the cable in pulley, fair lead, and drum areas. If the surface of the cable is corroded, relieve cable tension. Then carefully force the cable open by reverse twisting, and visually inspect the interior for corrosion. Corrosion on the interior strands of the cable indicates failure of the cable and requires replacement of the cable. If there is no internal corrosion, remove external corrosion with a coarse weave rag or fibber brush. Never use metallic wools or solvents to clean flexible cable. Metallic wools embed dissimilar metal particles, which cause further corrosion. Solvents remove the internal cable lubricant, which also results in further corrosion. After thoroughly cleaning the flexible cable, apply corrosion-preventive compound. This compound preserves and lubricates the cable.

Breakage of wires occur most of frequently where cables pass over pulleys and through fairleads. Typical breakage points are shown in Figure. Control cables and wires should be replaced if worn, distorted, corroded, or otherwise damaged.

Fig. 1. Typical brekage point.

Lockclad cable is used on some large aircraft for all long, straight runs.. It consists of the conventional flexible steel cable with aluminium tubing swaged to it to lock the cable inside the tubing. Lockclad cable construction has certain advantages. Changes in tension due to temperature are less than with conventional cable. Furthermore, the amount of stretch at a given load is less than with conventional cable.

Lockclad cables should be replaced when the covering is worn through, exposing worn wire strands; is broken; or shows worns spots which cause the cable to bump when passing over fairlead rollers.

TURNBUCKLES

The turnbuckle is a device used in cable control systems to adjust cable tension. The turnbuckle barrel is threaded with left-hand threads inside one end and right-hand threads inside the other. When adjusting cable tension, the cable terminals are screwed into either end of the barrel and equal distance by turn turning the barrel. After a turnbuckle is adjusted, it must be safe tied.

Fig.2. Cable connector.

CABLE CONNECTORS

In addition to turnbuckles, cable connectors are used in some systems. These connectors enable a cable length to be quickly connected or disconnected from a system. Fig.2, illustrates one type of cable connector in use. This type is connected or disconnected by compressing the spring.

HYDRAULICALLY OPERATED CONTROL SYSTEMS

As the airspeed of late model aircraft increased, actuation of controls in flight became more difficult. It soon became apparent that the pilot needed assistance to overcome the airflow resistance to control movement. Spring tabs which were operated by the conventional control system were moved so that the airflow over them actually moved the primary control system were moved so that the airflow over them actually moved the primary control surface. This was sufficient for the aircraft operating in the lowest of the high speed ranges (250-300 mph).

For high speeds a power assist (hydraulic) control system was designed. Conventional cable or push pull rod systems are installed and are tied into a power transmission quadrant. With the system activated, the pilot effort is used
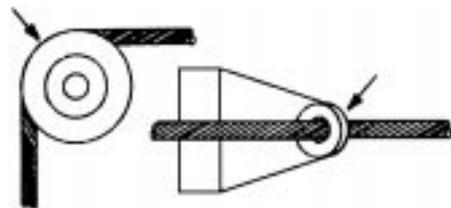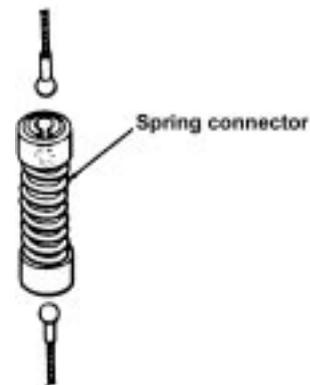
to open valves thereby directing hydraulic fluid to actuators, which are connected to the control surfaces by control rods. The actuators move the control surface to the desired flight condition. Reversing the input effort moves the control surface in the opposite direction.

MANUAL CONTROL

The control system from the cockpit is connected by a rod across the power transmission quadrant to the control actuating system. During manual operation, the pilot's effort is transmitted from the control wheel through this direct linkage to the control surface. Those aircraft which do not have the manual reversion system may have as many as three sources of hydraulic power primary block-up and auxiliary. Any or all of the primary controls may be operated by these systems.

Gust lock

A cam on the control quadrant shaft engages a spring-loaded roller for the purpose of centring and neutralizing the controls with hydraulic system off (aircraft parked). Pressure is trapped in the actuators and since the controls are neutralized by the cam and roller, no movement of the control surfaces is permitted.

Cable guides

Cable guides consist primarily of fairleads, pressure seals, and pulleys.

A fairlead (Fig.3) may be made from the nonmetallic material, such as phenolic or a metallic material such a soft aluminium. The fairlead completely encircles the cable where it passes through holes in bulkheads or other metal parts. Fairleads are used to guide cables in a straight line through or between structural member of the aircraft. Fairleads should never deflect the alignment of a cable more than 3mm from a straight line.

Pressure seals are installed where cables (or rods) move through pressure bulkheads. The seal grips tightly enough to prevent excess air pressure loss not enough to hinder movement of the cable. Pressure seals should be inspected

Fig. 3.Cable guides.

A Control or push-pull rod

B Torque tube

C Bellcrank

D Sector

E Cable drum
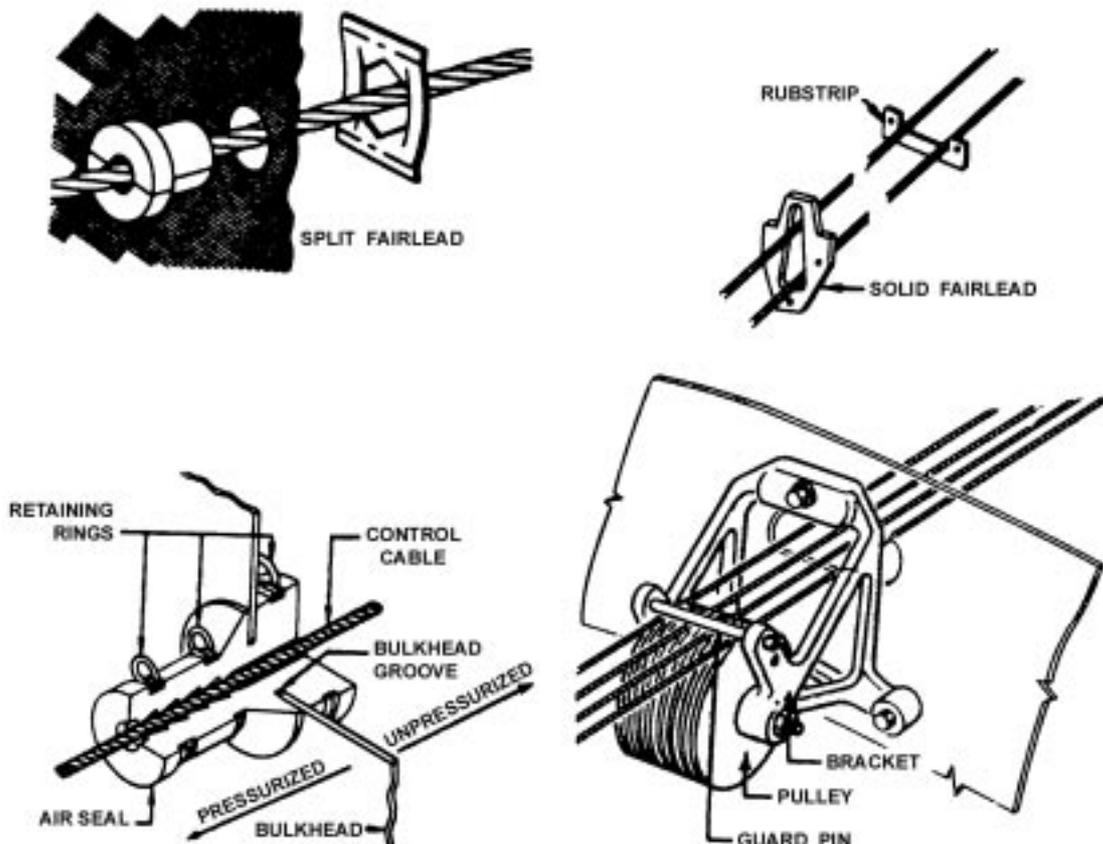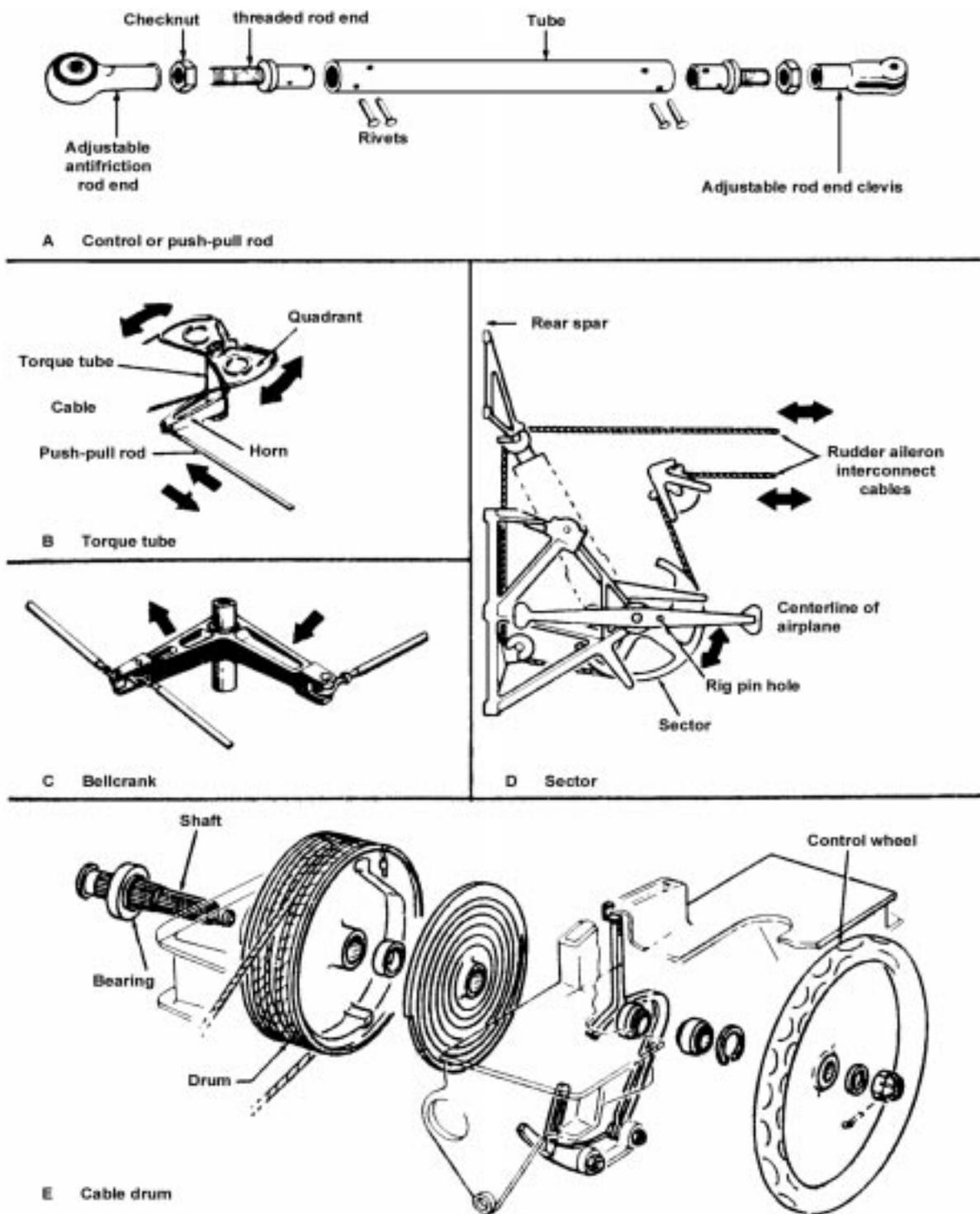
Fig. 4. Flight control system mechanical linkages.

at regular intervals to determine that the retaining rings are in place. If a retaining ring comes off, it may slide along the cable and cause jamming of a pulley.

Pulleys are used to guide cables and also to change the direction of cable movement. Pulley bearings are sealed, and need no lubrication other than the lubrication done at the factory. Brackets fastened to the structure of the aircraft support the pulleys. Cables passing over pulleys are kept in place by guards. The guards are close-fitting to prevent jamming or to prevent the cables from slipping off when they slacken due to temperature variations.

Mechanical linkages

Various mechanical linkages connect the cockpit controls to control cables and surface controls. These devices either transmit motion or change the direction of motion of the control system. The linkage consists primarily of control (push pull) rods, torque tubes, quadrants, sectors, bell cranks and cable drums.

Control rods are used as links in flight control system to give a push-pull motion. They may be adjusted at one or both ends. View A of Figure 4 shows the parts of a control rod. Notice that it consists of a tube having threaded rod end, or rod ends. An adjustable anti friction rod end, or rod end clevis, permits attachment of the tube to flight control system parts. The checknut, when tightened, prevents the rod end or clevis from loosening.

Control rods should be perfectly straight, unless designed to be otherwise, when they are installed. The bell crank to which they are attached should be checked for freedom of movement before and after attaching the control rods. The assembly as a whole should be checked for correct alignment. When the rod is fitted with self-aligning bearings free rotational movement of the rods must be obtained in all positions.

It is possible for control rods fitted with bearings to become disconnected because of failure of the peening that retains the ball races in the rod end. This can be avoided by installing the control rods so that the flange of the rod end is interpreted between the ball race and the anchored end of the attaching pin or bolt as shown in Fig. 5.

Another alternative is to place a washer, having larger diameter than the hole in the flange, under the retaining nut on the end of the attaching pin or bolt.

Torque tubes

Where an angular or twisting motion is needed in control system, a torque is installed.(Fig.4c) and 4d illustrate a bell crank and a sector. View B of Figure shows how a torque is used to transmit motion in opposite directions.

Quadrants, bell cranks, sectors, and drums change direction of motion and transmit motion to parts such as control rods, cables and torque tubes. The quardrant shown in (Fig.4b) is typical of flight control system linkages used by various manufacturers. (Fig 4c) and 4d illustrate a bellcrank and a sector. View E illustrates a cable drum. Cable drums are used primarily in trim tab system. As the trim tab control wheel is moved clockwise or counter clockwise, the cable drum winds or unwinds to actuate the trim tab cables.

Fig.5. Rod end flange interposed between the bearing race and the end of the attaching bolt.

Stops

Adjustable and non-adjustable stops (whichever the case requires are used to limit the throw-range or travel movement of the ailerons, elevator, and rudder. Usually there are two sets of stops for each of the three main control surfaces, one set being located at the control surface, wither in the snubber cylinders or as structural stops (Fig.6), and the other at the cockpit control. Either of these may serve as the actual limit stop. However, those situated at the control surface usually perform this function. The other stops do not normally contact each other, but are adjusted to a definite clearance when the control surface is at the full extent of its travel. These work as override stops to prevent stretching of cables and damage to the control system during violent maneuvers. When rigging control system, refer to the applicable maintenance manual for the sequence of steps for adjusting these stops to limit the control surface travel.


Fig.6. Adjustable rudder stops.

Control surface snubbers and locking devices

Various types of device are in use to lock the control surfaces when the aircraft is parked or moved. Locking devices prevent damage to the control surfaces and their linkage from gusts and high-velocity winds. Common devices that are in use are the internal locking brake (sector brake) spring loaded plunger, and external control surface locks.

Internal locking devices

The internal locking device is used to secure the ailerons rudder, and elevator in their neutral positions. The locking device is usually operated through a cable system by a spring loaded plunger (pin) that engages a hole in the control surface mechanical linkage to lock the surface. A spring connected to the pin forces it back to the unlock position when the cockpit control lever is placed in the "unlock" position. An over-centre toggle linkage is used on some other type aircraft to lock the control surface.

Control surface locking systems are usually so designed that the throttles cannot be advanced until the control surface are unlocked. This prevents taking off with the control surface in the locked position.

A typical control lock for small aircraft consists of a metal tube that is installed to lock the control wheel and rudder pedals to an attachment in the cockpit. Such a system is illustrated in Fig. 7.

Control surface snubbers

Hydraulic booster units are used on some aircraft to move the control surfaces. The surfaces are usually protected from wind gusts by snubbers incorporate in to the booster unit. On some aircraft an auxiliary snubber cylinder is connected directly to the surface to provide protect in. The snubbers hydraulically check or cushion control surface movement when the aircraft is parked. This prevents wind gusts from slamming the control surfaces into their stops and possibly causing damage.

External control surface locks.

External control locks are in the form of channelled wood blocks. The channelled wood block slide into the openings between the ends of the movable surfaces and the aircraft structure. This locks the surfaces neutral. When not in use, these locks are stowed within the aircraft.
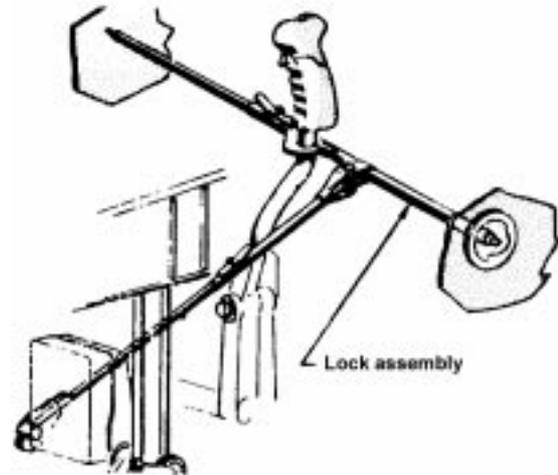

Fig.7. Typical control lock assembly for small aircraft.

POWERED FLYING CONTROLS

Because of the high loads imposed on the flying control surfaces, modern transport aircraft are provided with power-operated or power-assisted controls. Because of the importance of the flying control system, hydraulic power to each control surface is provided by a least two independent hydraulic systems (sometimes using separate actuators) plus an emergency system operated by electrical power or by ram air turbines. In addition, some systems allow for reversion to manual operation of the control surfaces, or tabs, in the event of all hydraulic systems failing.

A hydraulic sub-system for the operation of the flying controls, is often fed through a priority valve, which ensures that fluid under pressure is always available; the subsystem may also have a separate accumulator.

The unit which moves a control surface is a combined selector valve and actuator, usually known as a servo-control unit, the selector being connected by cables and rods to the pilot's controls. A typical servo-control unit is illustrated in Fig. 8. With hydraulic power available, operation of a pilot's control moves the spool in the selector, thus directing fluid to one side of the actuator and opening a return path from the other side. Movement of the actuator operates the control surface, and at the same time moves the selector back towards the neutral position. When control surface movement corresponds to the deflection of the pilot's control, the selector is in the neutral position, and fluid is locked in the actuator. When no hydraulic pressure is available, the connecting valve opens under spring pressure and the actuator is free to move. The control may then be operated by alternative servo-control units, or by manual linkage, depending on the particular installation.
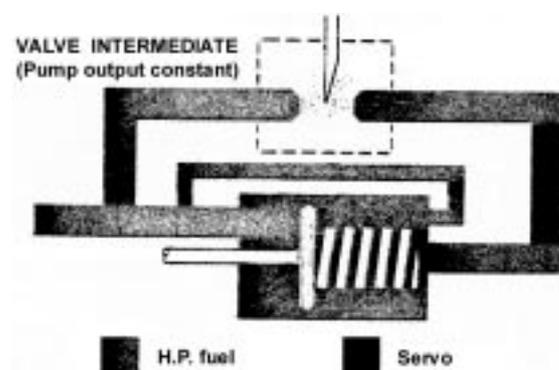

Fig. 8. Servo Control Unit.

An alternative method of operating the flying controls is by means of self-contained powered flying control units (PFCU'S). Control surfaces are divided into sections, and each section is operated by a separated PFCU, thus providing duplication to guard against failure of a unit. Each unit is controlled by mechanical linkage from the pilot's controls and auto stabilizer. The mechanical input rod to each unit is telescopic and spring loaded, so that failure of one PFCU will not prevent operation of the associated control system. In the event failure, or when a unit is inoperative, the actuating ram is mechanically locked in the neutral position, thus preventing movement of the associated section of the control surface. Actual operation is basically similar to that of the self-contained hydraulic system, and is not connected with the main hydraulic system, or with other PFCU's. The main body of each PFCU acts as a reservoir, and houses all the components necessary for operation of the unit, including electrically driven pumps and hydraulic actuator.

CHAPTER: 17
AUXILIARY SYSTEMS

RAIN-REMOVAL SYSTEMS

Rain-removal systems are designed to allow the pilot to have a clear view of the airport when taxing and to allow him or her to see the approach and departure paths and runway environment when taking off and landing during rain. The systems are not commonly used during flight at altitude.

Rain may be removed by the use of wind shield wipers, chemical repellents in combination with wind shield wipers, or by a flow of air.

Wind shield-Wiper Systems

Wind shield-wiper systems may be operated electrically, hydraulically, or pneumatically.

A typical electrically operated wind shield-wiper system is illustrated in Fig.1. This drawing shows the components of the wipers installed on an airliner. Each wiper on the airplane is operated by a separate system to ensure that clear vision through one of the windows will be maintained in the event of a system failure. The wiper blades clear a path 15 in [38.1 cm] wide through an arc of 40º.

Both wiper systems are electrically operated and controlled by a common gang switch located on the pilot's overhead panel. The switch provides a selection of four wiper-action speeds ranging from 190 to 275 strokes per minute and controls the stowing of the wiper blades in a PARK position when the system is not in use.

Each wind shield -wiper system consists of a drive motor, a control switch, a resistor box, a flexible drive shaft, a torque converter, and a wind shield-wiper assembly.
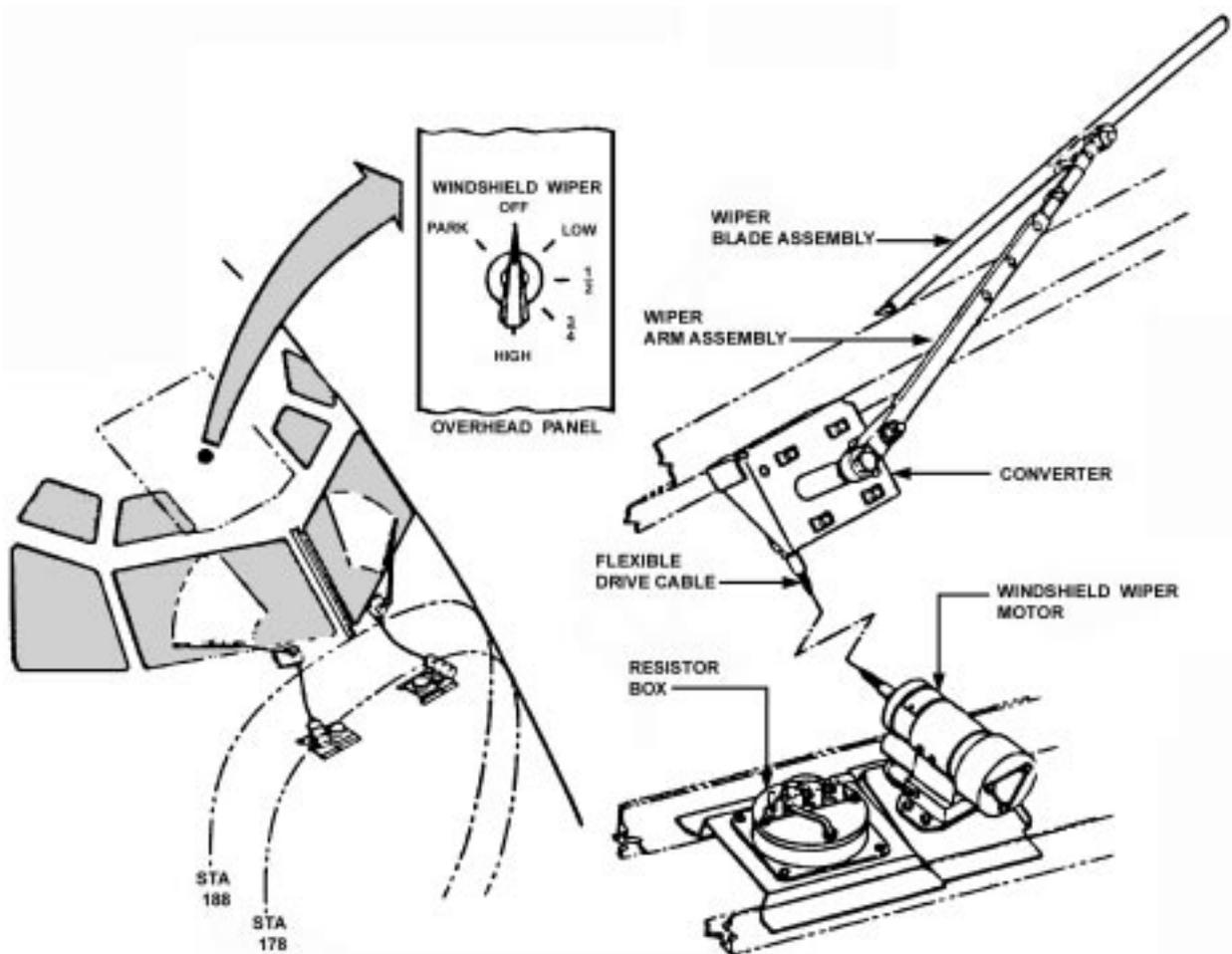
Fig.1. Windshield wiper system.

     Speed control for the wind shield wipers is accomplished by changing the voltage applied to the wind shield-wiper motor by means of resistance arranged in the resistor box. The required resistance is connected into the motor circuit by turning the wind shield-wiper switch to a selected speed. The rotary motion of the wind shield-wiper motor is transmitted by the flexible shaft to the converter. The converter reduces the shaft speed and changes the rotary motion to an oscillating motion of the wind shield-wiper arm. An electrical circuit for wind shield wipers is shown in Fig.2.

     Hydraulically and pneumatically operated wiper systems are similar in that each requires a pressure supply to be directed to an actuator. A typical system arrangement is shown in Fig. 3. A control unit alternately connects a pressure or return line to opposite sides of the actuator, causing the piston to move back and forth. The actuator piston incorporates a rack that operates a pinion gear at the base of the wiper and causes the side-to side motion of the wiper. A speed-control valve allows the pilot to select the speed at which the wipers will operate.

Rain-repellent systems

     To help maintain the clarity of vision through the wind shield during rain conditions, a rain-repellent system is provided for the wind shields of many modern aircraft. This system consists of pressurized fluid containers, a selector valve, solenoid-actuated valves, spray nozzles, push-button switches, a control switch, a time-delay relay, and necessary plumbing. A rain-repellent system and wind shield wipers for an airliner are shown in Fig.4. During rain conditions, the wind shield wipers are turned on, and the repellent is sprayed on the wind shield. The repellent is sprayed evenly by the wiper blades. The rain repellent should not be sprayed on the wind shield unless the wind shield is wet and the wipers are operated, nor should the wind shield wipers be operated on a dry wind shield.
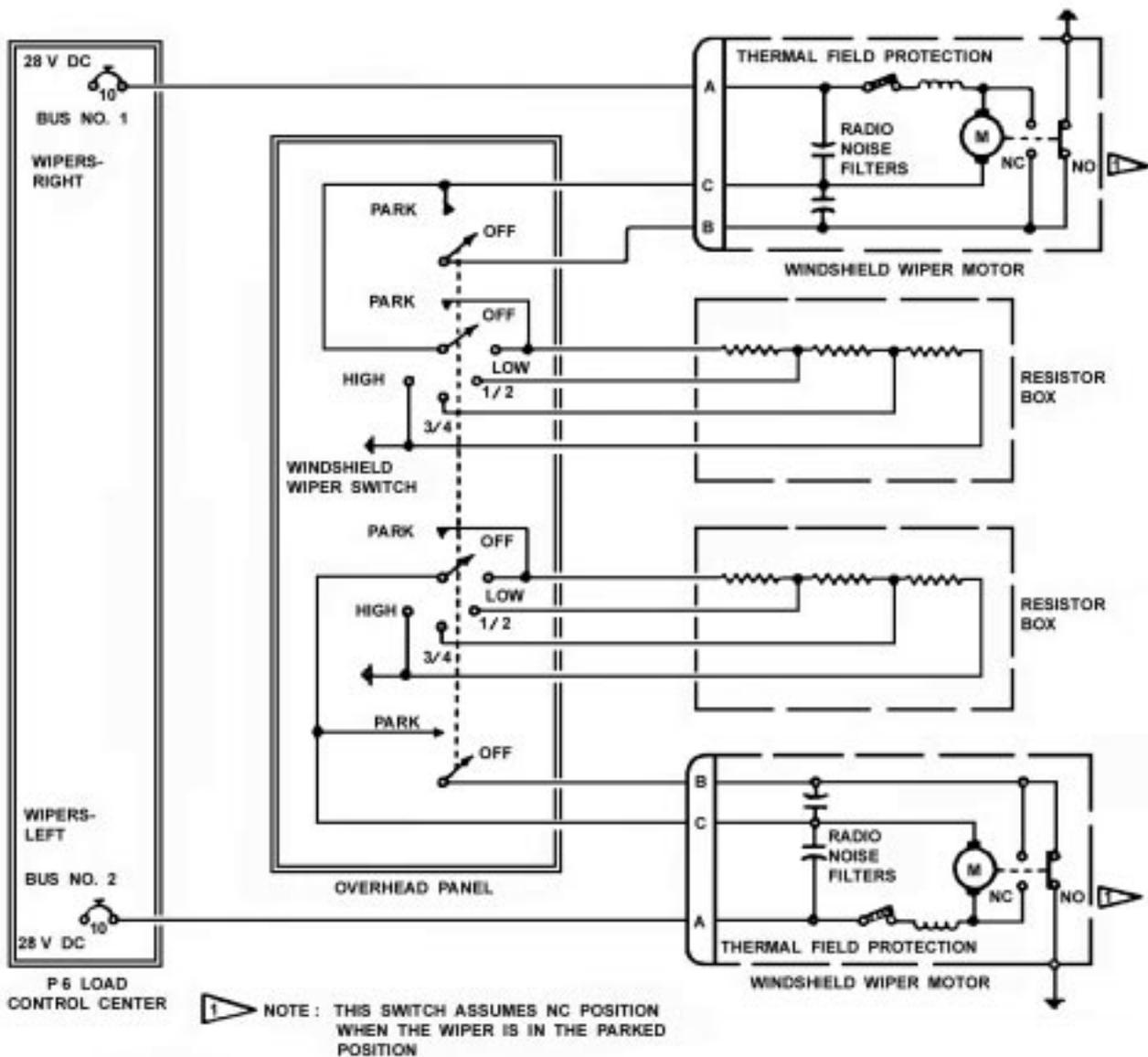

*Fig.2. Electric system for windshield wipers.*
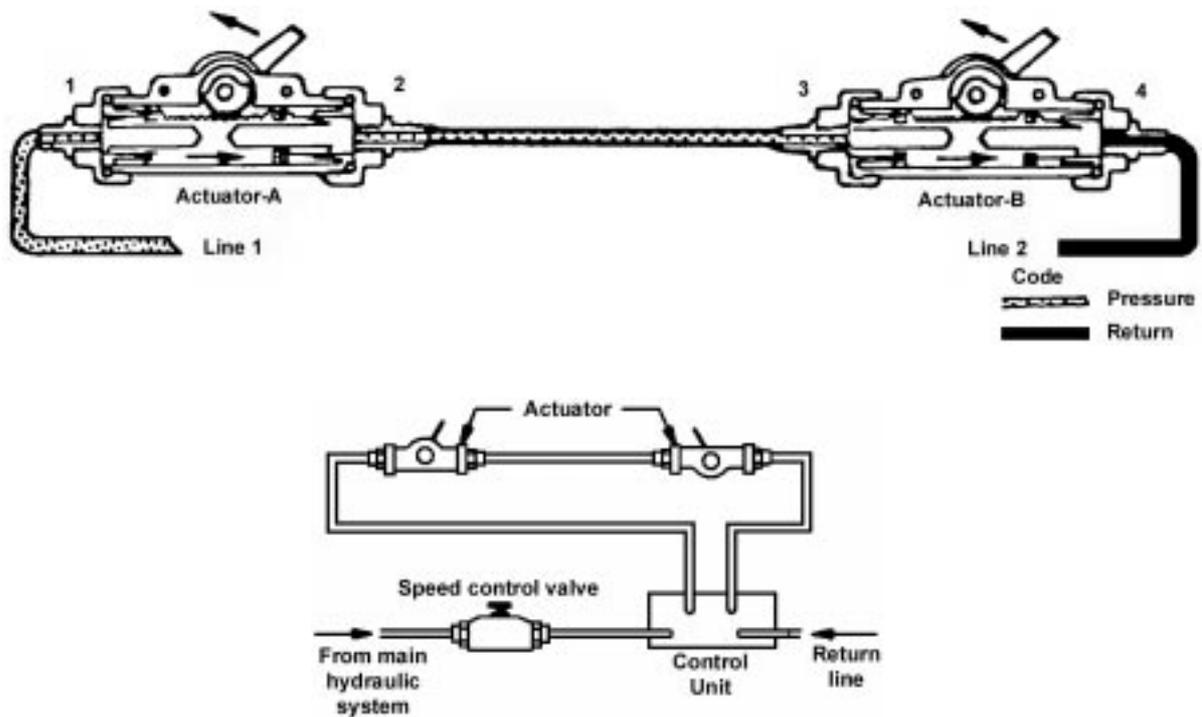
Fig.3. A hydraulic windshield wiper system.

The effect of the rain repellent is to cause the water to form small globules, which are quickly blown away by the rush of air over the wind shield in flight.

Pneumatic Rain-Removal system

Some turbine-powered aircraft use engine bleed air to prevent rain from striking the wind shield. When the pilot turns on the rain-removal system, bleed air at a high temperature and pressure is directed to an outlet at the base of the wind-shield, as shown in Fig.5. This flow of air over the windshield carries away the rain drops before they can strike the windshield. Any raindrops on the windshield when the system is turned on are also blown away.

WATER AND WASTE SYSTEMS

All modern airliners are required to incorporate water systems to supply the needs and comforts of the passengers and crew. Such systems include potable (drinkable) water for the galley and drinking fountain, water for the lavatories, and water for the toilet systems. Systems may include on or more tanks of water with connections to the various units that require a water supply. The passenger water system for one model of the Boeing 727 airplane is illustrated in Fig.6.

Potable water Supply

The water for drinking fountain or facets is usually drawn from main pressurized water tanks, passed through filters to remove any impurities and solids, cooled by dry ice or other means of cooling, and delivered to the facets and/or drinking fountain. Disposable drinking cups are supplied at each location in the forward and rear parts of the passenger cabin.
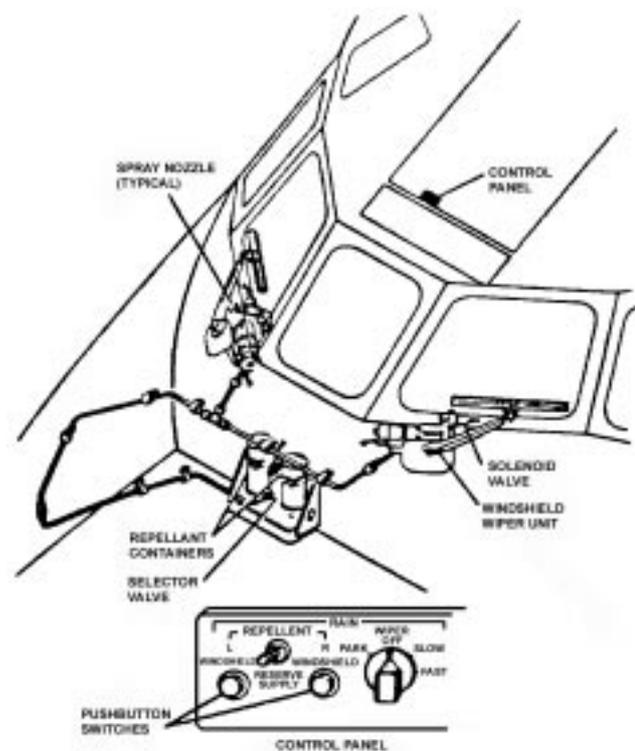
Fig.4. Rain repellent system.

Lavatory Water

Water for the lavatories is also drawn from the main water tanks and passed directly through suitable plumbing and valves to the lavatories. Hot water for washing is provided by means of electric water heaters located beneath the lavatory bowls. A typical hot-water supply is contained in a tank, which includes the thermostatically controlled heating unit to maintain the water at a temperature of 110 to 120°F [43.3 to 48.9°C]. Drain water from the lavatories can be drained overboard through drain masts or can be drained into the toilet waste tanks.

Toilet System

The toilet system is designed so there is no possible contamination of the passenger water supply from the system. In the airplane discussed here, separate, independent toilet systems are provided in the forward and aft passenger cabins. Toilets in each lavatory compartment are electrically powered flushing units that collect the waste material in a waste tank and combine it with the flushing agent by chemical and mechanical treatment. The units are primed initially with 3 gal [11.37 L] of a concentrated solution of disinfectant, deodorant, and dye. The toilet units are installed in each lavatory compartment entirely above the lavatory compartment floor. Each unit consists of a toilet shroud assembly, flushing components, and a waste tank. The components of a toilet system are shown in Fig. 7.

Fig.5. Pneumatic rain repellent system.

Toilet flushing action is initiated by turning the toilet flush handle. This begins a cycle in which flushing liquid is drawn into a rotating filter and pumped through the toilet bowl flush ring into the bowl with a swirling action. Waste material and flushing liquid flow out the bottom of the bowl into the waste tank. Servicing components in the forward and aft systems allow ground draining and cleansing of the toilet units.

The toilet shroud assembly consists of a standard commercial seat and cover attached to a shroud that covers the flushing components mounted on the tank top. The shroud is attached to the upper and lower ends of the shroud support angles.

The flushing components include a flush handle. timer, motor-and-pump assembly, filter assembly, and the required tubing. All the components, with the exception of the flush handle and timer, are mounted on the tank top. The flush handle and timer are located on the cabinet aft of the toilet unit. The stainless steel toilet bowl with a flexible restrictor in the bottom is also mounted in the tank top.

The toilet waste-tank assembly includes a glass-fibber tank of 17-gal [64.4-L] capacity fitted with a bulb-type spring-loaded drain valve and a tank top. The drain valve is operated by a cable from the toilet service panel. A rubber gasket is placed along the top edge of the tank to form a watertight seal when the tank top is installed. Access into the tank for maintenance purposes is obtained by removing the toilet bowl and base plate.

The drain valve, when fully open, permits unrestricted passage of waste from the tank to a service cart. In the closed position, it forms a positive seal. The valve is spring-loaded and self-closing and does not require lubrication. It is opened by pulling a handle on its related exterior service panel. When the handle on its related exterior service panel. When the handle is in the extended position, it can be rotated to latch it. A safety valve, which is operated by a control on the service attachment, is installed in the drain tube.

POSITION AND WARNING SYSTEMS

Each aircraft system may incorporate a warning system to indicate when that particular system is not functioning properly. The purpose of this section is to discuss systems that do nothing but indicate the position of components and warn of unsafe conditions. These systems include control surface indicator systems, takeoff warning systems, and stall warning systems.

Control-Surface indicating Systems

The purpose of control-surface indicating systems is to allow the flight crew to determine if a control surface is in the correct position for some phase of flight and to determine if a flight control is moving properly.

The most common type of control-surface indicating systems is that used for the elevator trim tab, and this will serve as an example for other mechanical indicating systems. The type of mechanism is found in most fixed-wing aircraft and is used by the pilot to indicate if the trim tab is properly positioned for some phase of flight, such as takeoff or landing before that phase of flight is initiated. If the trim tab is out of position, the pilot may have to use large forces on the flight controls to achieve the desired action. If the trim tab is properly positioned, then it will provide most of the force
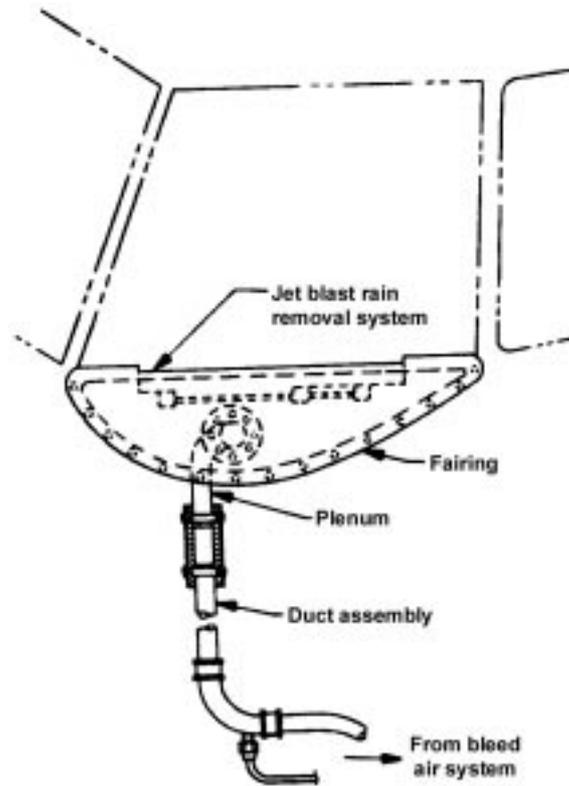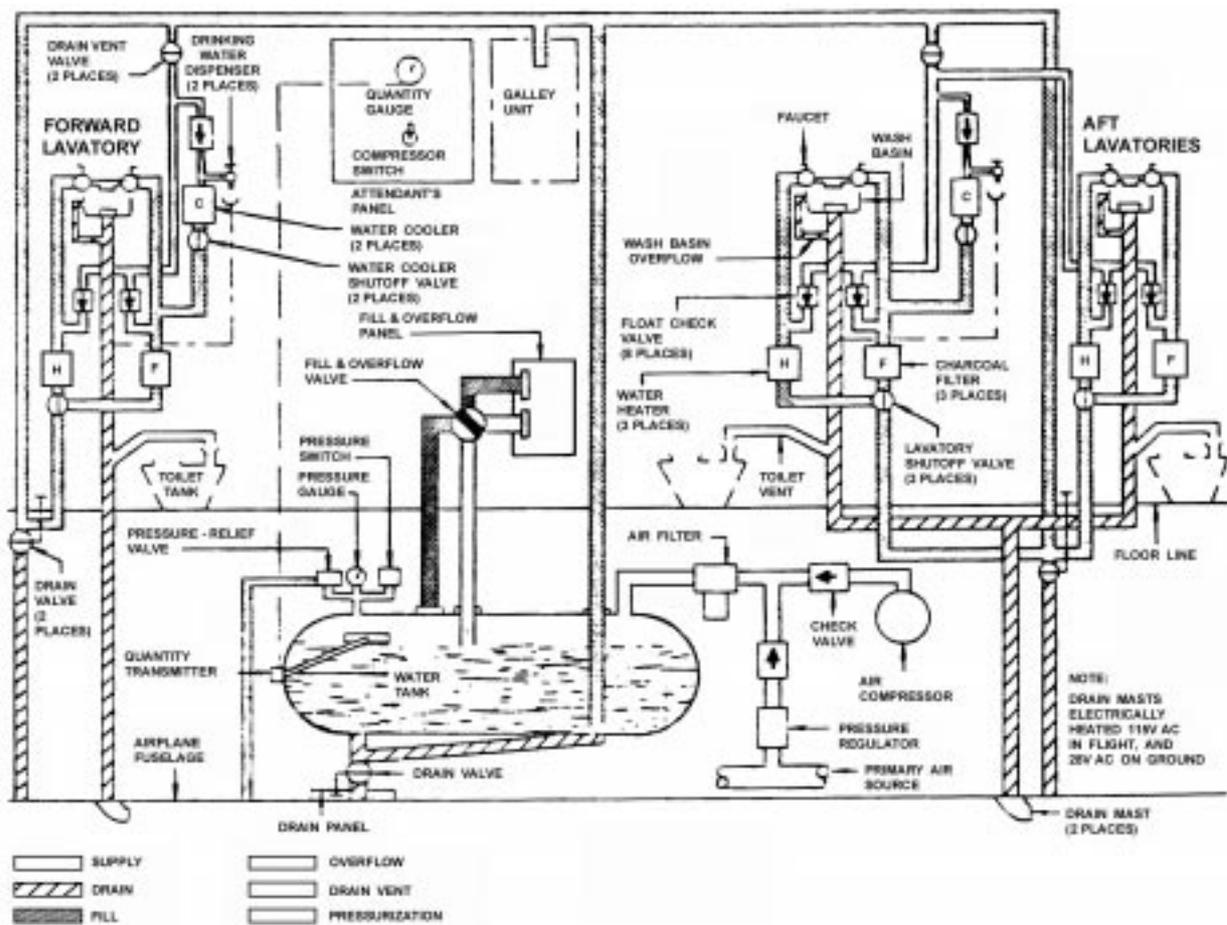
Fig. 6. Passenger water system for an airliner.

necessary to hold a specific attitude and the pilot will need to make only small adjustments about the trimmed setting of the control surface.

These types of systems often use a mechanical indicator to show the control position. In some systems, a cable is attached to the control horn of the trim tab, and as the tab moves the cable pulls against a spring at the pilot's position. As the spring is stretched or released by the movement of the trim tab, a pointer located where the cable connects to the springs moves along a scale, indicating the trim-tab position. In other systems a spiral groove in the trim-tab control wheel causes a pointer to move, indicating the position of the trim tab.

Either of these systems or similar system designs can be used to monitor the position of any flight-control surface. When inspecting these mechanical indicating systems, the technician should verify that the indicator agrees with the position of the surface being monitored.

Large aircraft may make use of electric control-surface indicating systems, such as the one shown in Fig. 8. In this system, synchro transmitters are located at each of the control surfaces. The voltage inducted into the armatures by their exciter winding is used at the synchro receivers to position the indicator pointers.

Takeoff Warning Indicator Systems

A takeoff warning indicator system is used to advise the pilot that one or more items are not properly positioned for takeoff. When a takeoff warning system actuates, an intermittent horn is sounded until the incorrect situation is corrected or until the takeoff is aborted.

A simplified takeoff warning system schematic for a large jet transport is shown in Fig. 9. Note that if any one of the several items is not in the correct position for takeoff and the throttle for no-3 engine is advanced beyond a certain position when the aircraft weight is on the landing gear, the horn will sound. The items that are checked by this system are that the elevator trim is in the takeoff range, the speed brake (spoilers) handle is in the 0° position, the steerable fuselage landing gear is centred, the wing flaps are extended. The exact aircraft configuration monitored by a takeoff warning system will vary, but the intent of each system is to prevent a takeoff with the aircraft in an usage configuration.

Stall Warning Indicators

A stall warning indicator is designed to indicate to the pilot when the aircraft is close to the stalling angle of attack. When the stall warning system is activated, the pilot will be given one or more of the following indications: a horn will sound, a light will illuminate, and/or a "stick-shaker" will start vibrating the control wheel column. The specific warning method varies with the aircraft design.
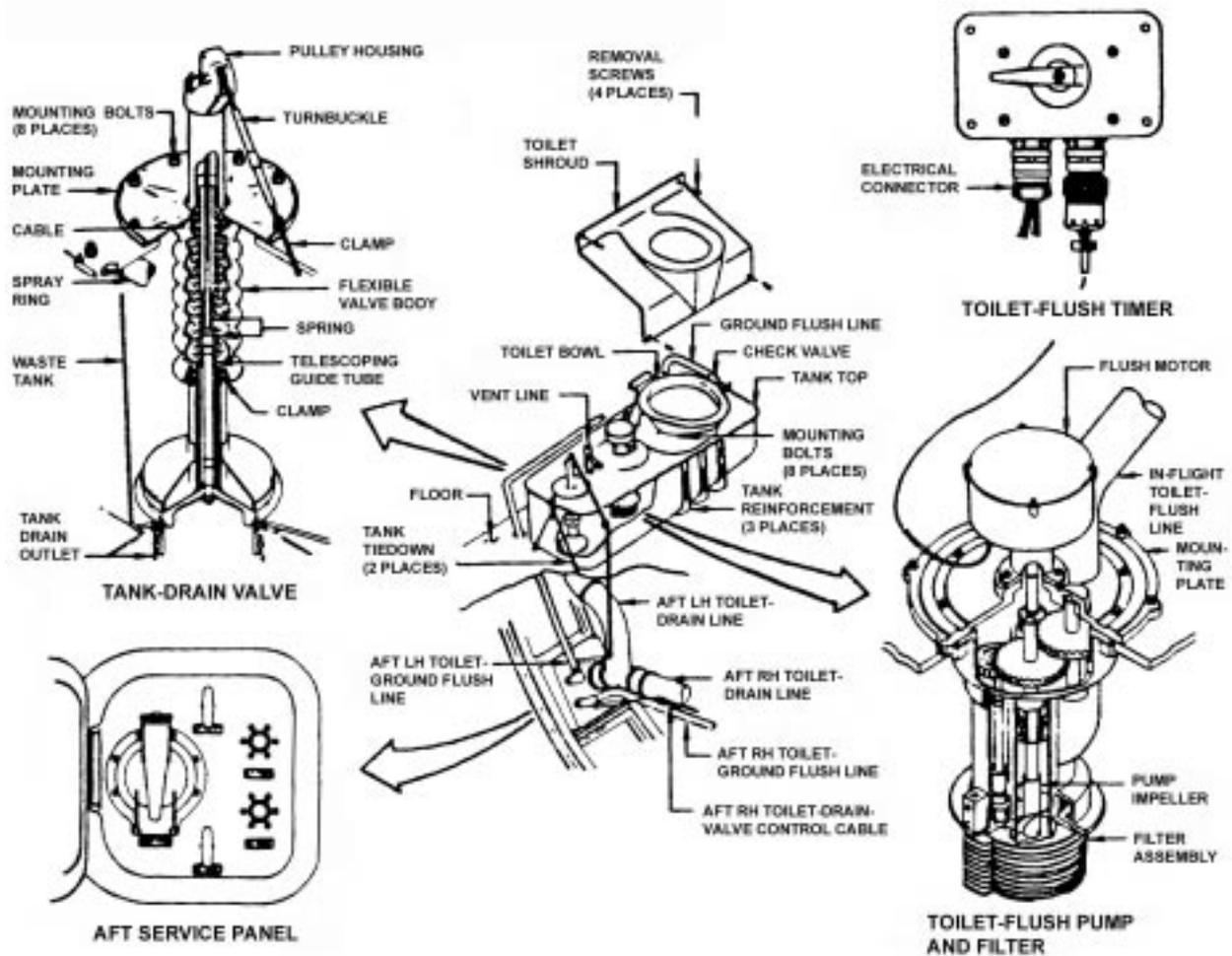
Fig.7. Toilet system components for an airliner.

Although some light aircraft do not have stall warning indicator systems, most have a system using a sensor vane on the leading edge of the wing similar to that shown in Fig. 10. When the angle of attack of the wing causes the airflow to be from below the vane on the sensor, the vane moves up and completes a circuit to activate the stall warning indicator.

A pneumatic stall warning indication system is used by some light aircraft. A slot in the leading edge of the wing is connected to tubing routed to the cabin area. A horn reed is positioned in the end of the tubing. When the wing angle of attack increases to the point where negative pressure exists on the slot, air flows through the reed and out the slot and creates an audible stall warning indication.

Modern transport aircraft use stall warning computer circuits to activate the stall warning system. Inputs to the computer include information about angle of attack, flap and slat position, and weight on landing gear. When the computer determines that a stall is imminent , a stick-shaker may start moving the control columns back and forth, an aural warning may be sounded, or an indicator may illuminate, depending on the specific system design.

AUXILIARY POWER UNITS

When a modern aircraft's engines are not operating, there are two available sources of power to operate its other systems. They are the aircraft's battery and the auxiliary power unit. Because of the limited capacity of the batteries, the amount of power they supply is insufficient to provide all but the very basic needs. Operation of an aircraft's air-conditioning system, for example, would require significantly more power than could be supplied by the batteries.

To accommodate the needs of the aircraft on the ground for substantial amounts of energy while its engines are not operating, modern aircraft are equipped with auxiliary power units (APUs). The APUs are gas-turbine engines, using the aircraft's own fuel supply, which provide the power to run the attached generators. In addition, the APU is typically large enough to provide sufficient pneumatic power to start the aircraft's engines. The presence of an APU eliminates the need for ground power units (GPUs).

The Boeing 747 auxiliary power unit is manufactured by the research Division of Garret Corporation. This unit, shown in Fig.11, is capable of producing approximately 660 lb./min. airflow to the pneumatic systems and 90 kVA from the two attached generators to the aircraft's electrical system. The APU has a separate battery for starting and is protected by its own fire-protection system.

During operations, as with other gas-turbine engines, the exhaust is extremely high. In the case of the Research APU previously identified, the exhaust-gas temperature (EGT) ranges from 1652°F [900°C] during starting to 1265°F [685°C]

LEFT FLIGHT SPOILER

RIGHT FLIGHT SPOILER

LEFT AILERON

RIGHT AILERON

FLT. SPLR.

AILERON

ELEVATOR

RUDDER

26 V AC ESS BUS

CB C349

SURF POS L.M.

SURFACE POSITION INDICATOR

26 V AC BUS 1

CB A10 SURF POS R.M.

LEFT ELEVATOR

RIGHT ELEVATOR

RUDDER

T: SYNCHRO (POSITION) TRANSMITTER

R: SYNCHRO (POSITION) RECEIVER
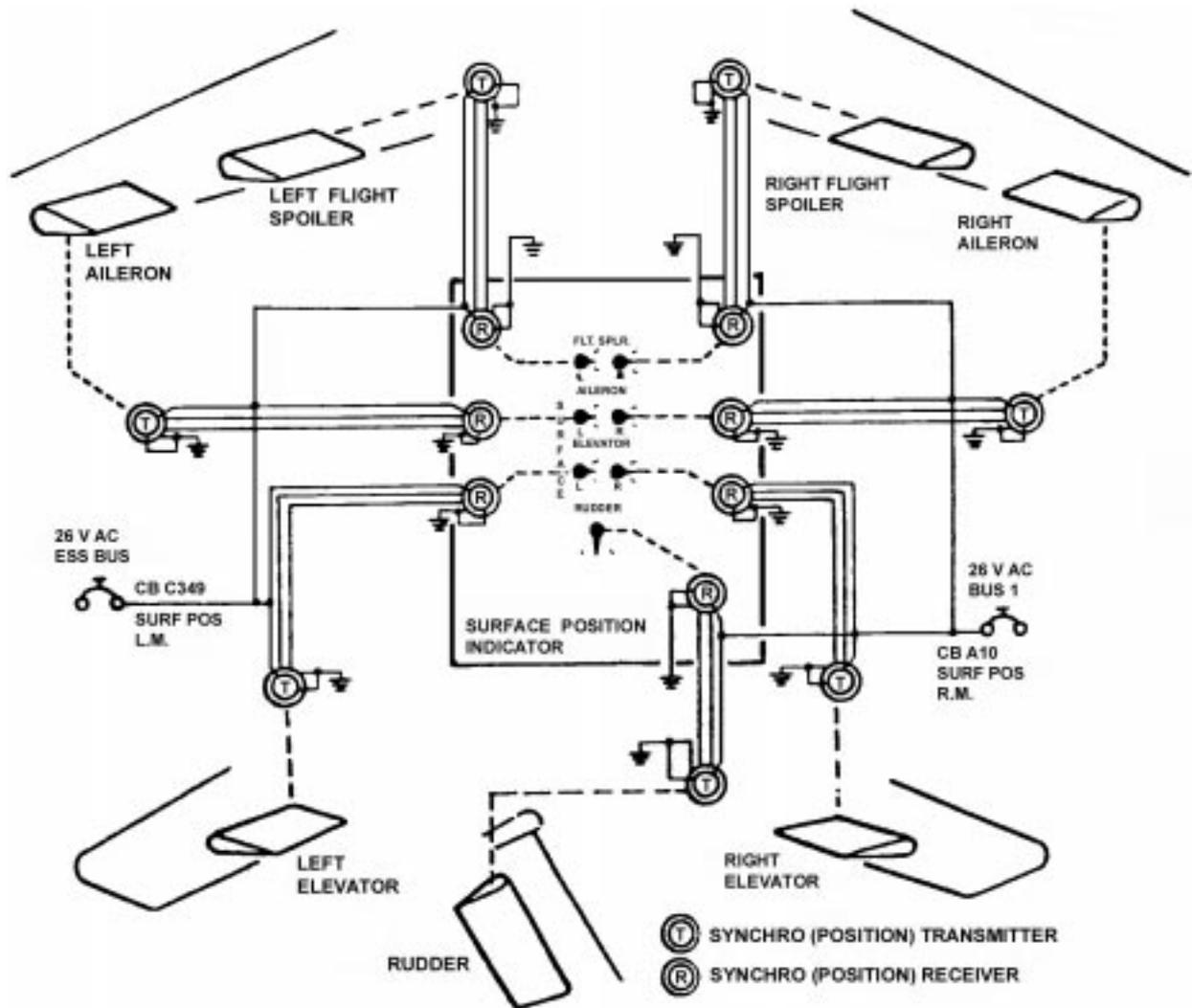
Fig. 8. Flight control position indicating system for a jet aircraft.
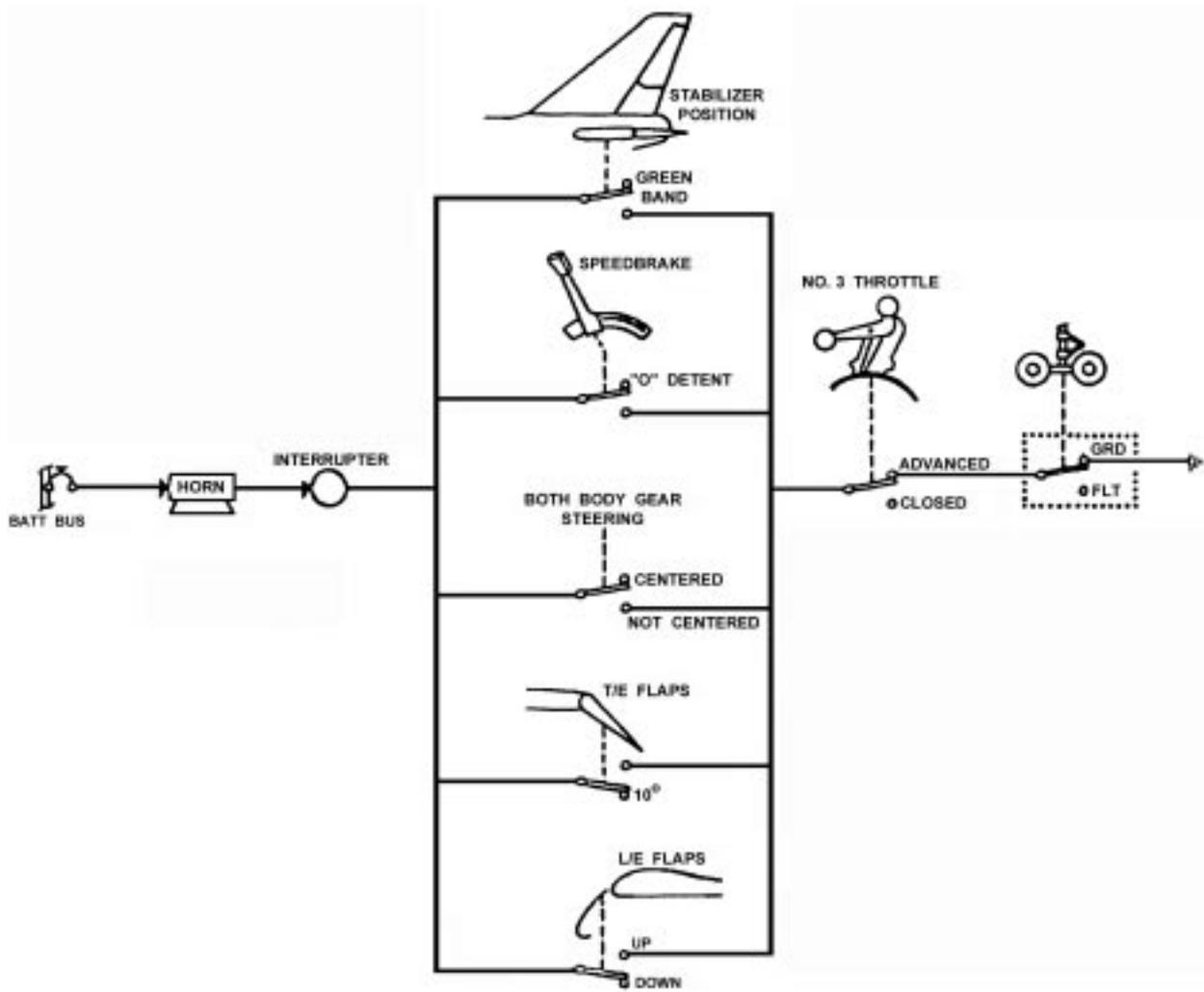
Fig. 9. Takeoff warning system schematic for an airliner.
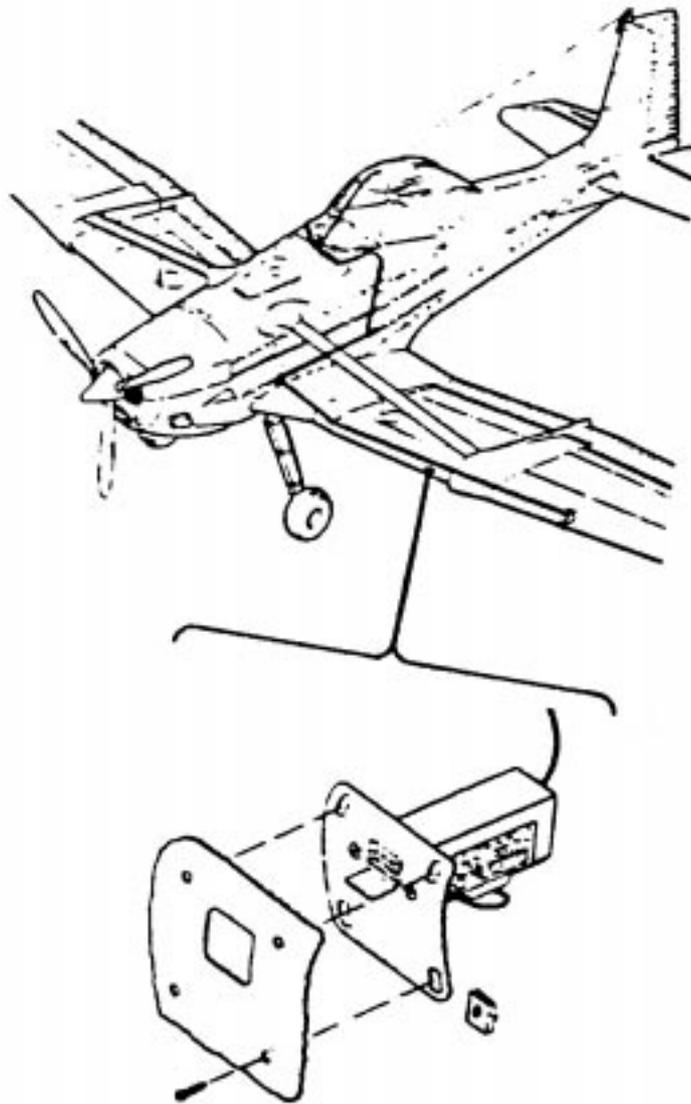
Fig. 10. Stall warning indicator installation.

during normal operations. Extreme care should be taken before operating the APU to ensure the exhaust-gas flow area is clear.

The principles for operating a typical APU parallel to those of other gas-turbine engines. A more detailed discussion of gas-turbine operations and associated systems of fuel, lubrication, and ignition is found in *Aircraft Power plants.* A description of the electrical generating systems and controls used with gas-turbine engines may be found in aircraft Electricity.

APU Operation and Control

Operating controls and indicating systems are typically separated by the functions they serve. The gas turbine operations and the control switch for the air bleed valve are found on the same panel. See Fig.12. The APU operations panel usually includes controls for the APU start and stop, fire-protection test and indicating, and the fire extinguisher manual discharge discussed earlier in this chapter. Additionally, controls for the fuel valve and APU inlet doors may be found on the panel along with the typical engine operation indicators.

The APU inlet door controls access to the gas-turbine compressor inlet and provides cooling air for the APU's accessories. This door may be powered by an electric motor or may use the suction caused by the operation of the gas turbine to open a spring loaded door.

Airflow and Bleed Air

The amount of airflow and its pressure are dependent upon the ambient temperature and the load on (power being drawn from) the APU. The greater the load and/or ambient temperature the lower the airflow and pressure.
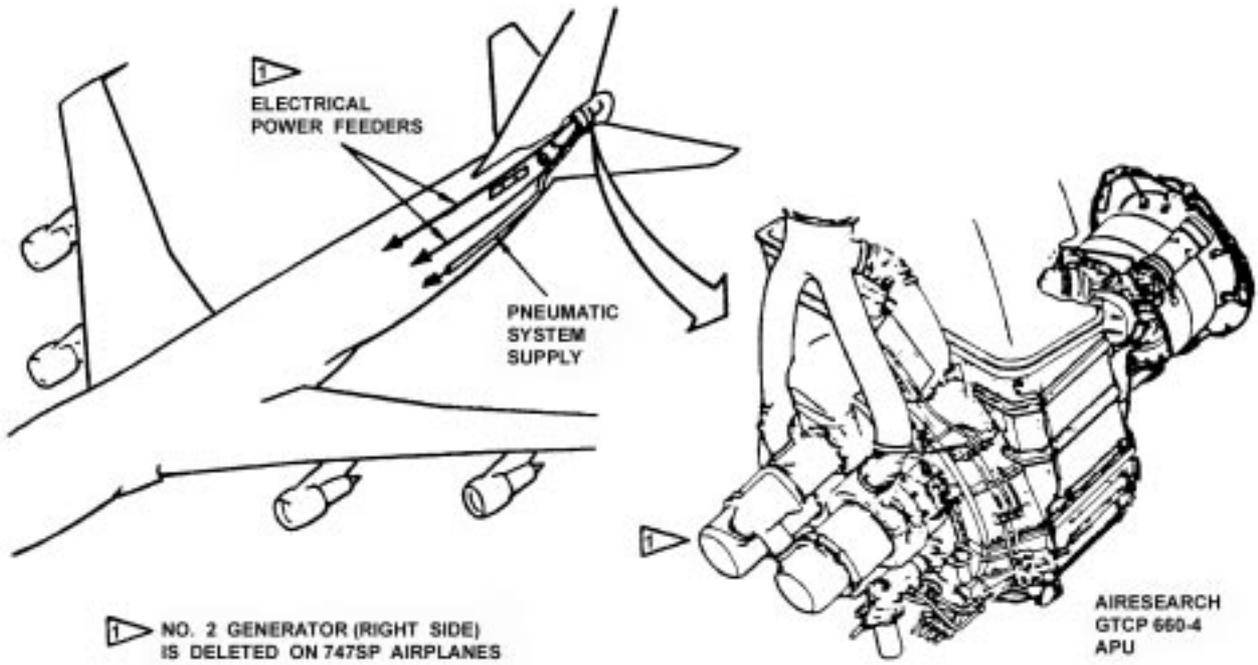
*Fig.11. Auxiliary power unit manufactured by AiResearch Division of Garret Corp.*
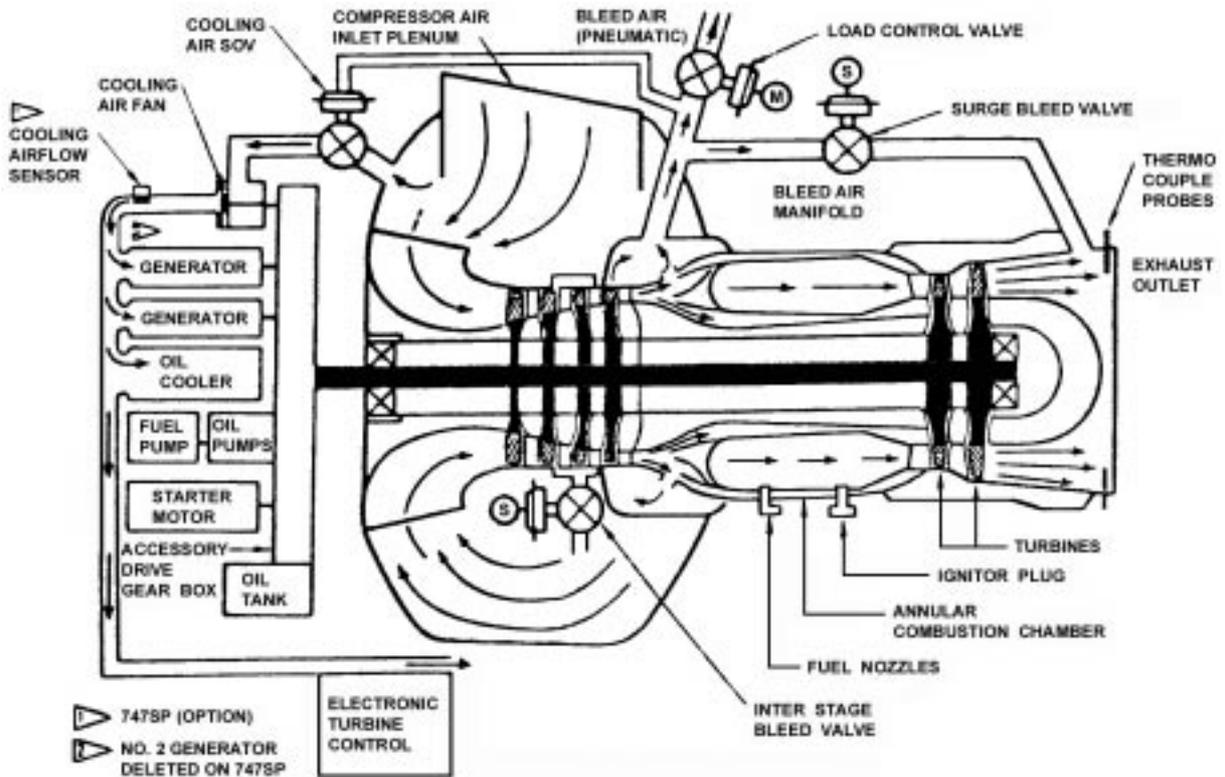
*Fig.12. APU control and indicating panel.*
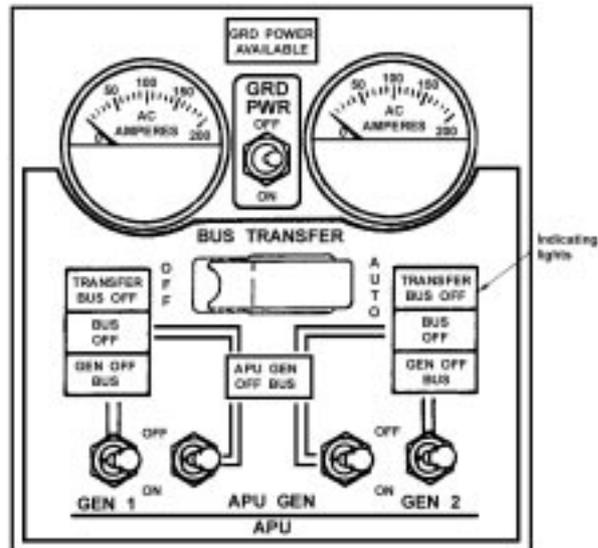
Fig.13. Cross section schematic of an APU.

The air-bleed valve should be closed during start-up and not operated until the APU is at approximately 95 percent power. When the APU bleed valve, also referred to as the "load control valve," is opened by placing its switch in the cockpit in the OPEN position, airflow is supplied to the aircraft's pneumatic power-distribution system.

Accessory cooling is provided from inlet air through a shut-off valve, which is closed unless there is a specified amount of pressure being discharged by the APU's compressor.

CHAPTER: 18
FIRE-GENERAL PRECAUTIONS

PREVENTION OF FIRE ON THE GROUND

Personnel engaged in the maintenance, overhaul and repair of aircraft, should be fully conversant with the operation of fire protection equipment provided and the action to be taken in the event of discovering a fire. Supervisors should satisfy themselves that all reasonable safety precautions are taken and that all apparatus is completely serviceable. Personnel should not wear footwear, with exposed iron or steel studs, nails or tips in hangars, fuelling and de-fuelling areas, and aircraft movement areas, and it is recommended that matches or other means of ignition should not be carried.

Fuelling Operations

Personnel concerned with fuelling should be fully conversant with the guidance material, with local aerodrome instructions and with the safety precautions detailed in the relevant aircraft Maintenance Manual. Fuelling should only be carried out at a site approved by the aerodrome authority, and the out at a site approved by the aerodrome authority, and the precautions should be observed.

Fuelling Zones

Fuelling zones should be established before fuelling commences. These zones should be regarded as extending at least 6m (20ft) readily from the filling and venting points on the aircraft and fuelling equipment. Within this zone, smoking, the use of naked lights and the operation of switches which are not of an approved pattern should be forbidden.
  a. Unless fuelling takes place in a designated no smoking area, "No Smoking" signs should be displayed not less than 15m (50ft) from the fuelling equipment and aircraft tank vents.
  b. Auxiliary Power Units (APUs) which have an exhaust discharging into the zone should, if required to be in operation during fuelling, be started before filler caps are removed or fuelling connections made. If an APU is stopped for any reason during a fuelling operation it should not be started again until fuelling has ceased and there is no danger of igniting fuel vapours.
  c. Ground Power Units (GPUs) should be located as far as practical from aircraft fuelling points and vents, and should not be connected or disconnected while fuelling is in progress.
  d. Fire extinguishers should be located so as to be readily accessible.

Precautions Prior To Fuelling

Before the transfer of fuel commences, the following procedure should be carried out:-
  a. The aircraft should be connected to an effective earthing point and to the fuelling equipment.
  b. When over wing fuelling, the nozzle of the hose should be bonded to the aircraft structure before removing the tank filler cap. When fuelling from hand-operated equipment, including pumping from cans or drums, similar precautions should be taken to bond the pumping equipment, hose nozzle and containers. If funnels are used they too should be bonded to the nozzle or can and to the aircraft. If a chamois leather filter is used, the funnel, and all metal parts securing the leather, should be included in the bonding circuit.
  c. When pressure fuelling, the fuel tank pressure relief valves should, if possible, be checked for correct operation, and the bonding lead on the fuelling hose should be connected to the receptacle, located adjacent to the fuelling point, before connecting the nozzle.

Precautions During Fuel Transfer

  a. When over wing fuelling, the amount of fuel required should be determined and the quantity of fuel delivered should be regulated so that no overflow occurs. Fuel should not be splashed nor allowed to run into the aircraft structure.
  b. When pressure fuelling, any fuel levelling devices between tanks should be operated as necessary. The correct sequence of operations is essential to avoid damage to tanks and subsequent leakage of fuel or vapour.

Precautions After Fuelling

When the transfer of fuel is completed, the bonding wires should not be removed until the filler caps have been refitted or the pressure fuelling hose disconnected, as appropriate.

Work On aircraft During Fuelling

Whilst fuelling is in progress, servicing, maintenance, test and repair activities within the fuelling zone should be closely controlled.
  a. All ground equipment such as trestles, jacks, steps etc., should be moved clear of the aircraft, to prevent damage to the aircraft as it settles because of the weight of fuel being uplifted.
  b. The main aircraft engines should not be operated.
  c. Only those electrical circuits essential to the fuelling operation should be switched on, except that some operators may permit certain specified maintenance work to be carried out during kerosene fuelling. The maintenance permitted is usually restricted to the replacement of complete unit assemblies. Testing and

functioning of defined systems and equipment may be continued unless fuel spillage occurs or fuelling equipment becomes defective. No maintenance work may be permitted on aircraft using fuels which present a higher degree of fire hazard.

d. Strobe lighting should not be operated.

e. The engines of vehicles normally employed for servicing aircraft, including those on electrically powered vehicles, should not be run within the fuelling zone unless they have been designed for the purpose. All vehicles, their engines and equipment, should be subjected to regular inspection and maintenance to preserve their safety characteristics.

f. All connections between ground equipment and an aircraft should be made before fuelling equipment is connected, and should not be broken until fuelling has been completed.

g. Battery trolleys may be used within the fuelling zone provided that connection is made to the aircraft before fuelling equipment is connected. The circuit should remain unbroken until fuelling has ceased.

h. Vehicles operating in the fuelling zone should not pass under or park beneath an aircraft unless specifically required to do so for maintenance or fuelling purposes. A clear exit path should be maintained.

i. Aircraft combustion heaters should not be used.

k. Maintenance work which may create a source of ignition should not be carried out in the vicinity of tanks or fuelling equipment.

l. All hand torches and inspection lamps, and their cable connections, used within the fuelling zone, should be of certified "flameproof" or 'intrinsically safe' type.

m. Only authorised persons and vehicles should be permitted within the fuelling zone and the numbers should be kept to a minimum.

Special Hazards

a. Aircraft should not be fuelled within 30m (100ft) of radar equipment under test, or in use in aircraft or ground installations.

b. When any part of an aircraft landing gear, e.g. the wheels, tyres and brakes, appears overheated, the Aerodrome Fire Service should be called and fuelling should not take place until the heat has dissipated.

c. Extreme caution should be exercised when fuelling during electrical storms. Fuelling should be suspended during severs electrical disturbances in the vicinity of the aerodrome.

d. The use of photographic flash bulbs and electronic flash equipment within 6m (20ft) of the filling or venting points of aircraft or fuelling equipment, should not be permitted.

Spillage Of Fuel

The actions to be taken in the event of a spillage of fuel will depend on the size and location of the spillage, the type of fuel involved, and prevailing weather conditions.

a. If, despite care, fuel is inadvertently spilled in the aircraft structure, it should be cleared before the main aircraft engines are started, Lowering the flaps may accelerate drainage in some cases. Flight should be delayed to permit the evaporation of spillage, and air blowers should be utilised as necessary.

b. In the case of a minor spillage of fuel on the ground, all liquid should be mopped up and the area allowed to dry out before starting any aircraft or vehicle engines in the vicinity.

c. In the case of major spillage of fuel (i.e. covering an area greater than $5m^2$ ($55 ft^2$), action should immediately be taken to stop the flow of fuel, to evacuate all persons from the area and to notify the Aerodrome Fire Service.

d. Fuel should not be washed into drains or culverts, but if such contamination does occur, large-scale water flushing should be carried out and the local water authority notified. Absorbent cleaning agents or emulsion compounds should be used to absorb spilled fuel, the contaminated absorbent being placed in suitable containers and removed to a safe location for disposal. The selection of tools and equipment to be used in removing spilled fuel and disposing of contaminated materials should have regard to minimising the risk of ignition.

Work In Hangars

Before commencing any inspection, overhaul or repair work involving the use of possible ignition sources in the vicinity of the fuel tanks, all tanks should be drained. De-fuelling should be carried out in the open air, by means of a fuel tanker utilising the pressure fuelling/de-fuelling connections on the aircraft, or by draining the tanks into suitable containers. In either case, adequate bonding precautions should be taken, the tanker or containers being bonded to the aircraft and the ground before draining commences. Care should be taken to avoid spilling fuel onto the ground, and containers should be sealed immediately after filling. To avoid danger form sparking between containers and ground contacts, the aircraft should normally be moved form the site first.

The draining of fuel tanks does not render them free from fire risk, as they will contain fuel vapour. It is therefore necessary to purge tanks of vapour before subjecting them to inspection or repair involving the use of heat, electrical equipment or other sources of ignition. The safety precautions applicable to the inspection and repair of tanks are included.

Special care is necessary during fuel flow testing, and foam or CO_2 type extinguishers should always be available whilst this work is in progress. The use of an enclosed flow test rig, similar to that described.

Electrical equipment used during maintenance work, e.g. portable lighting equipment, electric drills, soldering irons, etc., should be maintained in good condition to avoid generating sparks, and in any case this equipment should not be used when flammable vapours are present in the atmosphere. For work in areas where heavy fumes are present, e.g.

inside fuel tanks, flameproof torches must be used. Care should be taken that no flammable fluid is splashed on naked bulbs or other hot surfaces as spontaneous ignition may follow. Low voltage electrical supplies for inspection lamps, etc., are advantageous.

As far as possible only non-flammable cleaning fluids and paint strippers should be used, but if the use of solvents giving off flammable vapours is unavoidable, they should be handled with care and if spilt, should be wiped up immediately. During the use of such fluids the aircraft electrical system should be made inoperative with, for preference, the aircraft batteries removed.

In certain aircraft, special battery lead stowages are embodied. These should be utilised in accordance with the appropriate instructions contained in the Maintenance Manual.

The spraying of large surfaces with dope or paint should be carried out in a properly constructed and equipped spray shop. When touching up small areas, all electrical apparatus worked from a mains supply should be switched off or removed from the vicinity.

Open containers of dirty oil, fuel, dope or solvents should not be stored in aircraft hangars and should be removed from the vicinity of aircraft as soon as possible, otherwise accumulations of flammable vapour may result.

Magnesium and titanium swarf should be completely removed after drilling or machining operations. Special dry powder extinguishants, which are usually known by a trade name, should be used on fires of these combustible metals; water must not be used. The extinguishants form a crust or skin over the burning metal and thus exclude air.

Before permitting the refitting of floor panels or inspection covers, inspectors should ensure that the bays are clean and free all foreign matter, that all drains are unobstructed, and all applications of primers, sealing compounds, etc., in the boxed up area are dry. In addition, all electrical connections, fuse box covers, etc., should be checked, and the systems functioned, and if the bay houses part of the flying control system duplicate inspection of the flying controls should be carried out before fitting the covers or panels.

MAINTENANCE AND FIRE PREVENTION

The following recommendations give guidance on maintenance practices which will reduce the risk of fires occurring in flight or when ground running engines.

Power Plant

Faulty assembly or mechanical failure of engines or power-plant components can cause fire, and careful inspection is therefore essential to ensure that fractures, cracks or leaks are detected and rectified.

Attention should be given to main engine and APU starter systems, and in particular, to ignition harnesses and to high energy igniter plugs and leads in turbine engines. Maintenance instructions must be carefully carried out in accordance with the engine Maintenance Manual.

Pipes carrying flammable fluids are routed by design as far from exhaust systems and electrical apparatus as the installation permits, and, if disturbed, should be re-installed so that the original distances form such sources of ignition are not reduced. Great care must always be exercised to ensure that pipes are in good condition, are appropriately colour coded, are adequately clipped and bonded, and that unions are correctly secured so that leaks cannot occur, and that drains are clear.

It is most important to trace the source of any flammable fluid leakage and to rectify if immediately. Kerosene, lubricating oil, gasolene and most hydraulic fluids will ignite spontaneously if in contact with hot surfaces, such as exhaust pipes, combustion chambers, jet pipes and overheated brakes. Gasolene at ambient temperatures and kerosene at elevated temperatures will vaporise and form a combustible mixture with air, which may be ignited by sparks from electrical equipment or accumulations of static electricity. Fuel and oil drains should be checked for blockage and the routing of the pipes must be clear of cowlings and brake systems. Cowlings should be kept clean to obviate accumulations of flammable fluids, greases and dirt.

The flame traps or shutters of air intake systems must always be in good condition. Flame traps will burn if combustible sludge is allowed to seal opening in firewalls must always be refitted carefully and renewed if damaged. Gaps through or around a firewalls are not permitted. Seals must be securely fixed in position, approved sealants should be renewed as necessary, and distorted or damaged cowlings must be repaired or renewed.

The power plant bonding system is an important safeguard against fire and all bonding connections should be inspected frequently according to the recommendations.

A major failure, such as the fracture of a cylinder or induction manifold on a piston engine (particularly a super charged engine) is a serious matter, as air/fuel vapour mixture may be discharged and contact a hot surface in the power plant area, where ignition could occur. Careful visual examination may reveal minor defects before the danger of a complete breakdown arises.

Shortage of coolant in liquid-cooled piston engines will result in overheating with a grave risk of mechanical failure of the engine causing a fire. It follows that careful maintenance of cooling systems is an aid to fire prevention.

Cracked exhaust manifolds, pipes, ejectors, or turbine engine combustion chambers may allow hot gases or torching flame to impinge on vulnerable parts of the power plant installation, either causing fire directly or giving rise to mechanical failure which may start a fire. Exhaust systems and combustion chambers should therefore receive very careful examination.

Engine vibration is generally an indication of a serious defect and can also result in the cracking of pipes or leaking of high pressure hoses and loosening of pipe connections.

It is most important that all the appropriate fire precautions are taken during the operation of auxiliary power units whilst the aircraft is on the ground. Intakes and exhausts must be free from obstruction. Temperature and warning indicators should be observed and action taken accordingly.

A contributory cause of fires in engine bays is the saturation of flexible-pipe lagging by flammable liquids. This can occur when the outer covering (e.g. sleeveing of neoprene or rubber) has been damaged or has deteriorated, allowing seepage into the lagging. This condition can be detected by blistering or a soggy feel, as distinct from the hard feel of unsaturated pipes. If pipes are in a saturated condition they should be renewed.

ENGINE RUNNING PRECAUTIONS

Fires during engine starting and running can be avoided by observing the correct drill given in the relevant Manuals for the aircraft and engine concerned. General guidance on some important points is given in the following paragraphs:-

   a. Whilst engines are being started and ground run, fire extinguishing apparatus, preferably of the CO_2 trolley type with extending applicator and under the control of trained and experienced personnel, should be positioned near the aircraft. Additionally, a good communications system should be arranged between the cockpit and ground.

   b. Persons in control of engine ground running should be familiar with the approved ground running instructions in the appropriate Manuals and with the correct fire drill procedure.

Piston Engines

Care should be exercised when priming piston engines preparatory to starting, particularly when an electrical priming pump is used or when priming is carried out by pumping the throttle (to operate the carburettor accelerator pump). Over priming can cause an excess of fuel in the engine, and could result in an intake fire.

When excess-fuel conditions exist and an engine fails to start (a common occurrence when engines are hot) the fuel cock should be turned OFF (or the fuel cut-out closed) and the throttle should be fully opened. After ensuring that all ignition switches including booster coil switches are OFF, the engine should be turned. Most types of engines can be turned in the running direction by the propeller or starter, but when this has been done, precautions should be taken to dispel any accumulations of fuel in the exhaust system. On some small engines the propeller can be used to turn the engine in the reverse direction of rotation to expel the over rich fuel-air mixture through the air intake.

If an air intake fire occurs before the engine picks up, a previously agree signal should be made to the person at the controls, who should immediately turn off the appropriate engine fuel cock; it is often recommended to continue to motor the engine on the starter so that the burning fuel is drawn into the engine. If the engine picks up and runs, an air intake fire will probably cease without further action, in which case the fuel may be turned on again. Consideration should then be given to any damage which may have been caused to the intake filters by the intake fire.

If an intake fire persists or appears to be serious, a ground CO_2 type fire extinguisher should be discharged into the air intake. Outside action will also be necessary if burning fuel runs form the intake or exhaust on to the ground.

Should an engine fire occur whilst ground running, the drill given in the appropriate Manual should be followed. To help the person in charge of the ground fire fighting equipment, any other operating engines should be shut down.

Any practice which promotes accumulation of flammable fluid or vapour inside engine cowlings should be avoided. Exhaust systems must give complete sealing; flanges, gaskets and air intake sealing must be regularly examined and maintained. In shutting-down, engines should first be cooled by running at low power for a short period, and fuel cut-outs (if fitted) should be used strictly in accordance with the engine manufacturer operating instructions.

Gas Turbine Engines

The most frequent cause of fire during starting is the accumulation of fuel in the engine and jet pipe following an earlier 'wet start' (i.e. an unsuccessful attempt to start in which the fuel has failed to ignite and has been distributed throughout the engine and jet pipe and drained into the lower combustion chambers and drain system). It is necessary to ensure that the drain system operates correctly, and to drain the vent tank (which has a limited capacity), as advised by the manufacturer. It is normal practice to carry out a 'dry run' (i.e. motor the engine through the starting cycle with the fuel and ignition turned off) after a wet start before making another attempt to start an engine.

As kerosene spreads readily and does not evaporate quickly a very slight leak is significant and must be remedied. Fuel which may have collected in cavities, cowlings, etc., should be wiped up after maintenance operations before any attempt is made to start the engines.

If there is any indication of an internal engine fire when an engine is not running the fuel cocks should immediately be turned OFF and every attempt made to localise the fire. An outside assistant should discharge a CO_2 or BCF extinguisher into the intake or jet pipe if necessary.

When starting and running gas turbines, particular note should be taken of the jet pipe temperature. If this exceeds the manufacturer's limitations, a serious risk of mechanical failure followed by fire may result.

CHAPTER: 19
FIRE EXTINGUISHING EQUIPMENT

TYPES OF SYSTEMS

The extinguishing systems in general use are the fixed system, the portable system and the mixed system. The term 'fixed' refers to a permanently installed system of extinguishant containers, distribution pipes and controls provided for the protection of power plants and, where applicable, auxiliary power units. In some types of aircraft landing gear wheel bays and baggage compartments.

A portable system refers to the several hand-operated fire extinguishers provided to combat any outbreaks of fire in flight crew compartments and passenger cabins.

A mixed system is one used in some aircraft for the protection of baggage and service compartments. The distribution pipeline and spray system is fixed in the appropriate compartment and is coupled to adaptor points to which a hand operated extinguisher may be plugged in.

TYPES OF EXTINGUISHANT

The extinguishants in general use are described in the following paragraphs.

Methyl bromide (M.B.)

This extinguishant boils at 4.6^0C and is commonly used in fixed systems, particularly for the protection of power plants. Because of its toxicity, Methyl Bromide should not be used in confined spaces, flight crew compartments or passenger cabins. The effects of breathing the vapours may not be immediately apparent, but serious or even fatal after effects may be sustained at a later stage.

Bromochlorodifluromethane (B.C.F.)

This is semi-toxic extinguishant is particularly effective against electrical and flammable liquid fires. It is used in power plant systems, and for the protection of auxiliary power units in some aircraft; it is also used in certain types of portable extinguisher. It becomes gaseous at normal temperatures and condenses to liquid at-4^oC (25^oF), and can be stored and discharged at moderate pressures. It has little or no corrosive effect, although halogen acids will be formed if its products which have been decomposed by fire come into contact with water, e.g. condensation caused by fire. In contact with fire, B.C.F. volatilises instantly, giving rapid flame extinction with little or no deleterious effect on metallic, wooden, plastic or fabric materials.

Carbon dioxide (CO_2)

This gas extinguishant is also effective against electrical and flammable liquid fires and is used principally in portable fire extinguishers. It is noncorrosive and if the concentration needed to extinguish a fire is excessive it can have appreciable toxic effects. When discharged in a confined space, the vapour cloud can reduce visibility temporarily.

Water

In many aircraft, certain of the portable fire extinguishers in passenger cabins are of the water type, designed for combating fires involving ordinary combustible material such as paper, fabric, etc., where the quenching and cooling effects of water are of prime importance. These extinguishers are not suitable against electrical fires. An anti-freezing agent is normally included to permit operation at temperatures as low as -20^oC. Typical examples are the water/glycol extinguisher with 38% of inhibited ethylene glycol, and the 'wet-water' extinguisher with glycol, wetting agents to reduce surface tension, and inhibitors to impart anti-corrosive characteristics.

Bromotrifluromethane (B.T.M.)

This semi-toxic extinguishant is used in fixed systems for the protection of power plant and auxiliary power units. It is also widely used in cargo compartment fire suppression systems of some types of aircraft.

Dry Chemical

Dry chemical extinguishant takes the form of a non-toxic powder, e.g. potassium bicarbonate, and is used in portable fire extinguishers fitted in certain types of aircraft. It is very effective against fires involving flammable liquids and free burning material such as wood, fabrics and paper. Use of the extinguishant against fires in electrical equipment is not recommended, since it could render contactors and switches un-serviceable which may otherwise be functioning correctly in adjacent equipment. It does not have a quenching effect and thereby the dangers of distortion or explosion when used on hot surfaces, such as overheated wheel brakes, are minimised. Some dry chemical powders have a corrosive effect on some metals (including aluminium) which may require special attention when cleaning-up after the discharge of an extinguisher. Dry chemical extinguishers should not be used in flight crew compartments or passenger cabins where visibility would be seriously affected both during the discharge of powder and also as a result of its deposition on transparencies and instruments.

TYPICAL FIXED SYSTEMS

In the types of aircraft for which fixed fire extinguisher systems are specified, it is usual for the extinguishant to be stored in the containers under pressure and to be discharged by electrically firing cartridge units within the extinguisher discharge heads. The firing circuits are controlled by switches or fire control handles in the flight crew compartment; in some types of aircraft, control may also be automatic in the event of a crash landing. The layout of a system and the number of components required, depend largely on the type of aircraft and number of power plants, and also on whether fire protection is required for auxiliary power units, landing gear wheel bays and baggage compartments. Fig.1 diagrammatically illustrates a typical arrangement for power plant protection and indicates the components which, in general, form part of any fixed system. It also indicates the discharge control method normally adopted for multi engine fire protection and known generally as the 'two-shot system'. In this system the fire extinguishers for each power plant
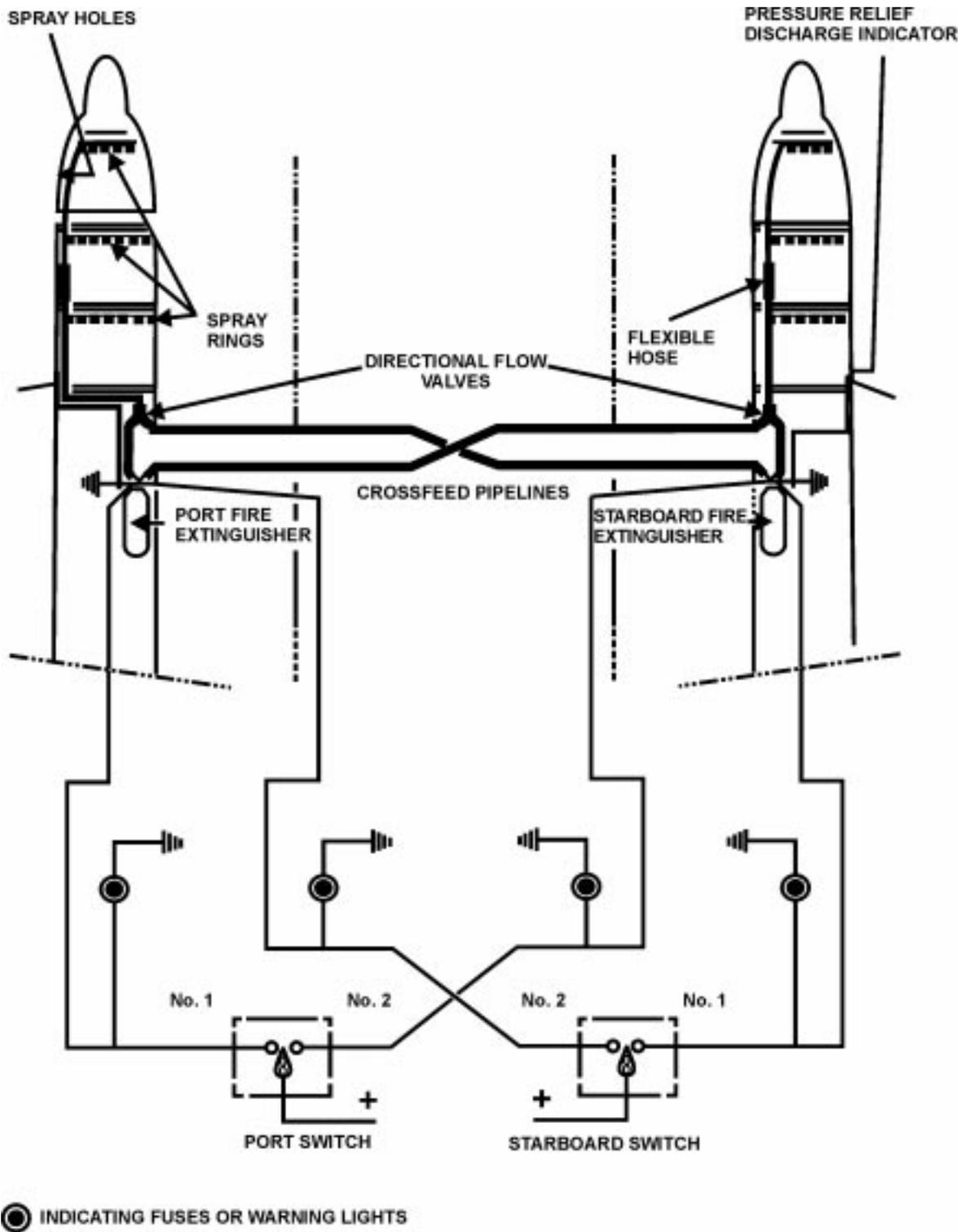
Fig. 1. Typical fixed extinguisher system.

are interconnected, so permitting two separate discharges of extinguishant into any one poser plant. In some aircraft incorporating crash switches the system may be so arranged that operation of the switches will cause an adequate and simultaneous discharge of extinguishant to each power plant. Brief descriptions of the principal components of a fixed fire extinguishing system are given in the following paragraphs. For precise technical details reference must be made to the manuals for the relevant aircraft and components.

Extinguishers

Extinguishers vary in construction but are normally comprised of two main components: (i) the steel or copper container and (ii) the discharge or operating head. A sectional view of an extinguisher widely used in a two-shot system is shown in Fig. 2. The container is in the form of a steel cylinder and has an externally threaded neck to which the discharge head is screwed and soldered. The discharge head contains two annular machined diaphragms, each bearing an externally threaded spigot on which a hollow charge plug is screwed to form an annulus between its inner end and its respective diaphragm. Each annulus is connected by a 'flash' hole to a port containing the appropriate cartridge unit. Below, and concentric with each diaphragm and charge plug, is a radially adjustable light-alloy hollow junction box fitted with a union to which an extinguisher discharge pipe is connected. The lower end of the junction box is closed by a cap which embodies a discharge indicator pin. A banjo coupling is fitted in the main body of the operating head and serves as a connection for a pressure discharge indicator.

When either of the cartridge unit is fired, sufficient pressure is created in the adjacent annulus to rupture the associated diaphragm. The spigot and charge plug assembly is thereby detached and forced down the hollow junction box beyond the outlet union and discharge pipe through which the extinguishant then flows to the spray pipes or rings.

Directional Flow Valves

These valves are a special form of non-return valve designed for use in two-shot systems to allow the contents of one or several extinguishers to be directed into any one power plant. The methods of connection may vary between different aircraft systems, but the one shown in Fig. 1 is typical and also serves to illustrate the two-shot operating sequence generally adopted. The extinguishers are controlled by individual firing switches each having three positions; No.1, OFF and No.2. When the port extinguisher is fired and the extinguisher is discharged to the port power plant. If the fire has not been extinguished, selection of the No.2 position then causes the starboard extinguisher to be discharged also into the port power plant via the cross feed line and port directional flow valve, the latter preventing extinguishant from entering the empty extinguisher of the port system. In order to extinguish a fire in the starboard engine, the starboard extinguisher switch is selected to its No.1 position, and the relevant cartridge unit is fired so that extinguishant is discharged to the starboard power plant. If selection of the No.2 position of the starboard extinguisher switch becomes necessary, then the port extinguisher will also be discharged into the starboard power plant via the appropriate cross feed line and the starboard directional flow valve, which prevents charging the empty starboard extinguisher.

Discharge Indicators

In fire extinguisher system of the fixed type, provision is made for positive indication of extinguisher discharge as a result of either (a) international firing, or (b) inadvertent loss of contents, i.e. pressure relief overboard or leakage. The methods adopted are generally mechanical and electrical in operation.

Mechanical Indicators

Mechanical indicators are, in many instances, fitted in the operating heads of extinguishers Fig.2., and take the form of the a pin which under normal conditions is flush with the cap of the hollow junction box. When an extinguisher has been fired, and after the charge plug has been forced down the hollow junction box, the spigot of the plug strikes the indicator pin causing it to protrude from the cap, thereby providing a visual indication of extinguishant discharge. In the extinguishers employed in some types of aircraft, mechanical type pressure gauges are embodied in the containers and these serve to indicate extinguishant discharge in terms of pressure changes and, in addition, serve as a maintenance check on leakage.

    (i) Protection against bursting of a fire extinguisher as a result of build-up of internal pressure under high ambient temperature conditions, is provided by a disc which fuses at a specific temperature, or a disc which bursts when subjected to bottle over-pressure. The disc is located in the operating head and when operated, the extinguishant discharges overboard through a separate pressure relief line. In order to indicate that discharge has taken place, a disposable plastic, or metal, disc is blown out from a discharge indicator connected to the end of the relief line exposing the red interior of the indicator. Discs are generally coloured, red, but in certain types of indicator, green discs are employed. Discharge indicators are mounted in a structural panel, e.g. a nacelle cowling, and in a position which facilitates inspection from outside the aircraft.

Electrical Indicators

Electrical indicators are used in several types of aircraft and consist of indicating fuses magnetic indicators and warning lights. These are connected in the electrical circuits are energised, they provide a positive indication that the appropriate cartridge units have been fired. In some aircraft pressure switches are mounted on the extinguishers and are connected to indicator lights which come on when the extinguisher pressure reduces to a predetermined value. Pressure switches may also be connected in the discharge lines to indicate actual discharges as opposed to discharge initiation at the extinguishers.

CONTAINER

OPERATING HEAD

BANJO COUPLING

HOLLOW JUNCTION BOX

ANNULAR MACHINED DIAPHRAGM

FLASH HOLE

HOLLOW CHARGE PLUG

SPIGOT

UNION

CAP

DISCHARGE INDICATOR PIN
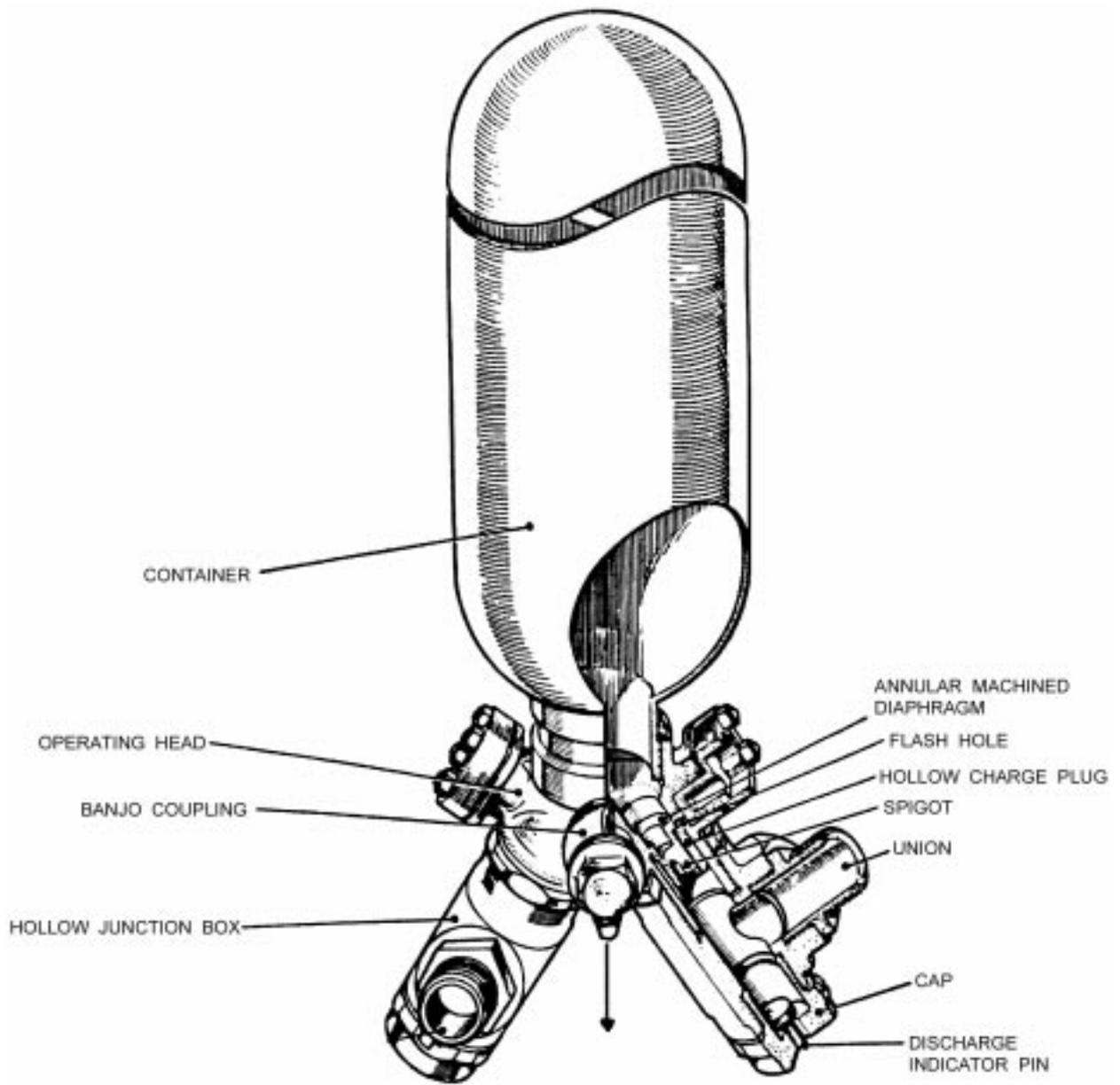
Fig. 2. Fixed type of extinguisher.

Pipelines

Extinguishants are discharged through a pipeline system which, in general, is compressed of light-alloy pipes outside fire zones and stainless steel rings inside fire zones, which are perforated to provide a spray of extinguishant in the relevant zones. In some cases, extinguishant may be discharged through nozzles instead of spray rings. Flexible fire-proof houses are also used, e.g. between a nacelle fire wall and spray rings secured to an engine.
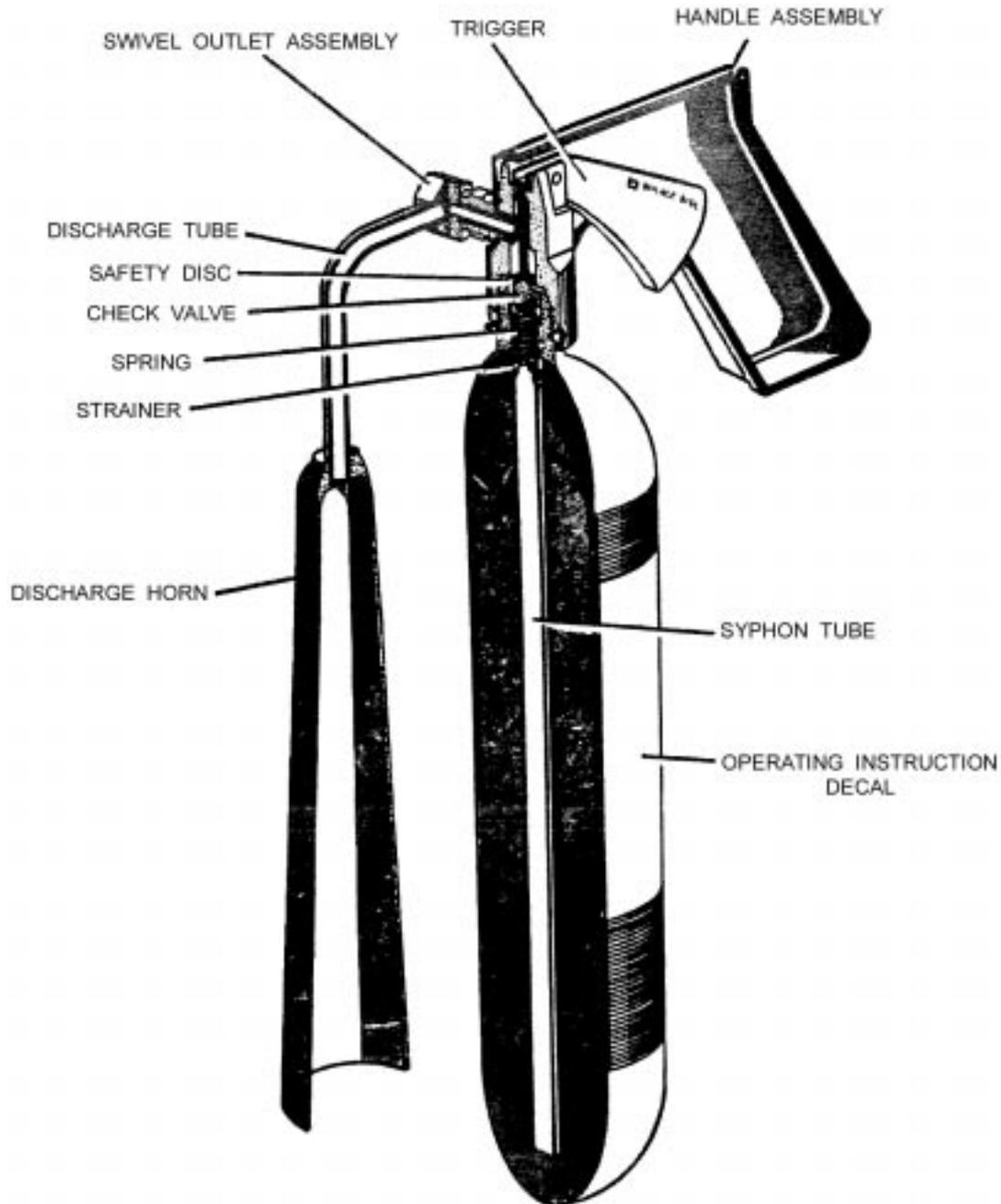
Fig.   3.Typical portable CO_2 extinguishers.
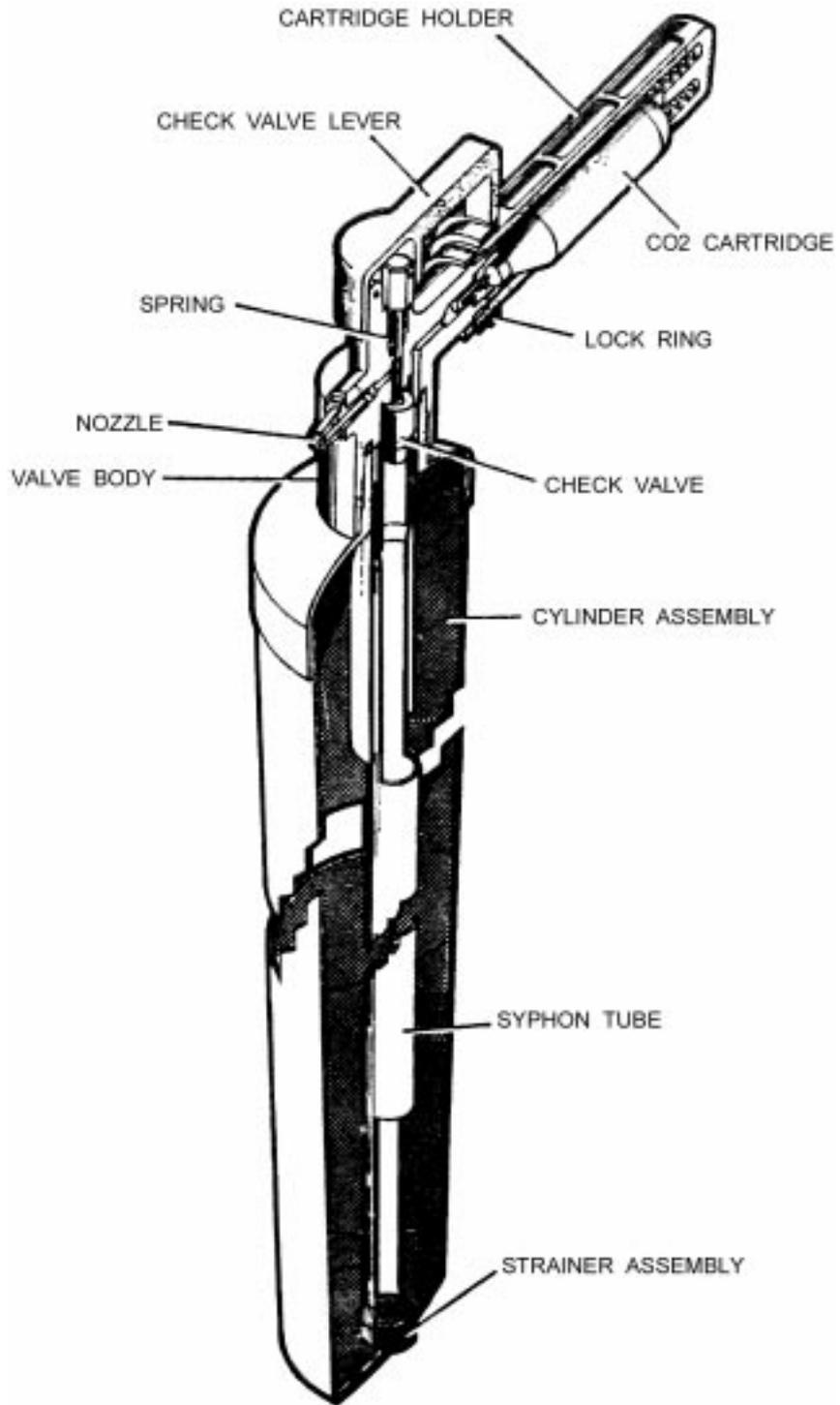
Fig. 4. Typical water extinguisher.

Portable Extinguishers

The portable extinguishers in common use are of the CO_2 type and the water type. Extinguishers containing extinguishant B.C.F. are also used in some aircraft. The type of extinguisher installed in a particular location is chosen to be appropriate to the nature of the possible fires in the compartment in which it is installed. Extinguishers are located in accessible positions and installed in suitable attachment brackets with quick-release metal straps. Brief descriptions of their construction and operation are given in the following paragraphs for general guidance.

CO_2 Extinguishers

A typical extinguisher (Fig.3)., comprises a steel cylinder and an operating head incorporating a pistol-type firing mechanism, check valve assembly and discharge horn which characterises CO_2 extinguishers generally. When the trigger is pressed, a lock wire and seal are broken and the spindle of the check valve assembly is forced downward, thereby removing the valve from its seat. This allows the extinguishant to flow up the siphon tube, through the centre of a safety disc, to discharge from the discharge horn. Releasing of the trigger alloys the valve to reset and seal off the flow. The purpose of the safety disc is to permit the release of extinguishant in the event of excessive internal pressures. When a safety disc bursts, the trigger of the firing mechanism springs downward and exposes the instruction 'REPLACED DISC' engraved on the side of the trigger.

Water Extinguishers

A typical extinguisher incorporating an antifreeze agent is shown in Fig.4. It comprises a cylinder and a valve body which houses a lever operated check valve assembly and a nozzle. A cartridge holder containing a cartridge of CO_2 is secured to the valve body, and, in addition to its main operating function, serves as a hand-grip. When the cartridge holder is twisted the cartridge is punctured causing the CO_2 to be released into the cylinder, thereby pressurising it. Depression of the check valve assembly lever moves the valve from its seating at the top of a syphon tube, allowing the extinguishant to be forced up the tube and to discharge through the nozzle. When the lever is released, the valve is returned to its seating under the action of a spring, and the flow of extinguishant is sealed off.

Some water extinguishers have a plastic head which contains an operating trigger and plunger mechanism, and screws into a threaded boss on the metallic container. The complete assembly is sealed by a rubber sealing ring. When the trigger is squeezed, the plunger mechanism breaks a seal within the operating head and thereby releases the extinguishant. The discharge is subsequently controlled by maintaining or releasing pressure on the trigger. In some cases, the containers are expendable and scrapped after discharge, and only the operating heads are subject to inspection and overhaul procedures.

Weight And Pressure Checks

The fully charged weight of an extinguisher should be checked at the periods specified in the approved Maintenance Schedule, and before installation, to verify that no loss of extinguishant has occurred. The weight, including blanking caps and washers, but excluding cartridge units, is normally indicated on the container or operating head. For an extinguisher embodying a discharge indicator switch, the weight of the switch cable assembly is also excluded.

The date of weighing and the weight should, where specified, be recorded on record cards made out for each type of extinguisher, and also on labels for attachment to extinguishers. If the weight of an extinguisher is below the indicated value the extinguisher must be withdrawn from service for recharging.

For extinguishers fitted with pressure gauges, checks must be made to ensure that indicated pressures are within the permissible tolerances relevant to the temperature of the extinguishers. The relationship between pressures and temperatures is normally presented in the form of a graph contained within the appropriate aircraft Maintenance Manuals.

In certain types of portable extinguishers, a check on the contents is facilitated by means of a disc type pressure indicator in the base of the container. If the discharge pressure is below the specified value, the disc can be pushed in by normal thumb pressure.

CHAPTER: 20
INSPECTION OF METAL AIRCRAFT
AFTER ABNORMAL OCCURRENCES

HEAVY OR OVERWEIGHT LANDINGS

An aircraft landing gear is designed to withstand landing at a particular aircraft weight and vertical descent velocity (the maximum being 10ft/sec at design landing weight). If either of these parameters is exceeded during a landing, then it is probable that some damage may be caused to the landing gear or its supporting structure. Over stressing may also be caused by landing with drift or landing in an abnormal attitude, e.g. nose or tail wheel striking the runway before the main wheels.

Some aircraft are fitted with heavy landing indicators, which give a visual indication that specified 'g' forces have been exceeded, but in all cases of suspected heavy landings, the flight crew should be consulted for details of aircraft weight, fuel distribution, landing conditions, and whether any noises indicative of structural failure were heard.

The damage which may be expected following a heavy landing would normally be concentrated around the landing gear, its supporting structure in the wings or fuselage, the wing and tailplane attachments and the engine mountings. Secondary damage may be found on the fuselage upper and lower skin and structure, and wing skin and structure, depending on the configuration and loading of the aircraft. On some aircraft it is specified that, it no damage is found in the primary areas, the secondary areas need not be inspected; but if damage is found in the primary areas, then the inspection must be continued.

Preliminary inspection which should normally be carried out after heavy landing are:-

Landing Gear

i) Examine tyres for excessive creep, flats, bulges, cuts pressure loss, and excessive growth.
ii) Examine wheels and brakes for cracks, other damage, and fluid leaks.
iii) Examine axles, struts and stays for distortion and other damage.
iv) Check shock struts for fluid leaks, scoring and abnormal extension.
v) Examine landing gear attachments for signs of cracks, damage or movement. In some instances this may require removal of certain bolts in critical locations, for a detailed magnetic crack detection test.
vi) Examine structure in the vicinity of the landing gear attachments for signs of cracks, distortion, movement of rivets or bolts, and fluid leakage.
vii) Examine doors and fairings for damage and distortion
viii) Jack the aircraft and carry out retraction and nose wheel steering tests in accordance with the approved Maintenance Manual; check for correct operation of locks and warning lights, clearances in wheel bays, fit of doors, and signs of fluid leaks.

Mainplanes

i) Examine the upper and lower skin surfaces for signs of wrinkling, pulled rivets, cracks and movement at skin joints. Intertial loading on the wing will normally result in wrinkles on the lower surface and cracks or rivet damage on the upper surface, but stress induced by wing-mounted engines may result in wrinkles on either surface.
ii) Check for signs of fuel leaks, and seepage from integral tanks.
iii) Examine root end fillets for cracks and signs of movement.
iv) Check flying controls for freedom of movement; power controlled systems should be checked with the power off.
v) Check balance weights, powered flying control unit mountings and control surface hinges for cracks, and the control surfaces for cracks or buckling.
vi) Where possible, check the wing spars for distortion and cracks.

Fuselage

i) Examine fuselage skin for wrinkling or other damage, particularly at skin joints and adjacent to landing gear attachments and centre section.
ii) Examine pressure bulkheads for distortion and cracks.
iii) Examine, for distortion and cracks, the supporting structure for heavy components such as galley modules, batteries, water tanks, fire extinguishers, auxiliary power units, etc.
iv) Check that the inertia switches for the fire extinguishers, emergency lights, etc., have not tripped.
v) Check instruments and instrument panels for damage and security.
vi) Check ducts and system pipes for damage, security, and fluid leaks.
vii) Check fit of access doors, emergency exits, etc., and surrounding areas for distortion and cracks.
viii) Check loading and unloading operation of cargo containers, and condition of cargo restraint system.

Engines
i) Check engine controls for full and free movement.
ii) Examine engine mountings and pylons for damage and distortion. Tubular members should be checked for bow greater than prescribed limits, and cracks at welds. Mounting bolts and attachments should be checked for damage and evidence of movement.
iii) On turbine engines check freedom of rotating assemblies, and on piston engines check freedom of rotation with sparking plugs removed.
iv) Examine engine cowlings for wrinkling and distortion and integrity of fasteners.
v) Check for oil, fuel and hydraulic fluid leaks.
vi) Where applicable, check the propeller shaft for shock loading in accordance with the procedure in the Maintenance Manual.

Tail Unit
i) Check flying controls for freedom of movement.
ii) Examine rudder and elevator hinges for cracks, and control surfaces for cracks and distortion, particularly near balance weight fittings.
iii) Examine tailplane attachments and fairings, screw jacks and mountings, for distortion and signs of movement.

Engine Runs
Provided that no major structural distortion has been found, engine runs should be carried out in accordance with the appropriate Maintenance Manual, in order to establish the satisfactory operation of all systems and controls. A general check for system leaks should be carried out while the engines are running, and on turbine the run-down time should be checked.

Inspection of Damaged Areas
If any superficial damage is found during the preliminary inspection, the supporting structure should be examined for distortion, loose rivets, cracks or other damage, and rigging and symmetry checks should be carried out to ascertain whether the damage has twisted or warped the main airframe structure. Where flying controls pass through supporting structure, cable tensions should be checked. On pressurised aircraft a cabin leak rate check should be carried out to ascertain whether the sealing of the fuselage is satisfactory and unaffected by the damage.

BURST TYRE INCIDENTS
If a tyre bursts during taxying, take-off or landing, fragments of the tyre may fly off the rotating wheel and cause damage to parts of the aircraft in line with the wheel disc. Where single wheels are employed, more serious damage may occur through the wheel rolling on the paved runway and transmitting shocks to the landing gear leg and supporting structure. Multiple wheel landing gears will generally be less seriously affected by a single burst type, but the axles, bogies, torque links or steering mechanism may become bowed or strained as a result of the effects of uneven loading.

In most cases the wheel on which the burst occurred will generally be damaged and must be returned for overhaul. In addition, the following inspections should be carried out:-

i) Examine for damage, the wheels and tyres which have not burst.
ii) Examine the brake units on the affected leg for damage. On those wheels which are not fitted with fusible plugs, the tyre burst may have resulted form overheating caused by a binding brake, and when the replacement wheel is fitted attention should be given to the operation of the associated brake including in particular, freedom of rotation of the wheel with brakes released.
iii) Examine the landing gear bay for damage and hydraulic fluid leaks.
iv) Examine the affected leg, including pipelines, operating jacks, etc., for damage and hydraulic fluid leaks.
v) Inspect the supporting structure and attachments of the affected leg, for cracks, warped panels and loose rivets. In some instances it may be specified that certain highly stressed bolts in the supporting structure or retraction mechanism bolts removed for non-destructive crack detection tests.
vi) Examine the adjacent fuselage or wing skinning, and landing gear doors, for damage.
vi) Examine the adjacent fuselage or wing skinning, and landing gear doors, for damage.
vii) Check rear-mounted engines for possible ingestion of debris.

FLIGHT THROUGH SEVERE TURBULENCE
If an aircraft has been flown through conditions of severe turbulence, the severity of the turbulence may be difficult to assess and report upon, but an indication may be obtained from the accelerometers or fatigue meters fitted to some aircraft. However, these instruments are designed to record steady leads, and force peaks recorded during flight through turbulence may be exaggerated due to instrument inertia, and should not be taken as actual loads. Generally if readings, exceeding -.5g and +2.5g are recorded on transport aircraft, then some damage may be found. With other types of aircraft (e.g. aerobatic or semi-aerobatic) accelerometers and fatigue meters are seldom fitted, and reported flight through turbulence should always be investigated.

Severe turbulence may cause excessive vertical or lateral forces on the aircraft structure, and the effects may be increased by the inertia of heavy components such as engines, fuel tanks, water tanks, and cargo. Damage may be expected at main assembly points such as the wing-to-fuselage joints, tail-to-fuselage joint, and engine mountings. Damage may also occur in those areas of the wings. Fuselage, tailplane and control surfaces where the greatest bending

moment takes place, i.e. part way along their length, and may be indicated by skin wrinkles, pulled rivets or similar faults.

An inspection for damage, after a report of flight through severe turbulence, should include the inspections described for over hot landing.

LIGHTNING STRIKES

Lightning is a discharge of electricity between highly charged cloud formations, or between a charged cloud and the ground. If an aircraft is flying, or on the ground in the vicinity of such a cloud formation, the discharge may strike the aircraft and result in very high voltage and currents passing through the structure. All separate parts of an aircraft are electrically bonded together to conduct a lighting strike away from areas where damage may hazard the aircraft, e.g. fuel tanks or flying controls, and during manufacture special precautions are often taken with non-metallic components such as wing tips, external fuel tanks and nose cones.

Lightning strikes may have two effects on an aircraft; strike damage where the discharge enters the aircraft, and static discharge damage subsequent to the strike. Strike damage is generally found at the wing tips, leading edges of wings and tail unit, and at the fuselage nose, but on some aircraft types other areas may be particularly susceptible, and this information should be obtained from the appropriate Maintenance Manual. Static discharge damage will usually be found at wing tips, trailing edges and antennae.

Strike damage is usually in the form of small circular holes in the exterior skin, either in clusters or spread out over a wide area, and often accompanied by burning or discoloration, blisters on radomes and cracks in glass fibre. Static discharge damage is usually in the form of local pitting and burning at trailing edges.

Inspection

Since both lightning and turbulence occur in thunderstorms, an inspection for lightning damage will often coincide with an inspection following reported flight severe turbulence. The areas mentioned above should be examined for signs of strike or static discharge damage, and bonding strips and static discharge wicks should be examined for burning and disintegration. All control surfaces, including flaps, spoilers and tabs, should be inspected for damage at their hinge bearings; unsatisfactory bonding may have allowed static discharge and tracking across the bearings, unsatisfactory bonding may have allowed static discharge and tracking across the bearings, causing burning, break-up or seizure. A check for roughness and resistance to movement at each bearing, break in or seizure. A check for roughness and resistance to movement at each bearing, will usually indicate damage at such points. In addition, the following inspections should be carried out:-

i)   Examine engine cowlings and engine for signs of burning or pitting. If a lightning strike is evident, tracking through the bearings may have occurred, and some manufacturers recommend that the oil filters and chip detectors should be examined for signs of contamination; this check should be repeated periodically for a specified number of running hours after the occurrence.

ii) Examine the fuselage skin and rivets generally, for burning or pitting.

iii) If the landing gears was extended when the lightning strike occurred, examine the lower parts of the gear for static discharge damage. Check for residual magnetism and demagnetize where necessary.

The inspections outlined in above paragraphs should be followed by functional checks of the radio and radar equipment, instruments, compasses, electrical circuit, and flying controls, in accordance with the relevant chapters of the approved Maintenance Manual. On some aircraft a bonding resistance check on radomes may also be specified.

DAMAGE FROM JET BLAST

Considerable damage may be caused to an aircraft through the action of another aircraft turning or taxying in the vicinity. The damage may be caused by blast or impact from debris, and may be particularly severe in the case of light aircraft.

Flying control surfaces should be inspected for distortion, particularly where they were unlocked and may have been driven hard against their stops.

An inspection for impact damage in the form of skin dents and cracked or chipped windscreens or windows, should be made, and the air intakes for engines, heat exchangers, etc., should be examined for debris which may have blown into them.

With light aircraft, further inspections may be necessary to ensure that no structural damage has been sustained, particularly when the jet blast has been sufficiently strong to move the whole aircraft.

OTHER OCCURRENCES

Occurrences not covered in the preceding paragraph or peculiar to a particular aircraft type, may necessitate a special inspection, and this is often specified in the appropriate Maintenance Manual. Where no specific instructions exist, experience on the type aircraft, combined with a knowledge of the structure and stress paths, will normally enable a satisfactory inspection to be carried out. As an example, if the flap limiting speed has been exceeded, the flaps should be examined for twisting and buckling, the hinge brackets on the wings and flaps should be examined for twisting and buckling, the hinge brackets on the wings and flaps should be examined for twisting and buckling, the hinge brackets on the wings and flaps should be examined for damage such as cracks and strained attachment rivets and bolts, and the operating mechanism should be examined for general distortion, bowing, cracks and security. Provided these checks are satisfactory, and operation of the system reveals no evidence of malfunction or excessive e friction, then the aircraft may be considered airworthy.

HELICOPTERS

The inspections necessary on helicopters following are checks which are required for the main rotor blades, head and shaft tail rotor and transmission, following heavy landings or flight through severe turbulence. Inspections are also outlined below are typical.

HEAVY LANDINGS OR FLIGHT THROUGH SEVERE TURBULENCE

Rear Fuselage Or Tail Boom

Examine for evidence of strike damage form the main rotor blades, and if damage is found check for cracks, security and symmetry.

Main Rotor Blades

Remove the rotor blades and examine them for twisting and distortion. Check the surface for cracks, wrinkles, or other damage, and check the security of the skin attachment rivets or structural bonding. If the main rotor blades are badly damaged through impact with tail boom or ground, certain components in the transmission may be shock-loaded, and it is sometimes specified that for example, the main rotor shaft, pitch change rods, and main gear box mounting blots, should also be removed for inspection.

Main Rotor Head

Disconnect pitch change rods and dampers, and check that the flapping hinges, and blade sleeves move freely, without signs of binding or roughness. Examine the rotor head and blade stops for cracks or other damage, and the dampers for signs of fluid leaks. Damage in this area may be an indication of further damage inside the main gearbox.

Tail Rotor

Examine the blades for damage and security, and the coning stops for evidence of damage. Damage to the tail rotor blades which is beyond limits, will normally entail either inspection or replacement of the hub, pitch change links, tail rotor gear box and driven shaft.

Rotor Overspeeding

The extent of the inspection will normally depend on the degree of overspeeding. Overspeeding below a specified limit will usually entail checking the rotor blades for distortion and damage, and the rotor head for cracks and smooth operation, but, if this limit is exceeded it is usually specified that both the main rotor head and tail rotor head should be removed for overhaul. If damage has occurred to the main rotor blades, the rotor head, shaft, pitch control rods, tail rotor and transmission should also be removed for overhaul, and the gearbox attachments should be inspected for damage.

CHAPTER: 21
RIGGING CHECKS ON AIRCRAFT

LEVELLING THE AIRCRAFT

The position or angle of main components is related to a longitudinal datum line parallel to the aircraft centre line and a lateral datum line parallel to a line joining the wing tips. Before these positions or angles are checked, the aircraft should (generally) be brought to the rigging position (i.e., with the lateral and longitudinal datum lines horizontal) by means of jacks or trestles, depending on the particular aircraft type, with the wheel just clear of the ground.

For the purpose of checking the level of smaller types of aircraft, fixed or portable datum pegs or blocks, on which can be rested a straight-edge and spirit level and which are generally attached to the fuselage parallel to or coincident with the datum lines, are used, although in some instances parts of the structure which run parallel with the datum lines (e.g. top longerons or canopy rails of some aircraft) may be utilised. A typical levelling arrangement is shown in Figure, above.

The methods of checking the levelling given above are also applicable to many of the larger types of aircraft but other methods are sometimes used, e.g. the "grid" method illustrated in Fig. below The grid plate is a permanent fixture on the floor of the aircraft and, when the aircraft is to be levelled, a plumb bob is suspended from a predetermined position in the roof of the aircraft over the grid plate. The adjustments necessary to the lifting gear to bring the aircraft to the level position are indicated by the grid scale, true level being obtained when the plumb bob is immediately over the centre point of the grid.

The method of bringing the aircraft to the rigging position depends largely on the size of type of aircraft and whether a nose wheel of tail wheel configuration applies, the general procedures applicable to each case being given below:

A level site capable of bearing the load to be applied should be selected for the operation otherwise, where trestles are used, it may not be possible to level the aircraft, and where jacks are used, the danger of the jacks toppling and dropping the aircraft would exist.
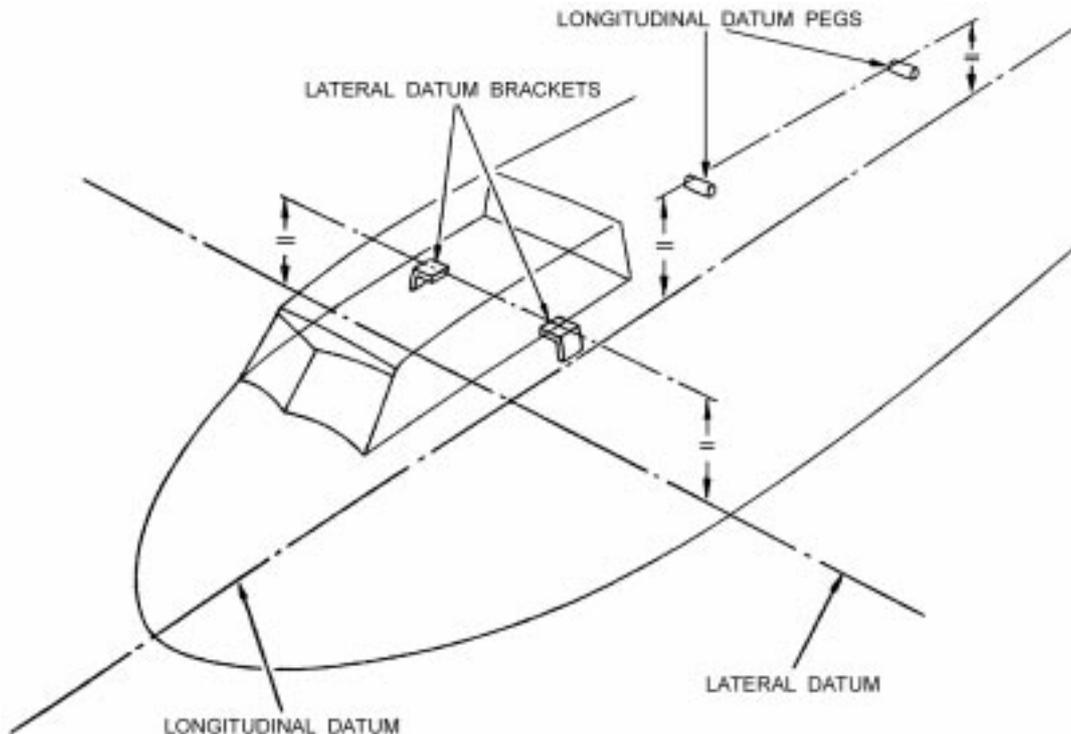
Fig. 1. Datum lines and levelling points.
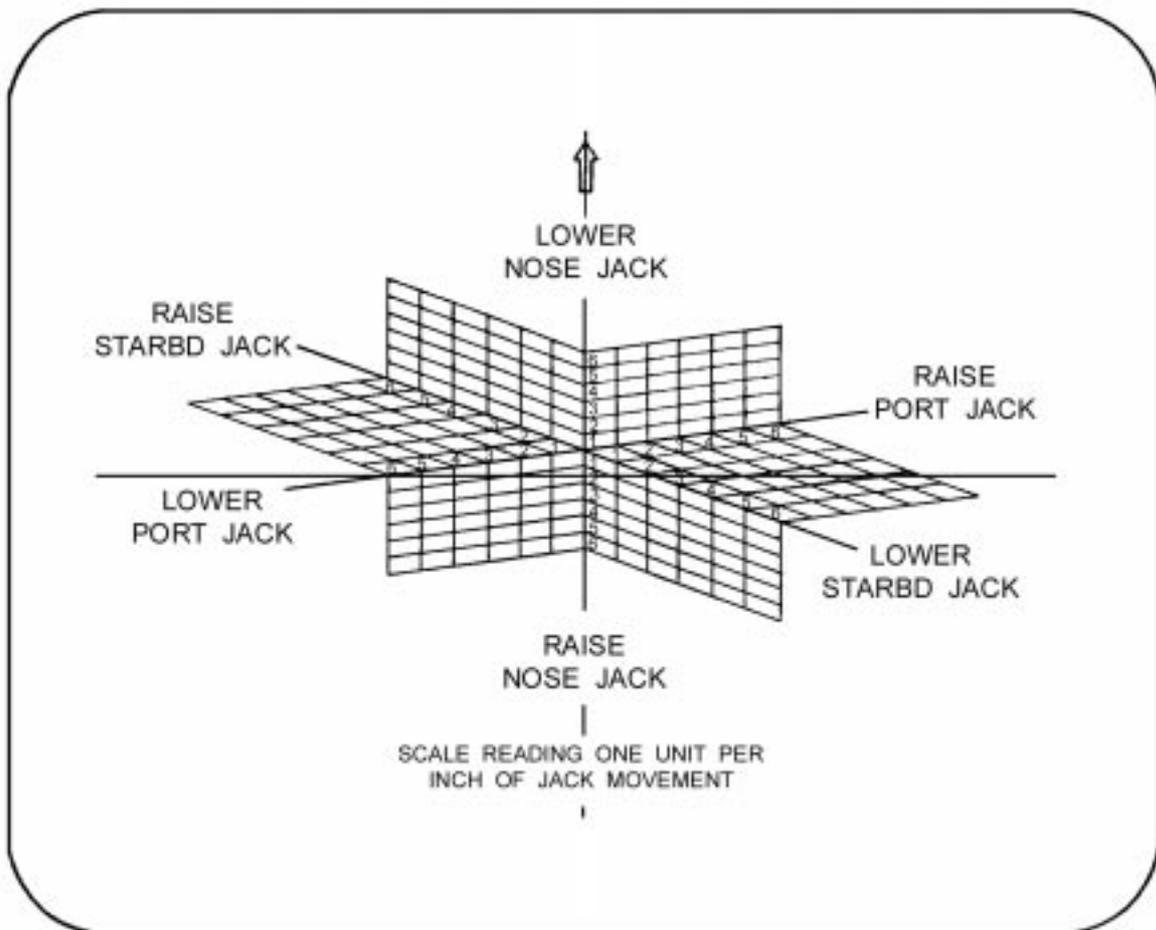
Fig. 2. Typical grid plate.

Rigging checks should not normally be undertaken in the open, but if this is unavoidable the aircraft should be positioned nose into wind. In many case the aircraft should not be lifted in strong winds or gusts.

The weight and loading of the aircraft for the rigging check should be exactly as described in the manual or as quoted on the original rigging chart supplied by the manufacturer. Variations from this condition, especially in the case of larger aircraft, will prohibit a comparison with the original figures. In any case the aircraft should not be lifted until it is ensured that the maximum jacking weight (if any) specified by the manufacturer will not be exceeded.

All equipment which may cause damage to the aircraft during the lifting operation should be moved away before lifting is commenced and no personnel other than those directly connected with the rigging check should be permitted on or around the aircraft for the duration of the complete operation.

For most aircraft the brakes should be OFF and the wheels chocked prior to lifting but for aircraft fitted with levered suspension undercarriage units the wheels should be left un-chocked.

Tail Wheel Aircraft

The tail should be raised to an approximately level position by means of the appropriate jacks or adjustable trestle accurately positioned under the rear lifting position. Where single-engine aircraft in particular are concerned, it may be necessary to weight down the tail to prevent the aircraft nosing over due to the weight of the engine. This weight must not be allowed to swing but must touch the ground and be secured by a taut rope to that part of the aircraft specified by the manufacturer.

The appropriate jacks or adjustable trestles should be accurately positioned under the main lifting points and the aircraft raised evenly by operating both jacks or trestle gears together until the wheels are just clear of the ground and the aircraft is in the (approximate) rigging position.

The lateral and longitudinal levels should be checked and adjusted as necessary by means of the lifting gear. Where hydraulic jacks are used, the locking devices provided must be applied immediately the aircraft has been correctly positioned and , to ensure the safety of personnel, at any time when the jack is not actually being operated during the lifting of the aircraft.

If steady trestles are placed under the wings after the aircraft has been supported in the rigging position, it must be ensured that they are not in contact with the wings when incidence or dihedral checks are being made, that no adjustments are made to the lifting gear with the steady trestles in position and that the trestles are removed before any attempt is made to lower the aircraft.

Nose Wheel Aircraft

The appropriate trestles or jacks should be accurately positioned under the main, nose and (if applicable) tail positions. The main and nose lifting gear should be operated simultaneously and evenly until the aircraft is just clear of the ground and the operation completed as described in above two last paragraphs.

RIGGING CHECKS

Although the dihedral and incidence angles of conventional modern aircraft cannot be adjusted (with the possible exception of adjustable tailplanes) they should be checked at specified periods and after heavy landings or abnormal flight loads to ensure that the components are not distorted and that the angles are within permitted limits. The relevant figures together with permitted tolerances are specified in the appropriate manual for the aircraft concerned, but the actual figures relevant to an individual aircraft are recorded in the aircraft log book.

The usual method of checking rigging angles is by the use of special boards (or the equivalent) in which are incorporated or on which can be placed an instrument for determining the angle, i.e. a spirit level or clinometer as appropriate. On a number of modern aircraft the rigging can be checked by means of sighting rods and a theodolite. Guidance on various rigging checks are given below:

Sequence Of Rigging Checks

A suitable sequence for checking the rigging is as follows; it is essential that the checks should be made at all the positions specified in the relevant manual.
  i)   Wing dihedral angle (S)
  ii) Wing incidence angle (S)
  iii) Engine alignment
  iv) Tailplane lateral level or dihedral
  v)   Tailplane incidence angle.
  vi) Verticality of fin.
  vii) Symmetry check.

Checking Aircraft With Rigging Boards
Dihedral

The dihedral angle should be checked in the specified positions with the special boards provided by the aircraft manufacturer or, if no such boards are provided, with a straight-edge and clinometer. The method of checking with both types of board are shown in Fig.3.

Incidence

The incidence is usually checked in at least two specified positions, inboard and outboard, on the component to ensure that it is free from twist.
  i)   There are a variety of types of incidence boards, some having stops at the forward edge which must be placed in contact with the leading edge of the wing, whilst others are provided with location pegs which fit into some specified part of the structure, but the main purpose in each case is to ensure the board is fitted in exactly the position intended and, if the rigging is correct, that a clinometer on the top of the board will register zero or within a permitted tolerance about zero. In most instances the boards are kept clear of the board will register zero or within a permitted tolerance about zero. In most instances the boards are kept clear of the wing contour (so that the incidence check is not influenced by any irregularities which may occur in the contour) by means of short feet attached to the board. A typical wooden incidence board is shown in Fig below although, of course, some are manufactured of metal.
  ii) It must be borne in mind that modifications in areas where incidence boards are located may affect results. For example, if leading-edge de-icing shoes were fitted this might seriously affected the position taken up by a board having a leading edge stop as in Fig.4.

Fig.3.   Checking dihedral.
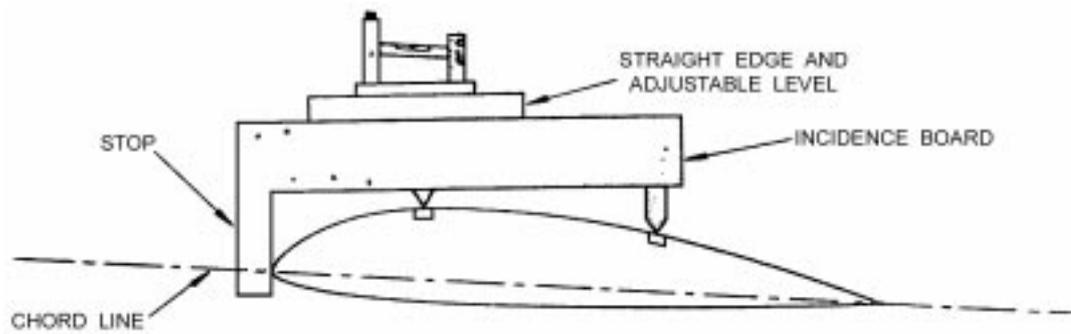
Fig.4. Typical incidence board.

iii) Where possible, the vertically of the incidence board should be checked with a plumb bob. Where the checks are being taken in the open and it is difficult to steady the plumb bob due to wind, the suspension of the plumb bob in a container of oil or water will be of assistance.

Verticality Of Fin

After the rigging of the tail planes has been checked, the verticality of the fin relative to a lateral datum can be checked from a given point on either side of the top of the fin to a given point on the port and starboard tail planes respectively; the measurements should be similar within prescribed limits. When the verticality of the fin stern post has to be checked, it may be necessary to remove the rudder and drop a plumb bob through the rudder hinge attachment holes, when the cord should pass centrally through all the holes. It should be noted that some aircraft have the fin offset to the longitudinal centreline to counteract engine torque.

Engine Mountings

Engines attached to the wings are usually mounted with the thrust line parallel to the horizontal longitudinal plane of symmetry but not always parallel to the vertical longitudinal plane, since, due to their disposition along the wing, the outboard engines are of ten offset a degree or so to enable the slipstream from the propellers to converge on the tailplane. The check to ensure that the position of the engine, including the degree of offset, is correct depends largely on the type of mounting, but usually entails a measurement from the centre line of the mounting to the longitudinal centre line of the fuselage at a point specified in the relevant manual.

Symmetry Check

Fig.5 illustrates the principle of a typical symmetry check, the relevant figures and tolerances for which will be found in the appropriate manual, although the actual measurements relating to the aircraft concerned are given in the aircraft log book.

i) For the smaller types of aircraft the measurements between points are usually taken by means of a steel tape. It is recommended that a spring balance should be used on the longer distances to obtain an equal tension, 5lb usually being sufficient.

ii) Where the larger types of aircraft are concerned, it is more usual to chalk the floor locally under the positions where the dimensions are to be taken, to drop plumb bobs from the checking points, marking the floor with an "X" immediately under the point of each plumb bob, and then to measure the distance between the centre of the markings. This method has the advantages of ensuring more measurement and reducing the amount of walking necessary on main planes and tail planes.

Rigging Checks On Biplanes

In general the rigging checks applicable to single-engined biplanes during reassembly after overhaul are follows, but specific requirements relating to a particular type of aircraft should be ascertained from the relevant approved manual. The use of rigging boards, etc., is described above as are other checks (such as the symmetry check) which are not peculiar to biplanes.

The fuselage should be levelled laterally and longitudinally. The centre-section should be placed on suitable trestles and the centre-section struts and wires (complete with fork-ends) attached.

The centre-section should be erected onto the fuselage and stagger and lateral symmetry checked. The stagger should be checked by dropping plumb bobs from the leading edge of the upper portion of the centre-section (or other defined position) and measuring the distance from the plumb bobs to the leading edge of the lower portion of the centre-section (or other defined position). If necessary the stagger can be adjusted by means of the front centre-section (or other defined position). If necessary the stagger can be adjusted by means of the front centre section struts on most aircraft of this type. The symmetry about the centre line should be checked by measuring from plumb bobs to the sides of the fuselage and can be adjusted, if necessary, by means of the bracing wires.

The port (or starboard) top main plane should be attached to the centre-section, care being taken to ensure that the main plane is adequately supported during the assembly. The landing wires should then be attached to the centre section, the port (or starboard) lower main plane attached to the centre-section, the interplane struts, flying wires and
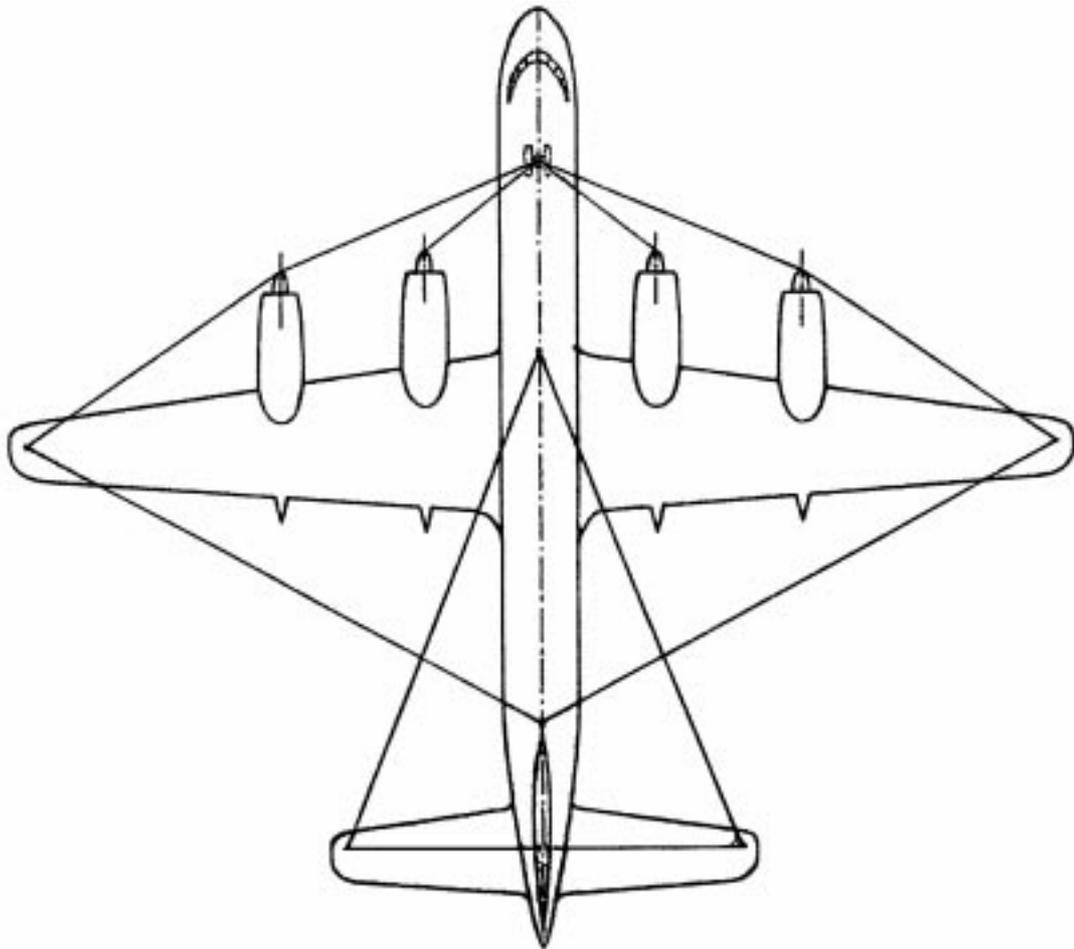
Fig.5. Symmetry check

incidence wires fitted and the whole assembly lightly tensioned up. The completed side of the aircraft should be steadied with a trestle whilst the opposite side is assembled in the same order.

After assembly the fuselage level should be re-checked and adjusted as necessary, after which the main planes should be trued-up by adjustments to the appropriate wires, the air being to achieve the correct dihedral first and then to work the incidence and stagger together. Care must be taken during rigging to ensure that the main flying and landing wires are not over-tensioned to the extent of bowing the main plane spars or inter-plane struts.

After the rigging of the main planes has been completed, it should be ensured that all fork ends, etc., are in safety, are not "butting" against the ends of the fitting and have been correctly locked that the wires are in streamline and that anti-chafing discs and spreader bars are correctly fitted to prevent vibration of the wires.

Empennage

The empennage should be attached in accordance with the instructions contained in the relevant manual and adjusted (where this is possible) to within the limits specified in the relevant rigging diagram. It should be noted that the tail plane struts are usually handed and, unless these are correctly positioned, the fairings will not be in line of flight.

TWIN-ENGINE BIPLANES

The general procedure for rigging twin-engined biplanes is basically similar to that described above for single-engined biplanes but it must be ensured that the weight of the engines is taken on the appropriate struts before completing the general rigging.

Checking Rigging With Sighting Rods

This method of checking rigging is used mainly on the larger types of aircraft and consists basically of sighting with a theodolite positions of datum marks on a series of rods of graduated lengths, each of which is inserted into a specified jigged position on the underside of the aircraft.

For the initial check, the aircraft should be brought to the rigging position and the sighting rods inserted at the appropriate stations.

A theodolite, erected at an appropriate distance and position from the aircraft should be levelled up with the datum mark on the master sighing rod (usually the shortest rod fitted under the fuselage) and then readings should be taken from this sighting line at each rod station and recorded. A typical method of taking the readings is illustrated in Fig.6.

The readings thus obtained must be within the tolerance permitted by the manufacturer, and entered in the aircraft log book for permanent record.

There are two basic methods applicable to the use of sighting rods and these are described below.

i) On some types of aircraft the sockets into which the sighting rods are inserted are adjustable in the vertical direction so that once variations from nominal figures have been recorded, the rods can be "zeroed" and permanently locked. Thus the sighting line on all subsequent checks should in fact coincide with the datum marks on the rods if the rigging is correct. Rods used for this method have the single datum.

ii) The second method is to use sighting rods on which are marked the datum line, on either side of which is also marked graduations indicating the permissible tolerance on the nominal figure in increments of 1/4 degrees. With this method the sockets into which the rods are inserted are not adjustable and subsequent readings should be given the actual figures recorded on the initial check.

When a component (e.g. wing or tail plant) is changed it will be necessary to again carry out the initial check to ascertain actual figures.

Lowering The Aircraft

Before any attempt is made to lower the aircraft to the ground it must be ensured that wing supports and any other equipment which might foul and damage the aircraft are moved clear. The aircraft should be lowered evenly and, when the aircraft weight is accepted on the undercarriage, the jacks should be further lowered to ensure that they can be removed without fouling the aircraft structure.

DEFINITIONS

Stager

The distance between the leading edge of the lower plane and the projection of the leading edge of the upper plane on the chord of the lower plane.

Anhedral

An inclination outwards and downwards relative to the lateral datum.
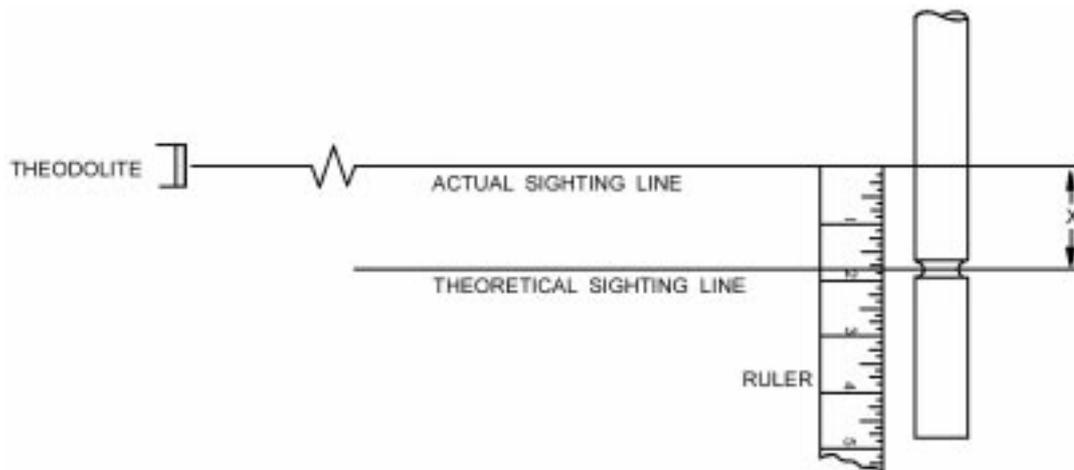
Fig.6. Typical method of taking readings.

Dihedral

The angle (or angles) at which the wings and tail planes are inclined outwards and upward relative to the lateral datum.

Flying Wires

Wires the principal function of which is to transfer the lift of the main planes to the main structure. These wires are sometimes termed "lift wires"

Landing Wires

Wires which brace the main plane against forces opposite in direction to the direction of lift, as occur, for example, in landing. These wires are sometimes termed "anti-lift wires".

Incidence

The angle between the chord line of the wing or tail plane and the longitudinal datum.

Incidence wires

Wire bracing the main plane structure in the plane of a pair of front and rear struts.

CHAPTER: 22
SOLVED QUESTIONS & ANSWERS
FROM AIRCRAFT STRUCTURE PART

1. What are the principal load carrying structures of an airplane?
Ans. The principal load carrying sections or components include the fuselage, lifting surfaces, control surfaces, stabilizers, and landing gear. The fuselage is the central aircraft component which has a cockpit or flight deck for the crew and a section for the passengers and cargo. The lifting surfaces include the wings on airplanes and gliders and the main rotors of helicopters. Control surfaces include ailerons rudders, elevators, flaps, spoilers, and trim tabs. Stabilizers are used to improve the pitch and yaw stability of the aircraft and the operating terrain.

2. Name five stresses.
Ans. The stresses (effects of applied forces) to which structural members are subjected are compression, tension, torsion, bending, and shear.

3. Compare stress and strain.
Ans. The term stress is often used interchangeably with word "strain" stress in an internal force of a substance which opposes or resists deformation. Strain is the deformation of a material or substance.

4. What is meant by stress analysis?
Ans. When an airplane is designed, the loads which are likely to be applied to parts or assemblies of the airplane during operation are carefully computed and analyzed by engineers. This process is called stress analysis. The performance of the stress analysis ensures that the airplane will perform according to its approved specifications without danger of failure.

5. Nomenclature and Definitions.
Ans. The definitions given below are provided as a convenient reference for the components of aircraft and some of the relationships between components.

Aileron
One of a pair of movable control surfaces attached to the trailing edge of each wing tip. The purpose of the ailerons is to control the airplane in roll by creating unequal or opposing lifting forces on opposite sides of the airplane. Large jet airplanes often employ double sets of ailerons a small inboard set for cruise speeds and a larger outboard set for approach and landing speeds.

Angle of Incidence
The angle between the chord of an airfoil and the longitudinal axis of an airplane.

Angle Of Stabilizer Setting
The angle of incidence of a vertical or horizontal stabilizer.

Angle Of Sweep
The angle between a reference line in a swept or tapered airfoil and a given reference line established for the purpose. For fixed airfoils, the angle is measured between the lateral axis of the airplane and the reference line of the airfoil usually the mean chord line.

Anti drag Wire
A wire in certain kinds of wing structures, running from an inboard point near the trailing edge to an outboard point near the leading edge, designed to resist forces acting on the wing in the direction of flight.

Anti lift Wires Same as landing wires.

Balanced Control Surface
A control surface that is in desired condition of equilibrium about its hinge axis. Such a surface can be balanced for either static or aerodynamic conditions.

Balancing Tab
A tab so linked that when the control surface to which it is attached is deflected, the tab is deflected in an opposite direction, creating a force that aids in moving the larger surface.

Boom (Also Tailboom)

A tubular or truss structure extending aft from the aircraft fuselage. Normally found on helicopters to support the tail rotor and its systems or to support control surfaces on an aircraft having a pusher propeller installation.

Bulkhead

A vertical structural member that, with other bulkheads often include walls or partial walls which separate fuselage compartments from one another. Lighter frames or formers are used for support between bulkheads.

Cabane

An arrangement of struts used to support a wing above the fuselage of an airplane.

Canard

An aircraft or aircraft configuration having its horizontal stabilizing and control surfaces in front of the wing or wings.

Cantilever

A beam or member supported at or near one end only, without external bracing.

Center section

The middle or central section of an airplane wing to which the outer wing panels are attached.

Chord Line

A straight line connecting the leading edge and the trailing edge of an airfoil.

Cockpit

On small aircraft, the area occupied by the pilot and passengers. On cabin airplanes, if the pilot's compartment is separated from the rest of the cabin, it is often called the cockpit.

Cockpit Canopy

A transparent cover for the cockpit.

Control Cables

Cables connecting the control levers with the control surfaces.

Control Stick

A vertical lever by means of which the pilot operates the longitudinal and lateral control surfaces of the airplane. The elevator is operated by a fore-and-aft movement of the stick, and the ailerons are moved by a sideways movement of the stick.

Control Surface

A movable airfoil or surface, such as an aileron, elevator, rudder vator, flap, trim tab, or rudder, used to control the attitude or motion of an aircraft in flight.

Control Wheel

A wheel or semiwheel used in connection with the control column in an airplane. Rotation of the wheel operates the ailerons for control about the roll axis. Fore-and-aft movement of the wheel operates the elevators to pitch the airplane about the lateral axis.

Cowling

A removable cover or housing placed over or around an aircraft component or section, especially an engine.

Decalage

The difference between the angles of incidence for two airfoils on the same airplane. It generally refers to the two wings of a biplane.

Dihedral Angle

The angle between the aircraft lateral axis and the projection of the wing axis of the airplane. If the tip of the wing is higher than the root section, the dihedral angle is positive; if lower, the dihedral angle is negative.

Drag Strut

Any strut used to resist drag or antidrag forces. In a wing it is a for-and-aft compression member. In landing gear it is a strut that runs diagonally up into the airplane to resist drag forces.

Drag Wire

A wire in certain kinds of wing structures running from a forward inboard point to an aft outboard point to resist drag forces.

Elevator
A movable auxiliary airfoil or control surface designed to control the pitch attitude of the aircraft and the angle of attack of the wing. It controls rotation about the lateral axis.

Elevons
Control surfaces which serve the functions of the elevators and ailerons on all-wing and delta-wing aircraft.

Fairing
A piece, part, or structure, having a smooth stream lined contour, used to cover a nonstreamlined object or to smooth a junction.

Fin
A vertical stabilizer.

Firewall
A fireproof or fire-resistant wall or bulk-head separating an engine from the rest of the aircraft structure to prevent the spreading of a fire from the engine compartment.

Flap
A hinged, pivoted, or sliding airfoil or plate, normally located at the trailing edge of a wing, extended or deflected downward to increase the lift and / or drag. It is generally used for takeoff or landing.

Frame
A vertical structural member which supports the stringers and skin of a wood or metal fuselage and gives the fuselage shape.

Fuselage
The main or central structure of a heavier-than-air aircraft, typically elongated and approximately streamlined, which carries the crew and passengers and to which the wings are attached.

Gap
The distance between the chords of two superposed airfoils.

Horizontal Stabilizer
A stabilizer mounted horizontally on an airplane affording longitudinal stability and to which elevators are attached.

Horn
A short lever fastened to a control surface to which an operating cable or rod is attached.

Inspection Door
A small door used especially for inspection of the interior of an airplane.

Intercostal
A rib or internal brace inside a box beam spar.

Interplane Strut
A strut between two wings or other surfaces.

Jury Strut
An auxiliary strut that braces a main strut or struts.

Landing Gear
The microstructure that supports the weight of the airplane on the ground, also called alighting gear.

Landing Wire
Wires or cables that brace the wings against the forces that are opposite to the normal direction of lift. These wires attach to the upper wire above the fuselage and to the lower wing near the outboard end on a biplane.

Leading Edge
The foremost or front edge of an airfoil or a propeller blade. The rearmost edge is called the trailing edge.

Lift Strut
A structural member attached at one end to some midpoint of a wing or stabilizer and at the other end to the fuselage. This external structural member holds the wing or stabilizer in a fixed position relative to the fuselage and carries structural loads between the surface and the fuselage.

Lift Wires
Wires or cables that brace the wings against the forces of lift. They are also called flying wires.

Longeron
A principal longitudinal (fore-and-aft) member of the framing of an aircraft fuselage, usually continuous across a number of points of support.

Main Rotor
The principal rotating airfoil used to generate lift and support the weight of a rotorcraft. A rotorcraft may have one or two main rotors. In a helicopter the main rotor generates propulsive thrust along with lift.

Nose Wheel
A wheel placed ahead of the main landing gear of an aircraft to support the weight of the forward portion of the airframe.

Plating
The heavy metal skin, often tapered in thickness, used to cover the wings and other parts of larger aircraft.

Rudder
A hinged or movable airfoil used to control the yawing motion of an aircraft.

Rudder Pedal
Either one of a pair of cockpit pedals for operating a rudder or other directional-control device.

Rudder Vator
A control surface, set at a pronounced dihedral (forming a wide V), that serves as both a rudder and elevator.

Shock Absorber
A device built into the landing gear to reduce the shock during landing or taking off.

Skip
A fixed type of landing gear made of tubular and/or flat structures, normally associated with helicopters.

Slat
An auxiliary airfoil contoured to the leading edge of a wing when closed. When open, it forms the slot to improve airflow at high angles of attack.

Slot
A fixed opening in the leading edge of an airfoil which is used to direct airflow over the surface at high angles of attack to improve control and lift at these attitudes.

Span
The maximum distance, measured parallel to the lateral axis, from tip to tip of any surface such as a wing or stabilizer.

Spar
A primary structural member of a wing, stabilizer, control surface, rotor, or other aerodynamic surface.

Spinner
A fairing of approximately conic or paraboloidal shape, fitted coaxially with the propeller hub and spinning with the propeller.

Spoiler
A device located on the top surface of a wing which can be extended to reduce or "spoil" the lift of the wing. This may be used to control the aircraft rate of descent, lateral movement (roll), or to increase braking effectiveness on landing.

Stabilator
A horizontal control surface that is designed to serve as both a stabilizer and an elevator. It is moved about its hinge line by means of the pilot's control.

Stabilizer
A fixed or adjustable airfoil or vane that provides stability for an aircraft.

Stagger
With two or more superposed objects or objects fixed in a row, the advance or the amount of advance of one object ahead of another. The amount of advance of one wing of a biplane ahead of the other, of a compressor blade ahead of another, or of one rotor of tandem-rotor helicopter ahead of the other.

Stagger Wire
On a biplane, a diagonal wire, usually one of a pair forming an X, running fore and aft between the two wings and helping to maintain a constant stagger.

Stringer
A longitudinal structural member installed between fuselage frames and formers to give support and strength to the skin.

Strut
A supporting brace that bears compression loads, tension loads, or both, as in a fuselage between the longerons or in a landing gear to transmit the airplane loads.

Sweepback
The backward slant from root to tip of an aerodynamic surface.

Tailboom
See Boom.

Tail Rotor
The small rotor mounted on a shaft at the tail of a helicopter to counteract the torque of the main rotor and provide directional control for the helicopter. Sometimes it is referred to as an anti torque rotor.

Tail Skid
On certain older airplanes, a skid attached to the rear part of the airplane on the underside and supporting the tail.

Tail Wheel
A wheel at the tail of certain airplanes used to support the tail section on the ground. A tail wheel may be steerable, retractable, fixed, castering, etc.

Trailing Edge
The aft edge of an airfoil surface.

Trim Tab
A tab attached to the trailing edge of an airfoil, used to aid in control surface operation.

Wing Rib
A chord wise member used to give the wing its shape and to transmit the load from the surface covering to the spars.

Wing Spar
A principal span wise member in the structure of a wing.

Wing Tip
The outer extremity of a wing.

Q.6.   Name three types of fuselages classified according to the method by which stresses are transmitted.
Ans. Fuselage is classified in three principal, types depending upon the method by which stresses are transmitted to the structure. The three type according to their classification are : Truss, Semimonocoque and monocoque.

Q.7.   What is a load carrying part of a monocoque fuselage.
Ans. Skin is the load carrying part of a monocoque fuselage.

Q.8.   Describe a truss structure.
Ans. A truss is an a assemblage of members forming a rigid framework, which may consist of bars, beams, rods, tubes, wires, etc. The truss-type fuselage may be sub classified as the Pratt truss and the Warren truss. The primary strength members of both Pratt and Warren trusses are the four longerons. As defined previously, the longeron is a principal longitudinal member of the aircraft fuselage. In the truss-type fuselage, lateral bracing is placed at intervals. The lateral structures may be classed as bulkheads, although this is not strictly true from the technical standpoint : the spaces between the bulkheads are called bays.

A Pratt Truss
Similar to the type used in present aircraft with tubular fuselage members is shown in figure. In the original Pratt truss the longerons were connected with rigid vertical and lateral members called struts, but the diagonal members were made of strong steel wire and were designed to carry tension only. In the Pratt truss shown in figure, the diagonal members are rigid and can carry either tension or compression.

A Warren Truss

Is illustrated in figure in this construction, the longerons are connected with only diagonal members. Normally, all members in the truss are capable of carrying both tension and compression. When the load is acting in one direction, compression loads are carried by every other member while the alternate members carry the tension loads. When the load is reserved, the members that are carrying tension previously now carry compression and those that were carrying compression now carry tension.

Q.9.   What is the term for the longitudinal (fore-and-aft) structural members of a semimonocoque fuselage?

Ans.   The longitudinal members of a semimonocoque fuselage are called as stringers, and they serve to stiffen the metal skin and prevent it from bulging or buckling under severe stress.

Q.10.   Describe the construction of a typical metal fuselage.

Ans.   The great majority of fuselages are all-metal and semimonocoque in construction. This applies to small, medium, and large aircraft. The interior structure to which the skin or plating is attached consists of longerons, frames, bulkheads, stringers, gussets, and possibly intercostal members riveted, bolted, or bonded together to form a rigid structure which shapes the fuselage. The skin or plating is riveted or bonded to the structure to form the complete unit.

Q.11.   Why does the skin thickness on a metal fuselage vary at different locations?

Ans.   Skin thickness on a metal fuselage vary at different location because the load which skin has to carry varies at different places. Places where the skin has to carry more loads there the thickness will be more e.g. the passenger cabin have thicker skin than the tail section.

Q.12.   What is a fail safe feature in aircraft construction?

Ans.   Many aircraft designs are now incorporating components which are termed " fail-safe." These major structural fittings are made in two parts and joined together by riveting or bonding. Each half of the two structural parts in capable of carrying the full required structural load of the assembly. With this design philosophy, the failure of one of the fitting components will not result in a structural failure of the attachment in flight. In some large aircraft, a fail-safe feature is also incorporated into the metal skin. For example, on a DC - 8, titanium rip-stop doublers are used to reinforce the skin at strategic fuselage frames and at each door and window. In addition, beaded doublers are used in the window belt area forward of the front spar.

Q.13.   Discuss the construction of fuselages for large jet airplane.

Ans.   Because of their size, transport aircraft fuselages are commonly constructed by first building sub assemblies of long panels several feet high. These panels are then joined on a mating jig to form the circular shape of a fuselage. The fuselage is then assembled by connecting the forward, mid, and aft fuselage sections.

The forward section tapers the cross section of the fuselage to the front of the aircraft. This section has provisions for the flight crew stations.

The transport fuselage contains one or more mid-section assemblies. These mid section assemblies are basically circular in shape with a constant cross-section size. The mid section contains structures to connect the fuselage to the wing and may include landing gear attachment points.

The aft section changes the cross-sectional shape of the fuselage into the size and shape necessary to join with the fuselage after body or tail cone. The after body or tail cone is the point of attachment for the aft flight control surfaces and, depending on the aircraft design, may also incorporate an engine installation area. The fuselage section are joined to complete the basic assembly of the fuselage.

Q.14.   List the principle load-carrying structural components in a light aeroplane wing.

Ans.   A cantilever wing contains all of its structural components in a light airplane wing are spars, ribs and surface coverings.

Q.15.   What is the primary structural design difference between a cantilever wing and semi cantilever wing?

Ans.   A cantilever wing contains all of its structural strength inside the wing structure and requires no external bracing. This type of wing is normally found on high-performance aircraft and on transports. The semi cantilever design obtains its strength both by internal wing design and external support and by bracing such is comes from struts and wires. This type of wing is usually found on light aircraft designs and relatively slow aircraft designed to carry heavy loads. All wings can be considered to be of semimonocoque construction as the internal structure carries the primary loads of the wing.

Q.16.   Discuss different types of construction for metal ribs in a light airplane wings.

Ans.   Typical metal ribs are shown in fig. Starting at the top of the illustration the built-up rib is used in conjunction with metal spars and is riveted to them. The stamped rib with lightening holes and the stamped rib with a truss-type cross section are used with either metal or wood spars. The rib at the bottom of the picture is stamped in three sections and is usually riveted to metal spars.

Q.17.   How is a metal wing sealed so it may be used as a fuel tank?

Ans.   Fuel tanks are included in the basic wing structure so that the wing serves as the fuel tank. This is known as an integral fuel tank design, also referred to as a "wet wing." The integral tanks are sealed with special compounds

applied to fasteners and between components during assembly. Areas of the wings that do not contain fuel are termed "dry bays".

Q.18. Discuss the construction of a large jet airplane wing. What is the mainframe of a large aircraft wing? What is meant by auxiliary structure of a wing?

Ans. The main frame of a modern transport wing consists of the spars, ribs, bulkheads, and skin panels with span wise stiffening members. The assembly of the structure may include the use of nonmetallic composite components and the bonding of metal structures as well as the use of conventional metal alloys and fasteners. The structural strength of the wing must be sufficient to carry its own weight along with the weight of the fuel in the wings, the weight of engines attached to the wings, and the forces imposed by the flight controls and landing gear. These stresses vary tremendously in direction and in magnitude during the aircraft's transitions from moving on the ground to flight operations to returning to the ground.

Transport wings consists of two or more main spars with intermediate spars used between the main spars in some designs. These intermediate spars assist the main spars in carrying the operational loads. The front and rear spars provide the main supporting structure for fittings attaching the fuselage, engine pylons, main landing gear, and flight surfaces to the wing. Between the spars are located ribs which, depending upon their design, may be used for purposes such as fuel bulkheads and the support of control surface along with providing the airfoil shape of the wing.

The auxiliary structure of the wing includes the wing tips, leading edge, and trailing edge. The leading edge of the wing incorporates leading-edge ribs, structural reinforcement members, and attachment points for components such as slats and leading - edge flaps. The trailing edge also incorporates structural members serving similar purposes to those of the leading edge. The trailing - edge structure normally incorporates an extensive structure to carry and transmit the loads imposed by the operation of the flight controls such as flaps and ailerons.

The wing internal structures are covered with large metal skin panels which have span wise stringers attached to achieve the desired structural strength of the wings. The leading edge and trailing edge are attached with permanent-type fasteners. The wing tips are removable for inspection and maintenance.

In many transports, the wing is constructed in three or more major assemblies, such as the left-and right - wing panels and a center-wing section. These sections are joined with permanent fasteners to form a one-piece wing which is attached to the fuselage.

The fittings used to attach the fuselage, engine pylons, main landing gear, and flight control surfaces to the wing are secured with interference-fit and close-tolerance fasteners and are not considered removable except for structural repair. An "interference-fit" fastener is a bolt, pin, or rivet which is slightly larger than the hole in which it is installed. It must be pressed into place, and during this procedure it tends to stretch the metal into which it is installed. The result is that there can be no "play" or clearance between the fastener and the installation regardless of expansion or contraction due to temperature changes. The fastener and the fitting essentially become one unit. Fuel tanks are included in the basic wing structure so that the wing serves as the fuel tank.

Q.19. What flight control surfaces are generally attached to the wing structure of a large airplane?

Ans. Control surfaces generally attached to the wing structure of a large airplane are ailerons, flaps, tabs, leading edge flaps and starts, spoilers and speed brakes.

Q.20. Describe the construction of a typical stabilizer for a light airplane and what is the purpose of a vertical stabilizer? What is dorsal fin.

Ans. The stabilizers and the control surfaces of an airplane are constructed in a manner similar to the wings but on a much smaller scale. They usually include one or more primary members (spars) and ribs attached to the spars. The vertical stabilizer (fin) may be constructed as a part of the fuselage or may be a separate member that is both adjustable and removable. The tail section of an airplane, including the stabilizers, elevators, and rudder, is commonly called the empennage.

Horizontal Stabilizer

The horizontal stabilizer is used to provide longitudinal pitch stability to the aircraft and is usually attached to the aft portion of the fuselage. It may be located above or below the vertical stabilizer or at some midpoint on the vertical stabilizer.

The stabilizer may be constructed of wood, steel tubing, sheet metal, or composites materials. The method of construction is similar to that used for wings, with spars, ribs, stringers, and a surface skin being used.

The horizontal stabilizer may be designed as a fixed surface attached to the tail cone or as a movable surface used to provide pitch trim.

If the stabilizer is designed to provide pitch trim, it normally is attached to the fuselage with a pivoting hinge as its rear spar. At the front spar is an attachment for a mechanical or hydraulic actuator which is controlled by the pilot to move the leading edge of the stabilizer up and down to change the trim of the aircraft.

Vertical Stabilizers

The vertical stabilizer for an airplane is the airfoil section forward of the rudder and is used to provide longitudinal (yaw) stability for the aircraft. This unit is commonly called the fin. The construction of the vertical stabilizer is very much like that of the horizontal stabilizer, and, as mentioned previously, it may be constructed as an integral part of the fuselage. The rear structural member of the fin is provided with hinges for the support of the rudder. On many aircraft a dorsal fin is installed immediately forward of the vertical stabilizer. The function of the dorsal fin is to improve the

yaw stability of the aircraft and to provide a streamline fairing between the vertical stabilizer and the fuselage.

Some aircraft, especially those equipped with floats of external cargo pods, may also require the addition of a ventral fin on the bottom of the fuselage in the area below the vertical stabilizer. Some aircraft also require the use of auxiliary vertical stabilizers, mounted on the horizontal stabilizer.

Q.21. Name the primary and secondary control surfaces of an airplane.
Ans. The primary control surfaces of an airplane include the ailerons, rudder, and elevator. Secondary control surfaces include tabs, flaps, spoilers, and slats.

Q.22. Discuss the need of a drain holes in the bottom surfaces of ailerons and other control surfaces.
Ans. A drain holes in the bottom surfaces of ailerons and other control surfaces is included to prevent water from becoming trapped inside the structure and causing the control surfaces to be thrown out of balance.

Q.23. Why is the hinge line of an aileron usually set back from the leading edge?
Ans. Aileron control systems operated by the pilot through mechanical connections require the use of balancing mechanisms so that the pilot can overcome the air loads imposed on the ailerons during flight. Balancing of the ailerons can be achieved by extending part of the aileron structure ahead of the hinge line and shaping this area so that the airstream strikes the extension and helps to move the surface. This is known as aerodynamic balancing. Another method which may be used is to place a weight ahead of the hinge line to counteract the flight loads. This is known as static balancing. Some aircraft may use a combination of these technique.

Q.24. Why are some ailerons rigged to provide differential control?
Ans. The geometry of the control system for the ailerons affects the amount that the ailerons move above or below the neutral setting. (The neutral setting fairs the ailerons with the wing contour). Some aircraft have their ailerons operating asymmetrically that is, they move up the same amount that they move down. Other aircraft have the ailerons operating asymmetrically that is, the upward-moving aileron moves further than the downward-moving aileron. This asymmetrical operation is used in some aircraft designs to reduce the amount of rudder pressure required when making turns. This reduces what is known as "adverse aileron yaw," which is caused by the downward-moving aileron creating an increase in aerodynamic drag, and results in the airplane yawing away from the direction of the desired turn. Aircraft having this arrangement are sometimes said to have differential ailerons.

Q.25. Why rudders are balanced both statically and aerodynamically?
Ans. Rudders are usually balanced both statically and aerodynamically to provide for greater ease of operation and to eliminate the possibility of flutter. It should be noted that some light-aircraft rudders do not use any balancing method. Different rudders for light aircraft are shown in below.

Q.26. How is aerodynamic balance accomplished an elevator?
Ans. It is aerodynamically balanced in manner similar to aileron ref. question 23.

Q.27. Describe Stabilators, ruddervators, and flaperons.
Ans. Some aircraft use combination control surfaces which combine the operation of at least two control and/or stabilizer surfaces into one component. By the use of combination surfaces, the construction of the aircraft can be simplified and the desired control response can be achieved. Examples of these types of control surfaces include stabilators, ruddervators, and flaperons.

A stabilator combines the function of a horizontal stabilizer and an elevator. This type of surface is used primarily on light aircraft designs and on some high-performance military aircraft. The stabilator usually incorporates a static balance weight on an arm ahead of the main spar. This weight can project into the aircraft structure or be carried on the forward portion of the tips of the stabilator. A stabilator is normally equipped with an anti-servo tab which doubles as a trim tab. The anti servo tab moves in the same direction as the control surface is moved to aid the pilot in returning the trimmed neutral position.

Ruddervators are flight control surfaces which serve the functions of the rudder and elevators. This is accomplished by mounting the surfaces at an angle above horizontal. When serving as elevators, the surface on each side of the tail move in the same direction, either up or down. When serving as a rudder, the surfaces move in opposite directions, one up and one down. When combined rudder and elevator control movements are made by the pilot, a control mixing mechanism moves each surface the appropriate amount to get the desired elevator and rudder effect.

Flaperons are surfaces which combine the operation of flaps and ailerons. These types of control surfaces are found on some aircraft designed to operate from short runways. The flaperon allows the area of the wing normally reserved for the aileron to be lowered and creates a full-span flap. From the lowered position the flaperon can move up or down to provide the desired amount of roll control while still contributing to the overall lift of the wing.

Q.28. Why are tabs usually attached to the trailing edges of flight control surfaces.
Ans. Tabs are small secondary flight control surfaces set into the trailing edges of the primary surfaces. These are used to reduce the pilot's work load required to hold the aircraft in some constant attitude by "loading" the control surface in a position to maintain returning a control surface to a neutral or trimmed-center position. Tabs allow the flight crew to reduce or eliminate the pressure that they must apply to the flight controls.

Q.29. What is a trim tab?

Ans. A fixed trim tab, is normally a piece of sheet metal attached to the trailing edge of a control surface. This fixed tab is adjusted on the ground by bending it in the appropriate direction to eliminate cabin flight control forces for a specific flight condition. The fixed tab is normally adjusted for zero control forces while in cruising flight. Adjustment of the tab is a trial-and-error process where the aircraft must be flown and the trim tab adjusted based on the pilot's report. The aircraft must then again be flown to see if further adjustment is necessary. Fixed tabs are normally found on light aircraft and are used to adjust rudders and ailerons.

Controllable trim tabs are found on most aircraft with at least the elevator tab being controlled. These tabs are normally operated mechanically by a cable and chain system, electrically by a screw jack mechanism or a motor to drive the cable and chain system, or hydraulically through actuators. When the pilot wishes to change the attitude of the aircraft with the trim system, be activates the trim control system and causes the trim tab to be deflected in the direction opposite to the desired movement of the control surface. When the trim tab is deflected into a airstream, the air tries to push the tab back flush with the control surface. Since the control mechanism prevents the tab from being pushed back flush, the whole control surface is moved.

Controllable trim tabs are adjusted by means of control wheels or cranks in the cockpit, and an indicator is supplied to denote the position of the trim tab. If the tabs can be operated electrically or hydraulically, they will incorporate some instrumentation to indicate tab position.

Q.30. What is the purpose of slat.

Ans. The use of slats on the leading edge of high-performance wings is a common method of reducing stalling speed and increasing lift at comparatively slow speeds. The slat forms the leading edge of the wing when not extended and creates a slot at the leading edge when extended. The slot permits air from the high-pressure area under the leading edge to flow up through the leading edge and to be directed along the top of the wing. This effectively reduces the possibility of stall at lower speeds. Slats which extend to form slots may be actuated aerodynamically or by mechanical control.

Q.31. Short note on servo tabs, anti servo tab and control tab.

Ans. Servo tabs are used to aid the pilot in the operation of flight controls. When the pilot moves a primary flight control, a servo tab deflects in the proper direction to aid the pilot in moving the control surface. This reduces the force which the pilot must supply to the control system to manoeuvre the aircraft.

An anti-servo tab is used to aid the pilot in returning surface, such as a stabilator, to the neutral position and prevent it from moving to a full deflection position due to aerodynamic forces. This type of tab has the opposite effect of a servo tab. The anti-servo tab often also serves as the pitch trim tab by allowing the pilot to adjust the neutral trim position.

A control tab is used on some transport aircraft as a manual backup to flight controls which are normally operated hydraulically. When in a manual reversion mode, the pilot can operate the control tabs, and by their tab action they will cause the flight controls to move in the appropriate direction.

Q.32. What type of landing gear is most commonly employed on aircraft?

Ans. Two type of landing gear are most commonly employed on aircraft they are fixed and retractable and it may also be classified according to arrangement of the aircraft.

A fixed landing gear is attached to the airframe so that it is held in a fixed position. As it is always in the airstream, this type of landing gear generates a significant amount of aerodynamic drag. This arrangement is normally found on relatively low speed aircraft and aircraft designed for simplicity of operation.

A retractable landing gear is carried partially or completely inside the airframe structure to reduce drag. When necessary for landing, the gear is extended by some mechanism. The gear is retracted into the airframe after takeoff.

An aircraft can have a combination of fixed and retractable landing gear and the wheels are retractable.

The basic landing-gear configurations for aircraft operating on land includes conventional, tricycle, quadra cycle, in line, and skids.

Q.33. What is the usual means for shock absorption in leading edge?

Ans. Various methods are used to absorb the force of ground contact upon landing. These methods can be divided into two types of "shock-absorbing" processes; the energy-dissipating type and the energy-returning type. An energy-dissipating-type landing gear cushions the contact with the ground and changes the energy of the contact into heat by causing a liquid to flow through a restricted orifice and/or heating air by compression. This heat is then radiated to the surrounding atmosphere. Examples of this type of landing gear include air-oleo and spring-oleo shock absorbers.

Energy-returning-type landing gear absorbs the shock of the aircraft contacting the ground and then returns the energy to the aircraft by exerting an upward force on the aircraft after a very short period of time. This type of landing gear includes the use of rigid gear legs, bungee cords, rubber disks, and spring-type landing gear.

In both types of shock-absorbing methods, some of the energy of ground contact is dissipated through the scrubbing of the tires and friction of motion between components and mounting structures.

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