PART I - PHASE I

THEORY OF FLIGHT

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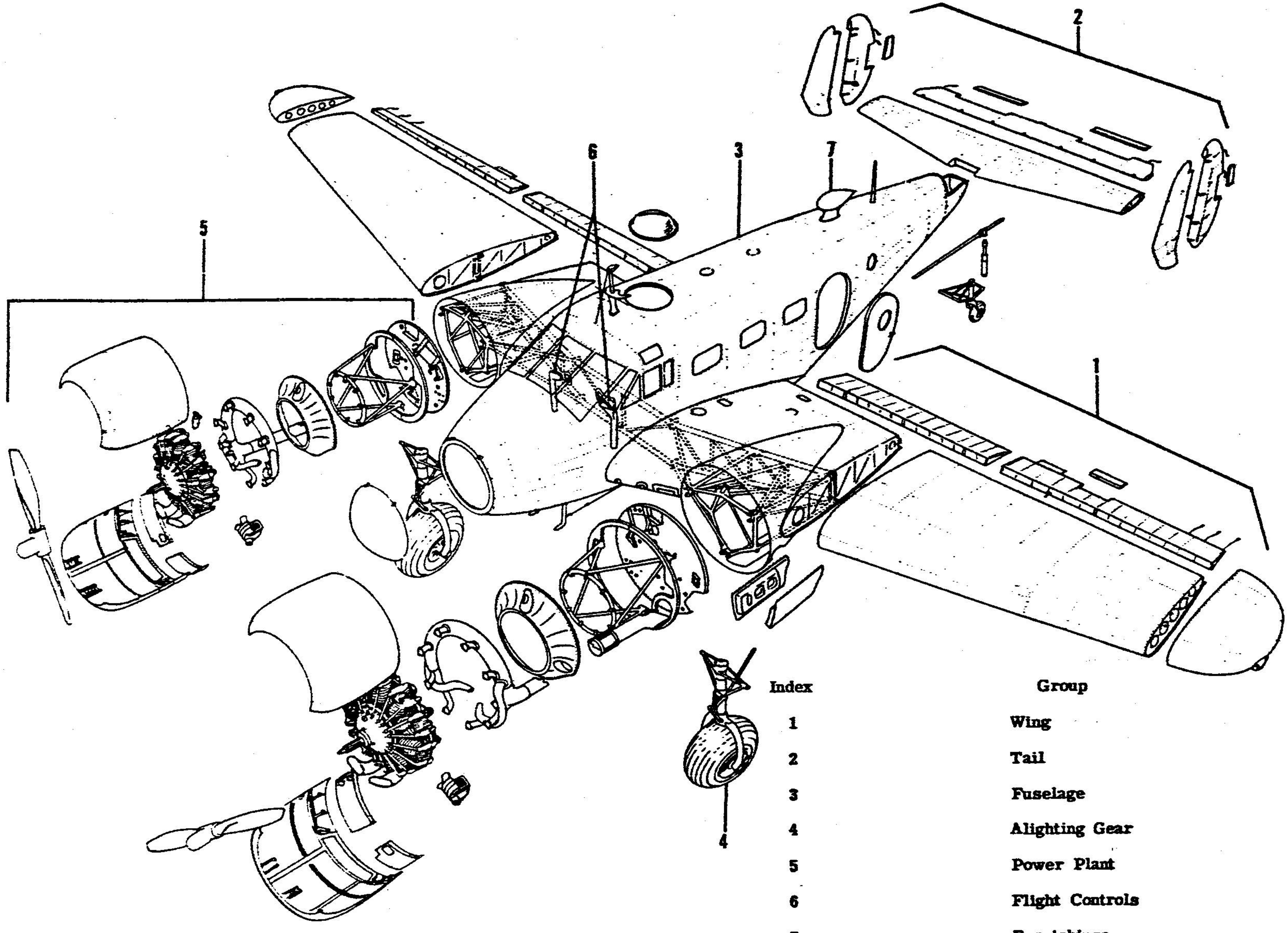

Index	Group	Figure
1	Wing	2- 10
2	Tail	11- 15
3	Fuselage	16- 22
4	Alighting Gear	23- 36
5	Power Plant	37- 61
6	Flight Controls	62- 71
7	Furnishings	72-106

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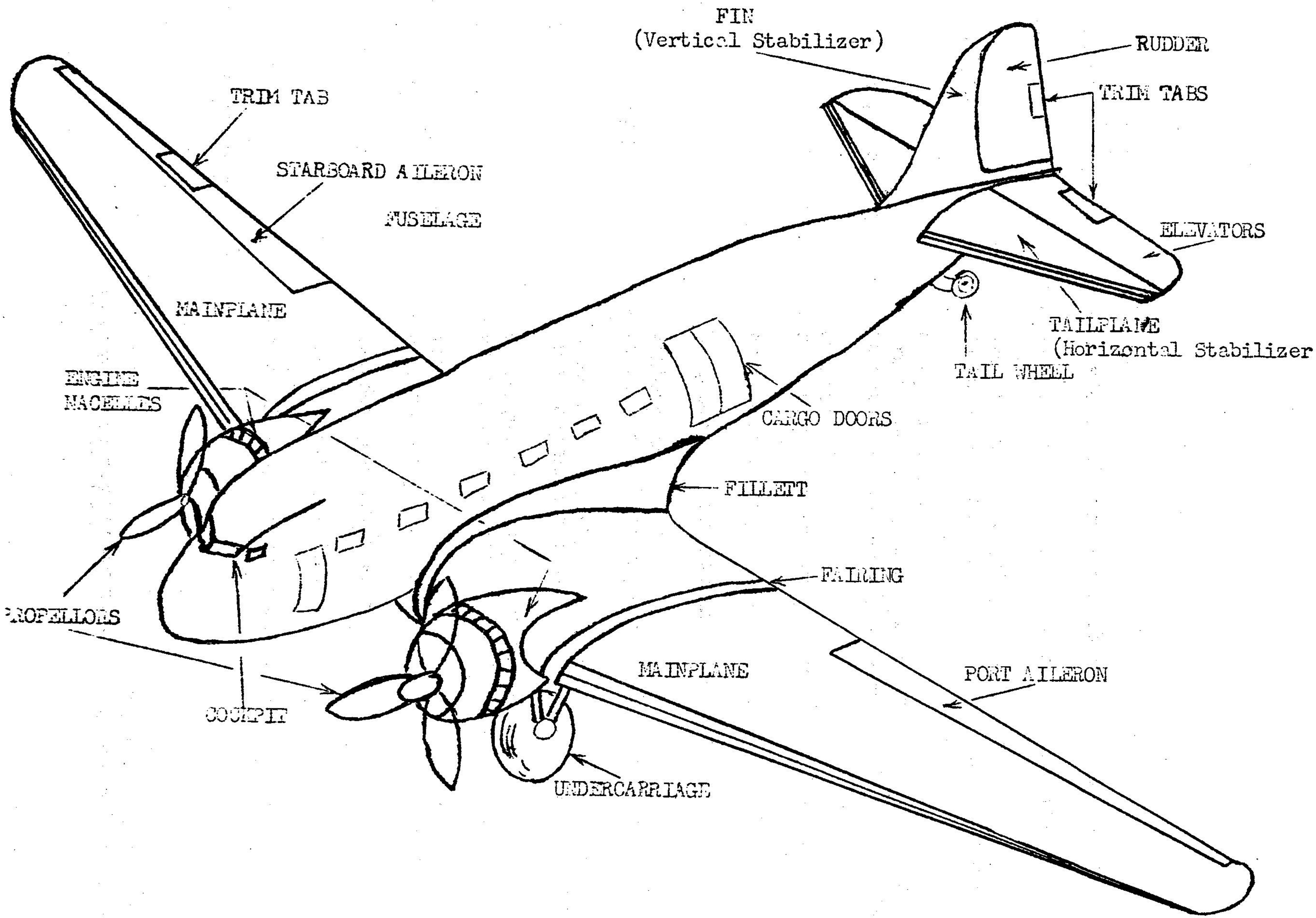
Figure 1. Exploded View


FIN
(Vertical Stabilizer)
RUDDER
TRIM TAB
TRIM TABS
STARBOARD AILERON
FUSELAGE
MAINPLANE
ELEVATORS
TAILPLANE
(Horizontal Stabilizer
TAIL WHEEL
ENGINE
NACELLES
CARGO DOORS
FILLETT
FAIRING
PROPELLORS
MAINPLANE
PORT AILERON
COCKPIT
UNDERCARRIAGE

ELEMENTARY AERONAUTICAL TERMS

(For complete list refer to Standard Glossary of Aeronautical Terms)

TYPES OF AIRCRAFT

Aircraft	- all types of air supported craft.
Aerodyne	- heavier than air-craft.
Aerostat	- lighter than air-craft.
Aeroplane	- a mechanically driven heavier than air-craft, with fixed wings.
Amphibian	- an aeroplane provided with a means for "taking-off" and alighting on both land and water.
Flying Boat	- an aeroplane whose main body or hull is its means of support on water.
Float Sea Plane	- an aeroplane provided with floats for its means of support on water.
Byplane	- an aeroplane with two supported mainplanes.
Flying Wing	- an aeroplane without the orthodox fuselage or tail unit.
Glider	- an aeroplane with fixed wings, but is not mechanically driven.
Gyroplane (Autogyro)	- an aerodyne, mechanically driven, whos support in air is derived from the reaction of air on a freely revolving motor.
Helicopter	- an aerodyne, capable of vertical ascent, supported in air by a mechanically driven motor.
Landplane	- an aeroplane with one supporting mainplane.
Pusher Aeroplane	- an aeroplane with the propeller mounted behind the engine.

Multi-Engine - having more than two engines.

Ornithopter - an aeroplane, supported in air by flapping wings.

Sesqui-plane - a by-plane on which the lower plane is much smaller than the upper.

Tractor Aeroplane - an aeroplane with the propeller mounted ahead of the engine.

Twin-Boom Aeroplane - an aeroplane having the pilot's cockpit in a small nacelle in the centre of the mainplane and the controlling tail surfaces mounted on slender members passing far enough back to give the necessary leverage.

Twin Engine - haveing two engines.

MAIN COMPONENTS

cabin - an enclosed space, similar in functions to a cockpit, but generally understood to be much larger to accommadate a crew of more than one man.

cockpit - an opening in the aircraft structure to accommodate pilot, instruments and controls, or a passenger.

mainplane - main supporting airfoil of the aircraft.

anter section - the central portion of a mainplane not of the through (or one piece) type.

keel surface - all the portion of the aircraft as viewed from the side.

fuselage - the main structural member of an aeroplane, to which are attached the mainplanes, tail unit etc.

cowlings - metal covers enclosing the engine(s).

fairing - a light member added to decrease head resistance or wake turbulence.

fillet - a fairing at the root of an airfoil, to reduce turbulence at the abrupt angle where it is attached to the fuselage.

longerons - the main longitudinal structural members of a fuselage.

nacelle - a streamlined enclosure, housing an engine, or crew, carried by mainplane of an aeroplane.

spar - the main structural member of an airfoil.

tab - a comparatively small controllable, or adjustable, surface to assist in stability and/or control.

hull - the main body of a flying boat, or amphibian.

keelson - the central structural member along the bottom of a hull.

gunwhale - the top longitudinal member of the side of a hull.

step - a break in the underside of a float or hull, designed to facilitate "take-off".

tumble home - the outward slope of a hull, or floats from gunwhale to chine.

chine - the extreme side member of a hull, running approximately parallel to the keel in side elevation.

flare - the inward slope of a hull, of float, from gunwhale to chine.

TAIL UNIT COMPRISES

(a) Elevators - control surfaces, controlling climb or dive (pitching about the lateral axis).

(b) Tail Plane - a stabilizing surface designed to give stability around the lateral axis.

(c) Rudder - a vertical control surface, controlling the yawning about the vertical axis.

(d) Fin - a vertical stabilizing surface, giving directional stability about the vertical axis.

(e) Tail Wheel (or skid) - the rear member of the alighting gear.

Tail Core - a streamlined fairing at the rear of a fuselage.

Empennage - a term designating collectively the rudder, elevators, tailplane and fin.

FLYING TERMS

Airworthy - the state of meeting with all the prescribed regulations and conditions laid down to ensure safety in flight.

Air speed - speed of the aircraft in relation to the surrounding air.

Aerobatics - evolutions voluntarily performed in an aircraft other than those required for normal flights.

Ground speed - the relation between the speed of aircraft and a point on the ground.

Aerofoil - a surface so designed to produce an aerodynamic reaction normal to the direction of motion.

Ceiling - (absolute) the height at which the rate of climb drops to zero in standard atmosphere.

Ceiling - (service) the height at which, with a given load, the rate of climb drops to 100 ft per minute in standard atmosphere.

Drift - sidewise component of horizontal flight, usually caused by cross winds.

Manometer - an instrument for measuring fluid pressure.

Venturi - a variable section tube, wider at each end than in the middle.

Stable - an object is stable if on being disturbed it will return to its original position.

Unstable - an object is unstable if on being disturbed it will continue to move farther and farther from its original position.

Turbulence - disturbed air flow.

Endurance - the maximum time a machine can remain airborne under specified conditions without refueling.

Cap - distance between the mainplanes on bi- or multi-planes.

Range - the maximum distance an aircraft can fly without refueling.

Side Slipping - motion of an aircraft, in flight, such that the relative airflow has a lateral component.

Radius of Action - half the range in still air.

Rigging position - the position of an aircraft erected on trestles, with the longitudinal and lateral axis level.

Tail Slide - rearward motion of an aircraft along its longitudinal axis.

Pancaking - alighting in an overstalled altitude.

Porpoising - undulating motion around the lateral axis of a flying boat (or other Water born types) while taxiing on water.

Loop - a complete revolution of an aircraft about its lateral axis, with the top of the wings inside of the curved flight path.

Drag - the total force opposing thrust of the propellor(s) and is the sum of the following drags.

Form Drag	- drag due to air resisting its deformations because of inertia.
Induced Drag	- the drag caused at the wing tip region, where the spiral airflow creates a lift with a considerable backward inclination.
Frictional Drag	- (skin friction) the drag caused by the tendency of air to cling to boundary layer over the aerofoil due to viscosity.
Parasite Drag	- the drag of non lifting surfaces.
Profile Drag	- the sum of form drag and frictional drag.
Camber	- the curvature of an aerofoil surface.
Longitudinal Axis	- running fore and aft through the centre of gravity.
Lateral Axis	- running from wing tip to wing tip through the centre of gravity.
Vertical Axis	- at right angles to both the longitudinal and lateral axis through the centre of gravity.
Longitudinal Stability	- stability about the longitudinal axis provided by the tailplane.
Lateral Stability	- stability about its longitudinal axis and is governed by three factors. Dyhedral angle, sweepback angle and the keel surface above the centre of gravity.
Directional Stability	- stability around its vertical axis. Is governed by keel surface behind centre of gravity.
Chord Line	- an imaginary line from the leading edge to the trailing edges of the airfoil.
Centre of Gravity	- the balance point. The point through which all weights act down.

Lateral Dihedral	- the upward and outwards slope of the wings from the point of attachment.
Longitudinal Dihedral	- the angle formed between the chord of the wing and the chord line of the tailplane.
Angle of Incidence(riggers)	- angle between the chord line of the main-plane and the horizontal datum line.
Aspect Ratio	- ratio of span to average chord.
Angle of Attack	- the angle between relative airflow and chord of the airfoil.
Down Wash	- the downward flow of the air behind the mainplanes.
Wash out	- decrease in angle of incidence toward the wing tip.
Equilibrium	- balance between forces when opposing forces are equal.
Fineness ratio	- ratio between the maximum depth of an airfoil and the chord.
Stalling Angle	- the angle of attack of an airfoil where the smooth airflow breaks away and becomes turbulent resulting in a loss of lift.
Pitching	- motion of an aircraft in flight about the lateral axis.
Rolling	- motion of an aircraft in flight about its longitudinal axis.
Yawing	- motion of an aircraft, in flight, about its vertical (normal) axis.
Dihedral	- the angle formed by the upward or downward inclination of the mainplane to the lateral horizontal.
Load Factor	- the ratio of the failing load of a structural member to the estimated basic load under specified flight conditions.
Pendalum Stability	- a method of obtaining stability (high-wing monoplanes).

Sweep Back - the distance the wings are set back from the point of attachment.

Wing Tip Vorticies - spiraling air at the wing tips due to high pressure air moving into the low pressure air on top of the airfoil.

Span - distance from wing tip to wing tip of an aerofoil.

Stall - to be at or above the angle of attack corresponding with the maximum lift coefficient of an aeroplane.

Buffeting - exaggerated vibration caused by the turbulent wake of other components of the aircraft.

<u>TYPES OF AIRCRAFT USED IN THE RCAF</u>

<u>Flying Training Type of Aircraft</u> (Havard, Chipmunk, Expeditor)

(a) Used for training pilots on initial training.

(b) Single or twin engined aircraft.

(c) Either low or high wing type aircraft.

<u>Fighter Type of Aircraft</u> (Sabre, CF100, Mustang)

(a) Used for defensive or offensive weapons by experienced pilots

(b) Eithe single or twin engined usually jets

(c) Usually low wing type of aircraft.

<u>Bomber Reconnaissance and Transport</u> (Dakota, Neptune, C119, North Star, Lancaster)

(a) Used for transporting cargo or passengers

(b) Usually twin or multi-engined.

(c) Either low or high wing type of aircraft.

COMPONENT PARTS OF AN AIRCRAFT

1 The component parts shown are parts of an aircraft which are common to almost all types:

(a) Fuselage
(b) Mainplane
(c) Aileron
(d) Flap
(e) Tailplane
(f) Elevator
(g) Fin
(h) Rudder
(j) Power Plant
(k) Trim tab
(l) Undercarriage
(m) Propellor
(n) Nacelle
(o) Fairing

OPERATION OF FLIGHT CONTROLS

Ailerons

(a) To move the ailerons the control stick or wheel is moved or turned to the right or left.
(b) Movement of the ailerons will roll or bank the aircraft.

Elevators

(a) To move the elevators the control column is moved fore and aft.
(b) Movements of the elevators will cause the aircraft to climb or descend (pitch).

Rudder

(a) To move the rudder, the rudder pedals are moved by the pilot's feet.
(b) Movements of the rudder will cause the aircraft to turn to the right or the left (yaw).

OPERATION OF AUXILIARY COMPONENTS

Trim tabs

(a) Moved by use of cables, drums, rods, electric motors, controlled from the cockpit.

Flaps

(a) Moved electrically, hydraulically, mechanically controlled from the cockpit.

NOTE - Flaps and trim tabs are not control surfaces.

PRINCIPLES OF FLIGHT

THE ATMOSPHERE

To understand theory of flight, some of the characteristics and properties of the atmosphere must be understood. The atmosphere is a mass of invisible gasses surrounding the earth. These are said to be the residue from the gaseous chemicals from which the earth was formed and are mainly 23% Oxygen and 76% Nitrogen augmented by minute quantities of lesser gasses such as Carbon Di-oxide, Argon, Krypton, etc. The depth of the atmosphere is calculated by some authorities to be approximately 100 miles, but there are differences of opinion on the actual figure wihci is, to the trainee of little consequence. The apparent blue tint of the atmosphere when viewed through great depths is created by the refractivity of innumberable notes of dust and forms of animal life and their microscopic eggs which are suspended in the air, given off by ponds, lakes, etc; the air itself is not blue.

For convenience, the atmosphere is divided into a number of purely imaginary sections. Ascending from the earth's surface there is a gradual drop in temperature with the increasing altitude until, at a certain altitude, the temperature ceases falling and remains constant. This certain altitude varies with climatic conditions, but is 36,000 in Standard Atmosphere. The atmosphere below this line is called the Troposhere and above, stratosphere. The regions above the Stratosphere, as yet unexplored, are referred to broadly as the Ionosphere. The imaginary line between Troposphere is Stratosphere is the Tropopause.

The Troposphere is in constant movement causing winds, updrafts, downdrafts, turbulence, etc. The violence of air movement is tabulated in the "Beaufort Scale of Wind Forces". The various degrees of wind velocity are given a Beaufort number and the reaction of common objects such as sail boats, leaves of trees, etc., is shown for each number.

PROPERTIES OF ATMOSPHERE AND EFFECT OF ALTITUDE

The atmosphere possesses several properties which greatly effect the flight of an aeroplane.

1. Invisibility

This property makes it difficult to study the action of moving air, but has been overcome as can be seen under "wind tunnels" in these notes.

2. Density

Mass (or weight at sea level) per unit volume. At sea level one cubic foot of air weighs .08 lbs., which compared with water (62¼ lbs per cu. ft.) seem slight, but it is this property which makes the flight of an aeroplane possible. Because air is compressible the lower layer is dense, due to the weight of air above them than the higher layers. Therefore, air density decreased with altitude, making flight increasingly more difficult the higher an aeroplane ascends. Flight, (not rocket propulsion), is impossible in a vacuum.

3. Pressure

Air exerts a pressure on the surface of theearth and on any body suspended within it. At sea level (in Standard Atmosphere) this pressure is 14.7 lbs. sq. in. In other words, a column of air one inch square and the height of the atmosphere, weighs 14.7 lbs. Naturally, the air pressure decreases with altitude, since the column of air one inch square is shorter, consequently the air above it weighs less. The change in pressure is greater near the earth's surface. Air pressure acts at right angles to the surface of any body suspended within it and on all sides of the body; i.e. upwards, downwards, laterally, etc. Archimedes Principle of buoyancy holds good for air, that is, any body immersed in air is buoyed up by a force acting upward equal to the weight of the air it has displaced. This is the principle governing the flight of balloons and other lighter than aircraft.

4. Viscosity

Air, to a limited extent, is viscous. That is, a moving layer of air tends to move the adjacent layers with it, similar to friction between two solids of which one is moving. This property has much to do with formation of turbulance boundary layer and drag, this being discussed later.

5. Compressibility

Air is compressible. This fact is utilized in increasing engine performance by use of superchargers, and is an important factor when studying supersonic speeds. For normal flight, however, it has little importance.

6. Temperature Changes

The radiant heat from the sun passes through the atmosphere without warming it to any great extent. The heat is, however, absorbed by the arth and this stored heat is given off to the air in contract with the earth's surface. These more dense lower layers absorb more heat than the upper thinner layers. This partially explains the steady fall in temperature with increasing altitude. Air warmed by the earth will obviously rise, causing "convection currents"; however, as the warm air rises it meets with decreased pressure and expanding, loses temperature. The temperature drop is approximately one degree Fahrenheit per 300 feet in altitude.

(111) LAWS OF FLUIDS (LIQUIDS & GASSES)

As previously mentioned, Archimedes Law of Buoyancy applies to air. Another law applying to air is that areas of high pressure will seek to equalize themselves with areas of low pressure. This is important in the study of flight. Further, air obeys the following laws common to all gasses:

1. Boyle's Law states that at a constant temperature, the volume of an enclosed mass of gas varies inversely with the pressure. Simply, the gas in a container will decrease in volume proportional to the force exerted on it.

2. Charles' Laws: Charles' first law states that the volume of a mass of gas changes in proportion to changes in temperature, provided pressure remains constant. Simply, air expands when warm, contracts when cold.

3. Charles Second Law states: The pressure of a mass of gas changes in proportion to the change in termperature, provided the volume remains constant. A simple example: the pressure in a stoppered bottle will increase if warmed, decrease if chilled. Enough pressure may build up to shatter the bottle if heated sufficiently.

4. Newton's Laws: Air possesses the property of inertia and obeys the Laws of Motion laid down by Newton. The first law states: Every body persists in a state of rest or of uniform motion in a straight line, unless compelled by external force to change that state.

5. Newton's Second Law states: The rate of change of speed or direction of a body is proportional to the force causing it.

6. Newton's Third Law states: For every action (or force) there is an equal and opposite reaction.

(IV) WIND TUNNELS

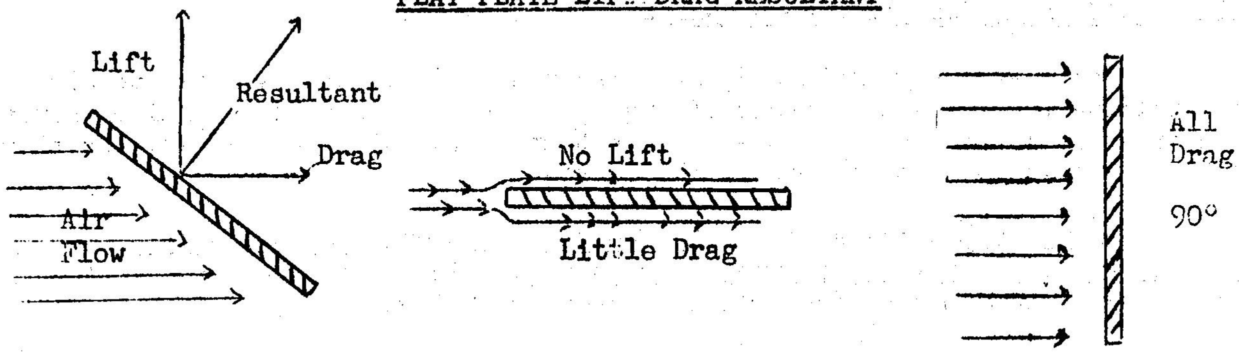
The study of aircraft flight presents many difficulties, if the observations are made on actual machines. By using scale models or even full size machines in wind tunnel experiements, all the risk and many of the difficulties are overcome. In wind tunnels the model is fixed and the air moves, but the action is the same as in actual flight where the conditions are reversed.

(V) FLAT PLATE THEORY

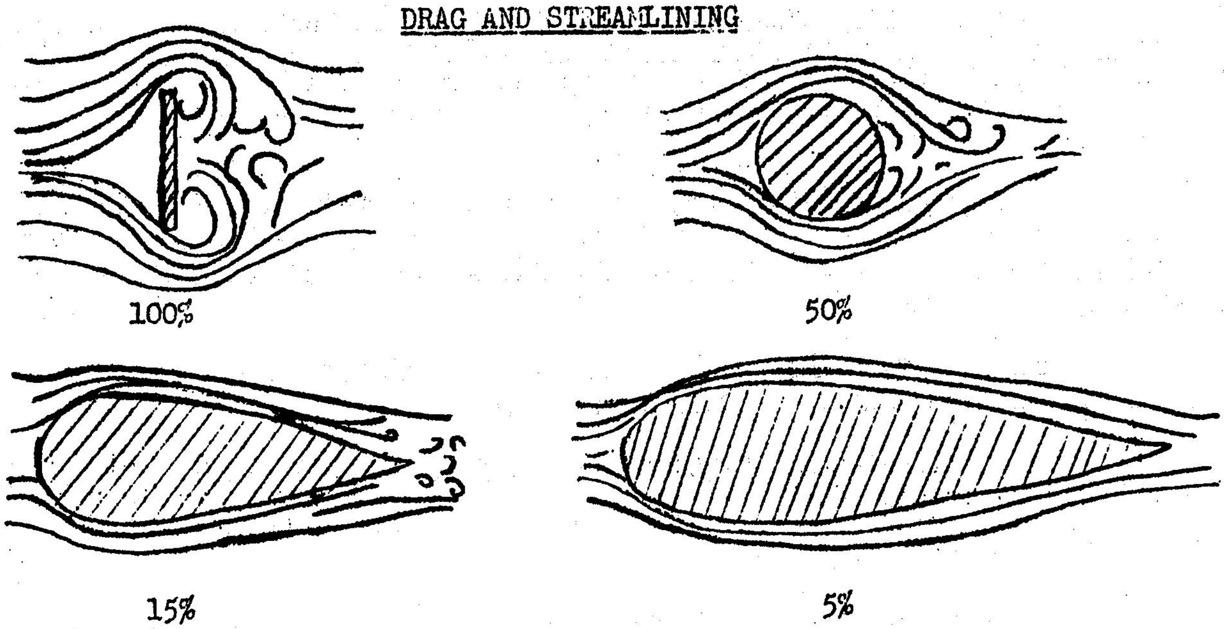
If a flat plate is held in a relative airflow with the front or leading edge inclined upward the plate will tend to move upward and backward. This is caused by a decrease in pressure of the air over the plate and an increase below the plate. The total reaction (resultant) acts approximately at right angles to the plate. This reaction is divided into two components:

1. the upward force is termed LIFT and
2. the backward force is termed DRAG.

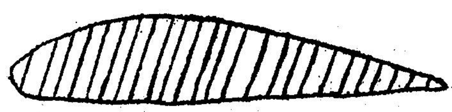
FLAT PLATE LIFT DRAG RESULTANT



DRAG AND STREAMLINING



General Purpose



High Lift

High Speed

The LIFT acts upwards at right angles to the relative airflow and is the desirable component of the resultant. The DRAG acts parallel to the airflow and is the undersirable, but unavoidalbe component of the resultant.

(The angle at which the plate is inclined to the relative airflow is called the ANGLE OF ATTACK). If the plate is held parallel to the airflow there will be no lift and very little drag. As the plate is gradually inclined upward at the leading edge lift increases, but so does drag. Until a certain angle is reached, lift increases; after this angle is passed, drag increases greater than lift. (This certain angle where most lift is created for the least amount of drag is called the OPTIMUM ANGLE OF ATTACK and is the most efficient angle of attack.) Beyond this point drag increases rapidly until when the plate is held at 90 degrees to the airflow, the resultant is all drag and no lift.

It must be understood that lift really acts over the total surface of the plate but it is represented by one average force line its strength being equal to all the lift forces acting on the plate which acts through one point. Similarly, the weight acts all over the plate, but is represented by one force line acting through the centre of gravity.

(Normally, if the centre of lift is ahead of the centre of gravity;) the plate will tend to rotate over backwards. (The plate is then said to be UNSTABLE.) If by the addition of weights, the centre of gravity is made to coincide with the centre of lift, or even ahead, the plate will not rotate andis then said to be STABLE.

It is apparent from the foregoing that the shape of an object effects its resistance to airflow. The flat plate held at right angles to the airflow offers 100% resistance. An object of round cross-section offers only 50% of this resistance. The addition of a tapered tail, to reduce the wake eddies, reduces resistance to 15%, a nose fairing, to reduce head resistance, reduces the drag to 5%.

This addition to a body to reduce drag is know as STREAMLINING. The resistance or drag of a body, therefore, depends on its shape, size, and its attitude to the air. Air density also effects drag and experiements prove that drag increases to the square of velocity, i.e. if speed is doubled, drag increases four times; if speed is tripled, drag increases nine times, etc.)

(VI) GENERATION OF LIFT

It was learned early in experimental flight that a cambered (curved) aerofoil was much more efficient than a flat plate. (See Fig 3. Not only does it give a depth to facilitate structural strength but generates far more lift.

THE VENTURI

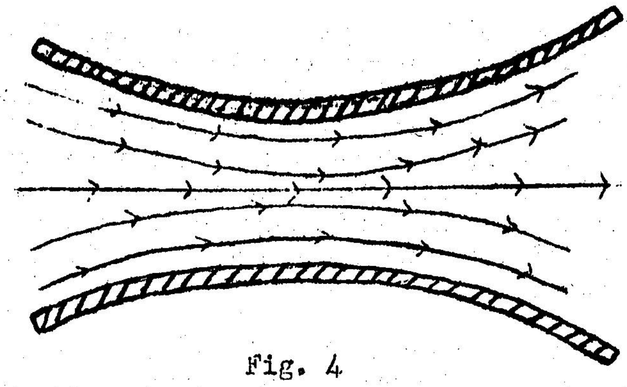
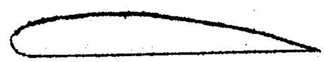
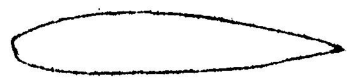


Fig. 4

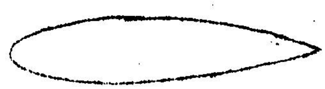
Concave Underside



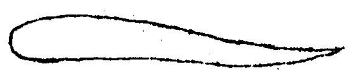
Flat Underside



Convex Underside



Symmetrical



Reflex Curve
Fig. 5

PRINCIPLE OF AEROFOIL DESIGN

The reason for the higher efficiency of a cambered aerofoil is as follows:

N.B. There are three forms of energy. Position (potential), moving (kinetic), and pressure. Bernoulli's theorum states that in an ideal fluid the sum of these energies is, constant. In simple words this means that if one of these enefgies is decreased, one or both of the others is increased, so that the total of the three is always the same value. Therefore, if the speed of an airflow is increased, the pressure of the air is decreased.

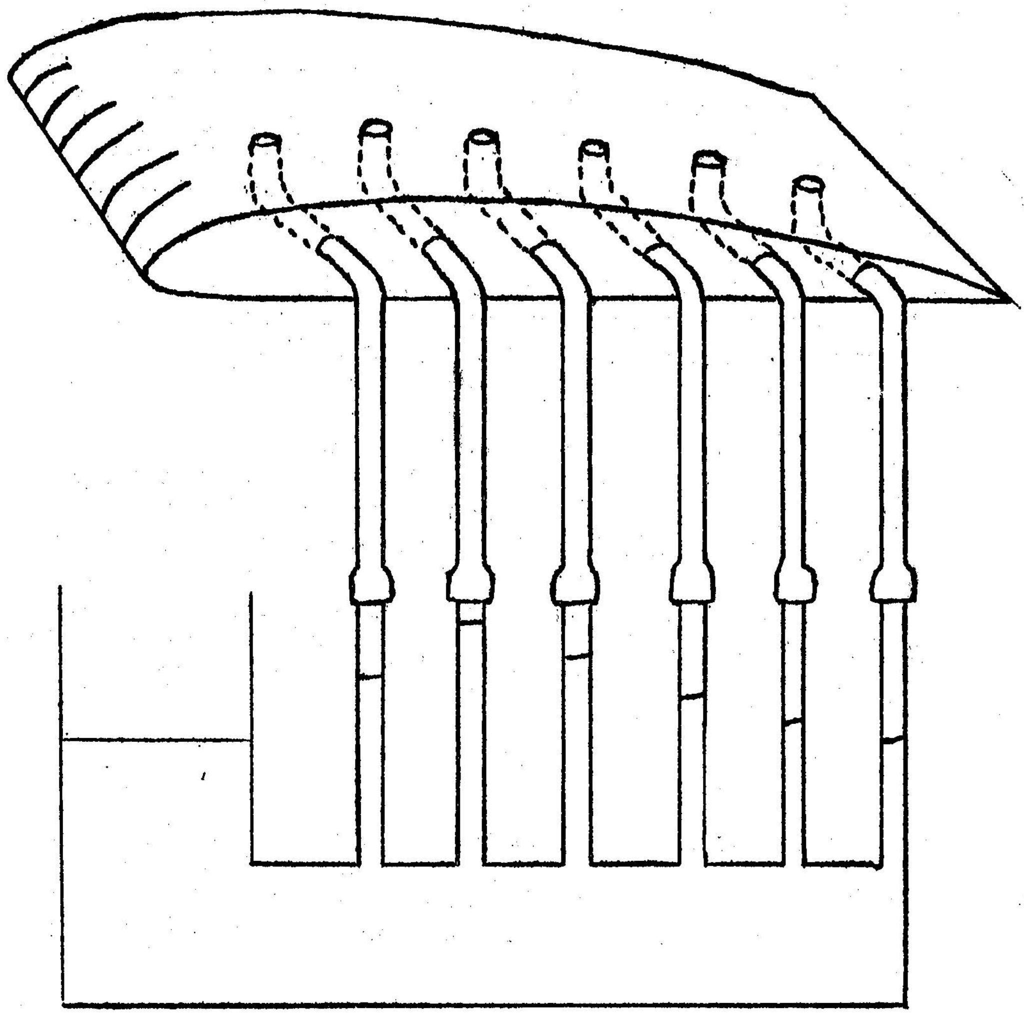
N.B. (When air flows through the throat of a VENTURI (bell mouthed tube of variable section), the air must increase its velocity to permit the same volume of air to flow through the small throat). Consequently there is a decrease of pressure in the venturi throat.

Above a cambered aerofoil there is a venturi effect between the curved upper surface and the still air a certain distance above it. (Still air resists any effort to move it, therefore, at some distance above the aerofoil the air remains undisturbed) The result is an increase in velocity of airflow over the aerofoil, giving a decrease in pressure over the aerofoil. Below the aerofoil the air is slowed down due to its property of viscosity which makes its layers tend to cling to the lower aerofoil surface, thus giving an increased pressure. The decreased pressure above the aerofoil and the increased pressure below the aerofoil results in an upward force which is termed **LIFT**.

(VII) AEROFOILS

Visualize any aerofoil surface cut in half vertically, the end view of one half is called the aerofoil section. There are many such sectional shapes. In general, deep, high cambered aerofoils are used on slow machines that are required to generate high lift for heavy loads. This aerofoil sections are used on fighter aircraft where the important requisite is speed.

In order to define any angle with reference to an aerofoil section, a datum line has to be created from which to measure. This imaginary datum line is the CHORD LINE which is defined as a straight line passing through the centre of curvature of the leading and trailing edges. The proportion of the depth of the aerofoil to length of the chord is called the FINESS RATIO. The proportion of the average chord length to the wing span is the ASPECT RATIO.



Fluid in the tubes varies in height
as pressure varies in points over
the aerofoil

PRINCIPLE OF THE MANOMETER

Fig. 6

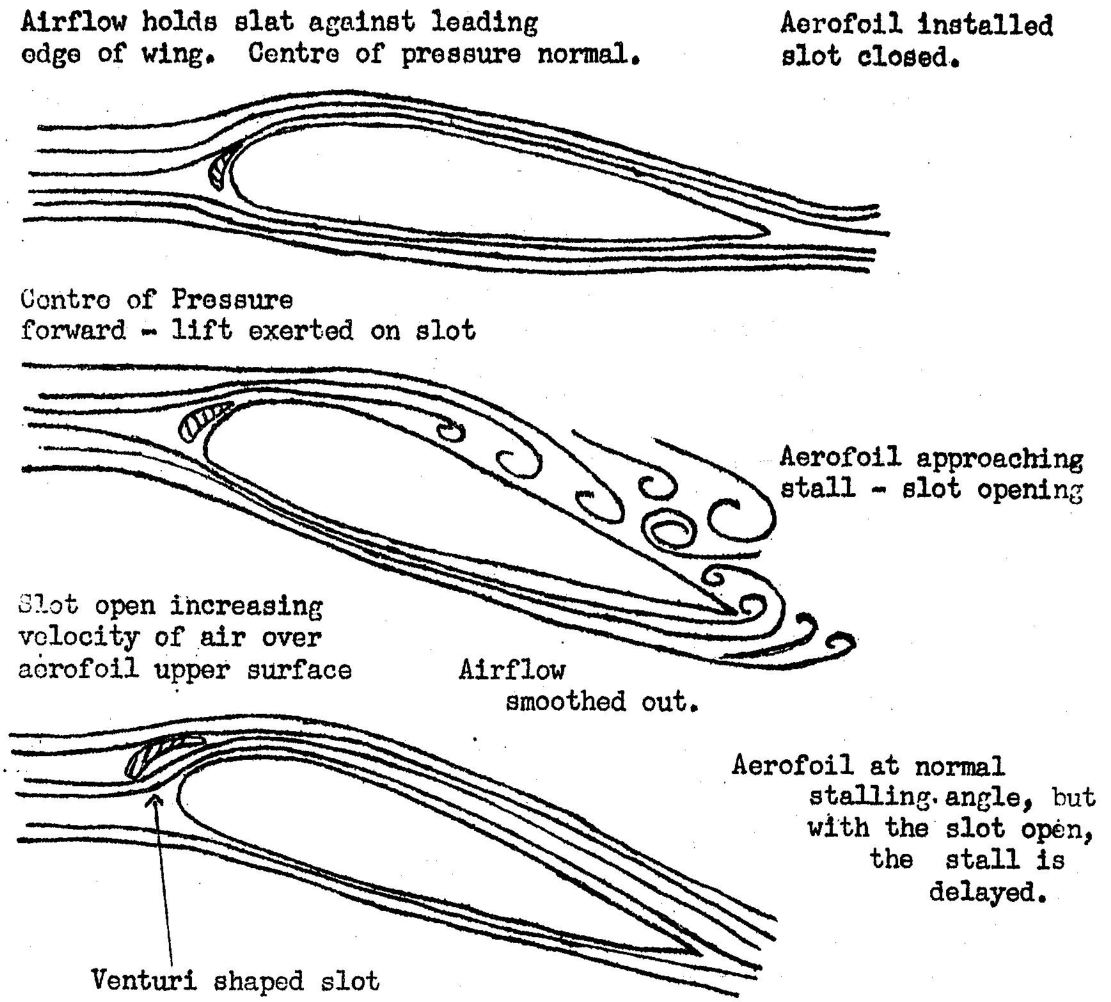
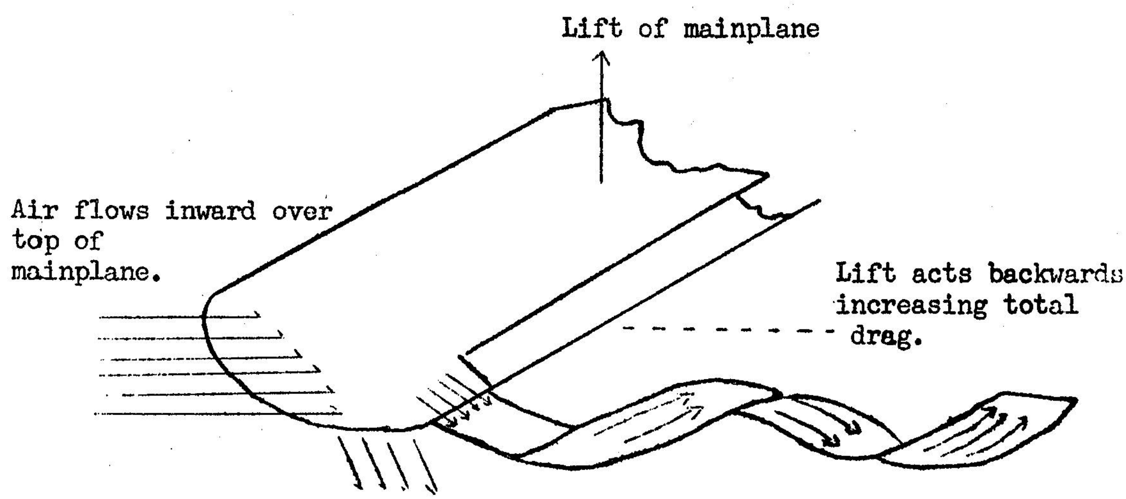


Fig. 7 Handley Page Slat.

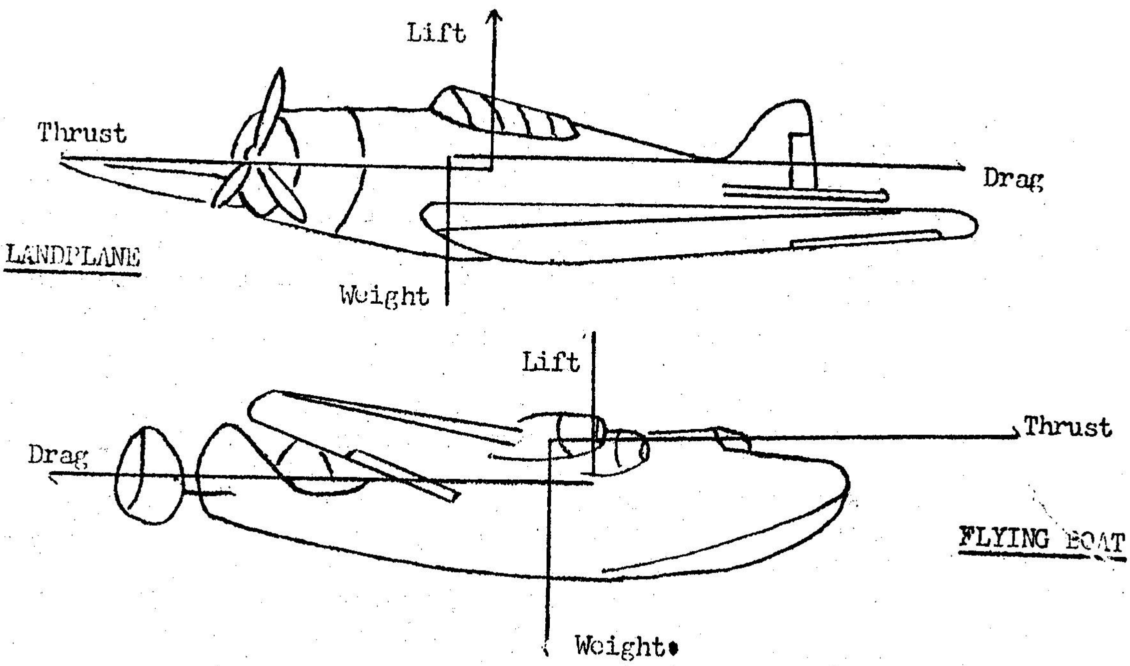


The efficiency of an aerofoil section can readily be determined if the increase in pressure below and the decrease in pressure above it can be measured. An instrument designed to do this is a MANOMETER. Holes in the upper and lower aerofoil surfaces are connected to tubes in a fluid filled reservoir. Any decrease in pressure will draw fluid up the respective tube and any increase in pressure will force it down. A graph can be drawn, the various points corresponding to the fluid height in the various tubes, thus giving a pressure plotting chart. Such experiements prove that the decrease in pressure above is greater than the increase in pressure below the aerofoil. Therefore, the upper surface actually creates more lift than the lower surface. At some angles of attack, on some aerofoils, the upper surface contributes as much as four fifths of the total lift. Aerofoils will even produce lift with negative angles of attack. Experiments with pressure plotting charts show that the greatest lift forces act nearest the leading edge. If a line were drawn to represent the position of a single force that would create the same result on the aerofoil as the total of all the actual lift forces, it would act upward approximately one third of way back from the leading edge.

THE CENTRE OF PRESSURE is that point where this single force line intersects the chord line. Up to a point, increasing the angle of attack will increase the lift more rapidly than it will increase the drag, therefore, the centre of pressure moves forward. If the air flow over the upper surface of the aerofoil breaks away from the latter and ceases to flow smoothly, the lift decreases whereas the drag still continues to increase, therefore, the centre of pressure moves backward.

This critical point, where the smooth airflow breaks away from the aerofoil resulting in a loss of lift, is called the STALLING ANGLE. The maximum angle of attack possible in the present aerofoil sections without stalling, is 16 degrees. It should be understood that as the angle of attack is increased, the centre of pressure moves forward, this results in the nose of the aircraft tending to tilt upward which would increase the angle of attack still further. This vicious circle is known as instability and is a serious problem in flight. This can be overcome by use of control at the elevators.

(It should now be clear that the lift of an aerofoil depends upon its shape and the angle of attack. This quantity is called the LIFT COEFFICIENT.) Similarly, the drag is proportional to the shape of the aerofoil and its angle of attack, this quantity being called the DRAG COEFFICIENT. The lift of an aerofoil is actually dependent on four factors; the lift coefficient, the area of the aerofoil, the density of the air and the square of its velocity. In the same manner the drag is dependent on the drag coefficient, the wing area, the density of the air and the square of the velocity.



(Fig. 9) FORCES ACTING ON AIRCRAFT

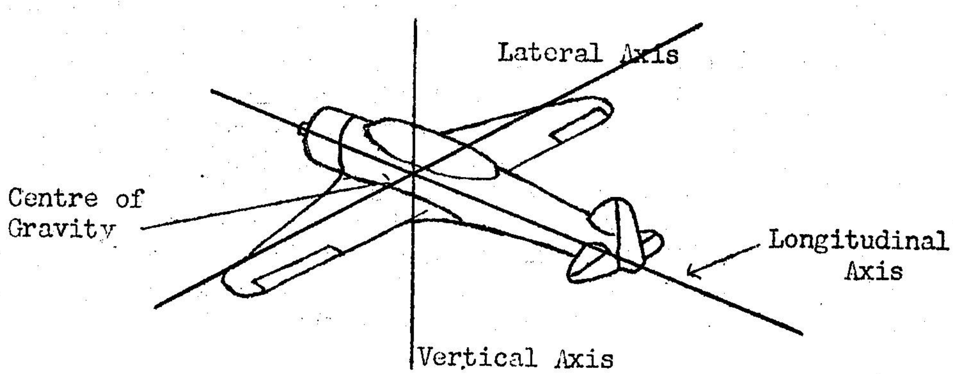


Fig. 10 The Three Axis

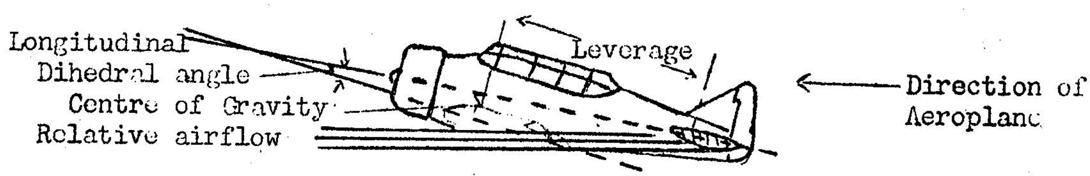


Fig. 11 Corrective effect of Tailplane for Longitudinal Stability

As previously mentioned, the stalling angle is that angle of attack where the smooth airflow breaks away from the upper surface of an aerofoil, causing turbulence and a great loss of lift. If this turbulence could be eliminated or delayed, a greater angle of attack would be possible without losing lift. An effective method to delay the stalling angle is by the use of slots. The most common type of these is the automatic HANDLEY PAGE SLAT. A small auxiliary aerofoil is attached to the leading edge of the main aerofoil by a suitable lever arrangement. At normal angles of attack this auxiliary aerofoil (slat) is held against the leading edge of the main aerofoil by the airflow. As the angle of attack of the main aerofoil is increased, the centre of pressure moves forward until it approaches the slat. The angle of attack of the slat obviously also increases until a point is reached where lift is exerted on the slat. At this point the slat moves forward and outward from the main aerofoil, creating a slot between the slat and the wing. This slot is of a venturi shape which will increase the velocity of the air rushing through it and so over the top of the aerofoil. This increase of velocity over the upper surface of the wing smooths out the turbulence and decreases the air pressure still further, restoring lift. The stalling angle is thus delayed. On some aircraft the use of built in slots is employed. There are merely rectangular holes built into the wings near the leading edge at a pre-determined angle, and are also of a venturi shape in cross section. In this case there is no movement of mechanical parts when the wing approaches the stalling angle, but the airflow is automatically directed by the slots over the upper surface of the wing at an increased velocity (due to the venturi effect), at this point, which similarly delays the stalling angle, lift acts at right angles to the airflow. Therefore, since the air-flow is deflected downwards and the spiraling air leaves the trailing edge, the lift at the wing tips will act more backward than upward, thus adding to the drag. This component of the total drag is INDUCED DRAG. It should be noted that induced drag is a direct result of producing lift. Apart from induced drag, the turbulence at the wing tip destroys lift and reduces the efficiency of the aerofoil at that point. If, therefore, the wing tip is designed to be small compared to the wing area and the percentage of less will be reduced. This is achieved by tapering the mainplane or using a high aspect ratio. Both of these are considered more efficient than short bread wings. This loss of lift at the wing tip is called MARGINAL LOSS. Since, in flight, air pressure is decreased over the top of the wing and pressure is increased under the bottom, it can readily be understood that the air over the top tends to flow toward the centre (inward due to the greater atmospheric pressure outside of the wind tending to neutralize with the lesser pressure over the top. Similarly the air flows outward under the bottom. This results in a corkscrew or spiral of air leaving the wing tip, deflecting the air downwards at the trailing edge.

(VIII) FORCES ACTING ON AN AEROPLANE

There are four forces acting on any aeroplane in flight. The LIFT created by the mainplanes, and sometimes to a very samll extent the tailplane. WEIGHT, or the pull of gravity, which opposes lift. THRUST acting forward created by the pull or push of the propellor's(s): DRAG acting backwards and opposing thrust. An aircraft must be capable of flying in a state of EQUILIBRIUM, i.e. at a constant speed and a constant altitude: To achieve this the lift must be equal to the weight (not greater) and the thrust must be equal to the drag (again not greater). This may seem incredible, but as long as thrust is greater than drag the aeroplane will continue to accelerate, similarly as long as lift is greater than weight, it will continue to gain altitude. At reat, an aircraft is influenced by weight. On taking off, as the throttle is opened, thrust increases rapidly, ground, lift is created and increased until the lift is greater than weight. The aircraft then leaves the ground. The forward speed increases until the drag builds up equal to the degree of thrust, then remains constant. Similarly, to increase speed in flight, thrust is instantly made greater by opening the engine(s) throttle, the machine accelerates until the drag is equal to the new value of thrust, and then its velocity once again remains at the new constant. The degree of lift is governed by the altitude of the aircraft.

In a land plane, the four forces are arranged in two "couples". The lift acts through the centre of pressure, is controlled by the designer's position of the mainplane andis most commonly placed behind the weight, (acting through the centre of gravity), which produces a nose down couple. To counteract the nose down tendancy, the thrust (acting through the centre of the propellor), and drag are arranged to produce a nose up couple. This is accomplished by designing the aircraft with the thrust line below the drag line. The advantage of this arrangment of the forces is that in the event of engine failure, the machine will automatically nose down and assume a stable gliding angle.

To keep the engine(s) and propellor(s) amply clear of the water, flying boats, of necessity, have a high thrust line. The mass of the hull lowers the drag line, therefore, the thrust line is above the drag line, producing a nose down couple. Consequently, the lift weight couple has to be arranged to produce a nose up tendency, achieved by desinging the lift to be in front of weight. Should the engine(s) fail in this case, however, the lift weight couple will raise the nose of the aircraft and it will stall. This is overcome by designing the tailplane to have a positive rigger's angle of incidence to give a positive angle of attack in flight, or a lift producing aerofoil section. The resulting lift gives a nose down moment. This is undesirable in normal flight, where the four forces give the aircraft equilibrium, so is eliminated by inclining the front of the engine(s) upward which deflects the thrust line downwards on the tailplane. The downward force of the slipstream opposes the upward force of tailplane lift, destroying the nose down moment. Now, in the event of engine failure, the down load on the tailplane is removed and it creates sufficient lift which, with its leverage, can force the nose down against the influence of the lift weight couple. The flying boat will then automatically assume a stable gliding angle.

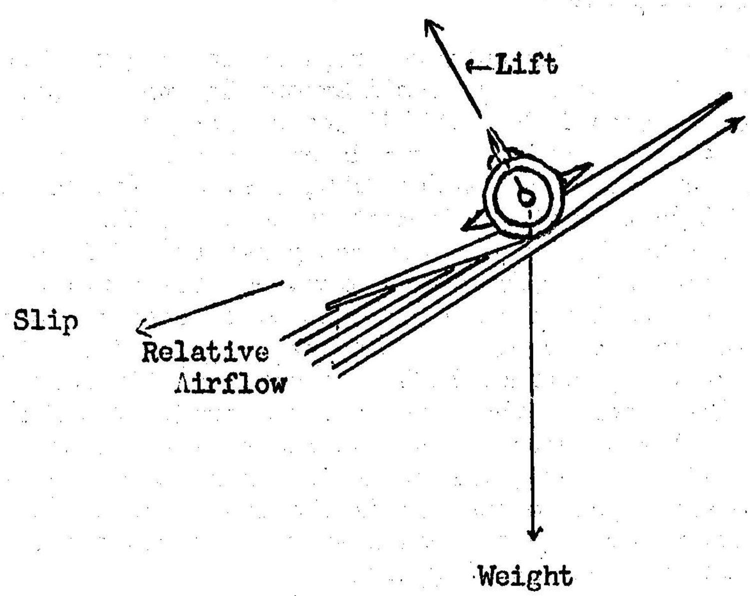


Fig. 12 · Corrective action of Dihedral for Lateral Stability

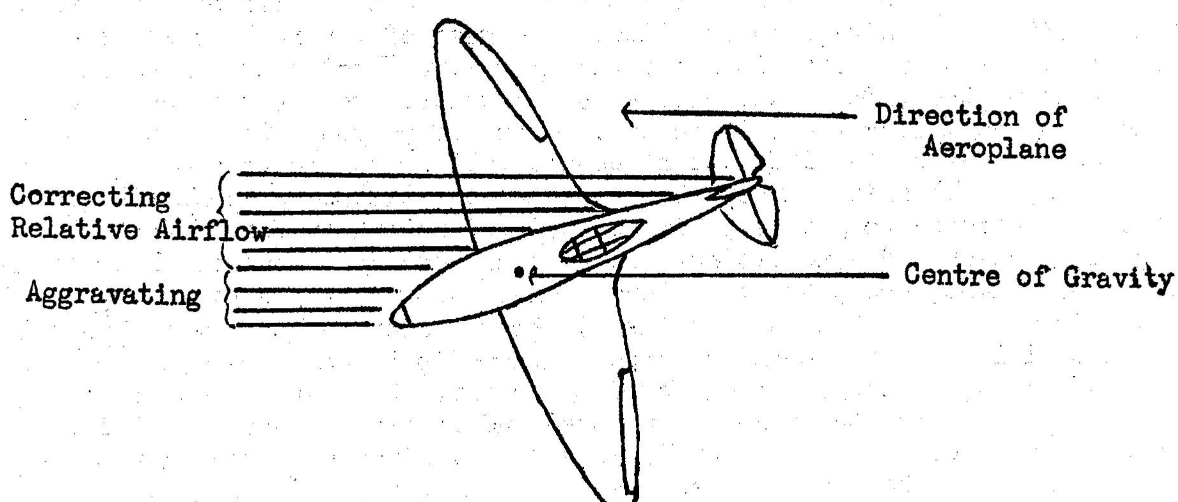


Fig. 14 Directional Stability

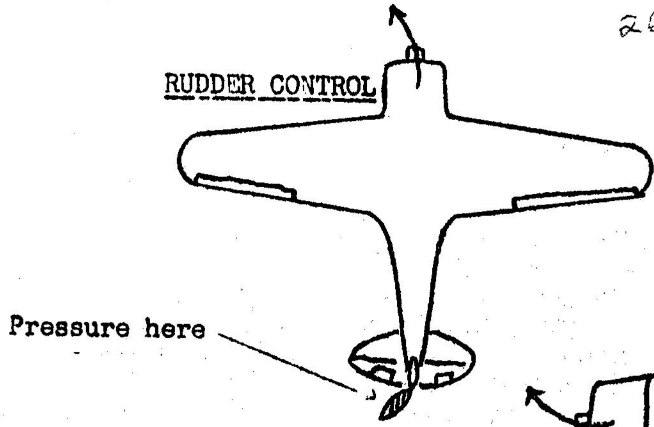
Drag is now known as the total force opposing thrust. This is comprised of several types of resistance INDUCED DRAG has already been discussed FORM DRAG is that drag due to the displacement of air, proportional to the size and shape of a structure and its attitude to the airflow. The viscosity of the air makes it reluctant to pass over a surface and the rougher the surface, the greater the resistance, this is known as FRICTIONAL DRAG, or colloquially, SKIN FRICTION. The total drag of an aerofoil is sometimes as ACTIVE DRAG and the drag of any non-lifting surface sometimes known as PARASITE DRAG. Form drag and frictional drag are sometimes combined, the total being called PROFILE DRAG.

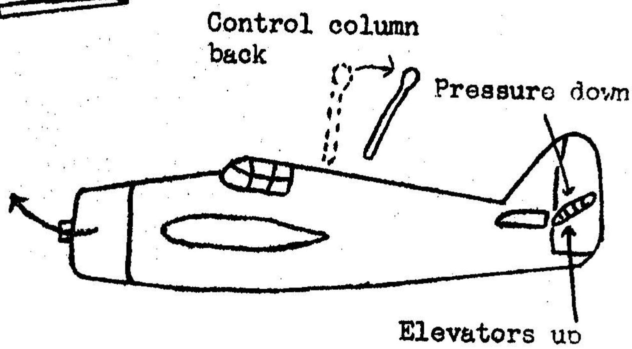
(IX) STABILITY AND CONTROL

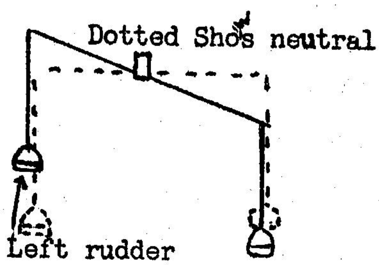
Stability is the ability of an aircraft to return to an original condition of flight after being disturbed by an external force, without control by the pilot. This is referred to as inherent stability. For purposes of explanation, three imaginary lines are assumed to pass through an aircraft, each of these referred to as an axis.

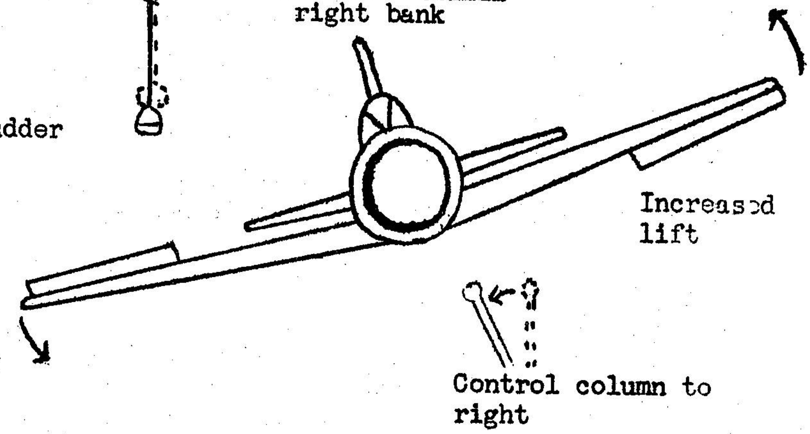
One axis passes fore and aft through the fuselage, this is the LONGITUDINAL AXIS about which the aircraft ROLLS. The VERTICAL or NORMAL AXIS passes downward through the centre of gravity, about which the machine YAWS. The LATERAL or TRANSVERSE AXIS passes hroizontally through the centre of gravity at right angles to the other two about which the aircraft PITCHES. These imaginary axis are considered to move with the aircraft.

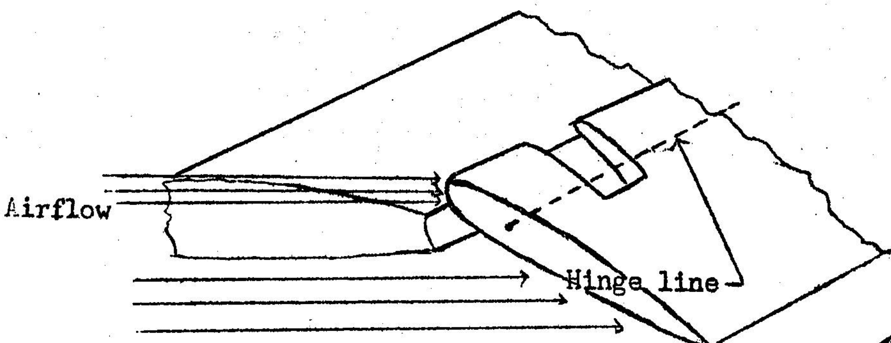
Longitudinal stability, (Stability about the lateral axis), is provided by the TAILPLANE. If the nose is deflected upward, the machine continues forward momentarily on its original course, due to inertia. This presents the tailplane with a positive angle of attack to the airflow, which creates lift and raises the tail. As the tail rises, theangle of attack decreases until it once again produces no lift. Therefore, the meachine is restored to its normal attitude. Similarly, a nose down disturbance will present the tailplane with a negative angle of attack which presents it with a corrective down load and restoring the machine to its normal attitude. (The corrective action of the tailplane depends on the distance it is from the centre of gravity which must be great enough to provide sufficient leverage to compensate for the increased lift on the wings as the nose moves up.) Sometimes the LONGITUDINAL DIHEDRAL is mentioned. This is the angle of incidence of the mainplane and the tail setting angle, measured from an extension of both the respective chord lines. (It may be + or -).



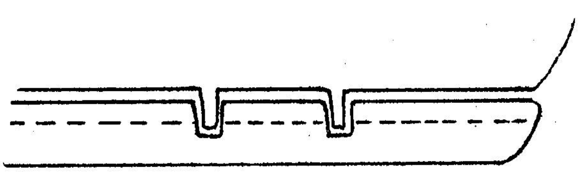




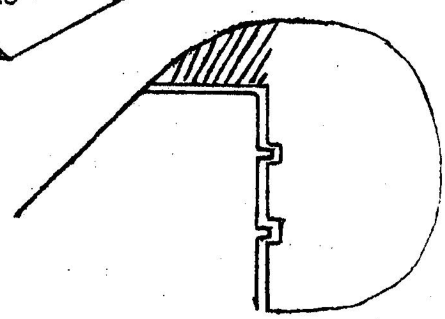




Air flow showing aerodynamic action

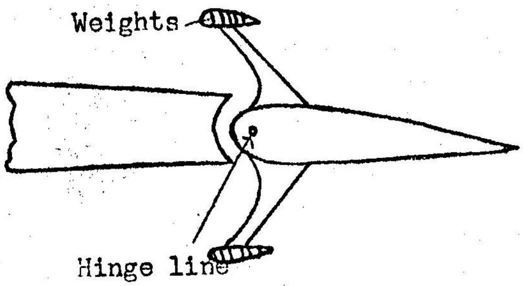


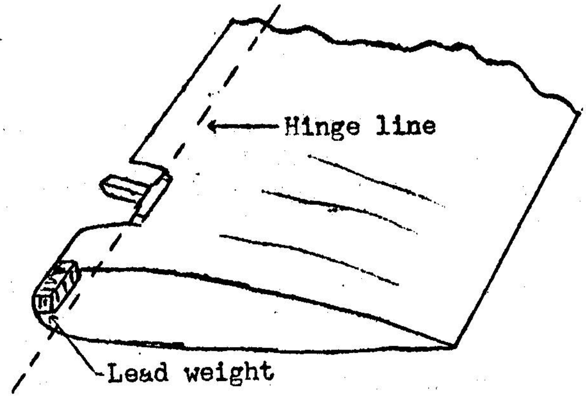
Inset hinge aileron



Horn balance on rudder

Aerodynamic Balances

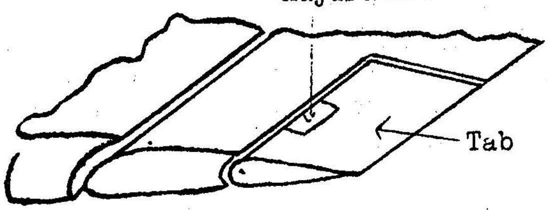


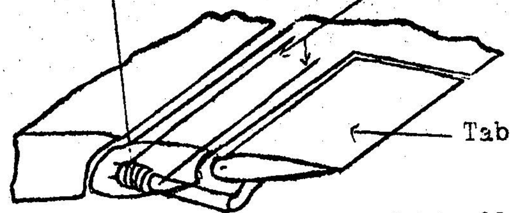


External

Internal

MASS BALANCES

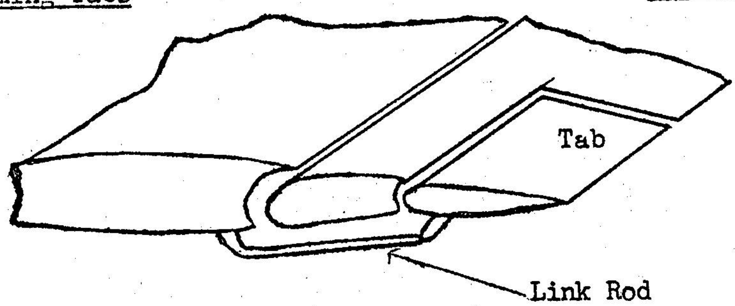




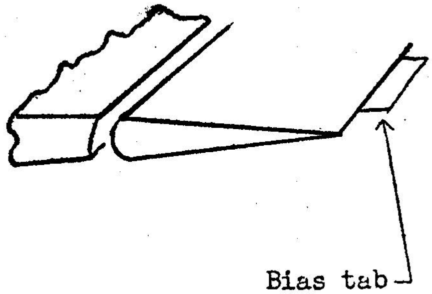
Fixed

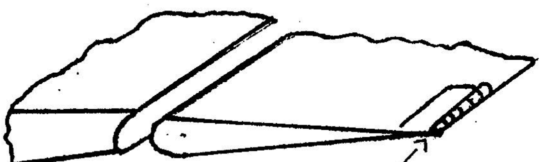
Trimming Tabs

Controllable



Balance (or Booster) Tab





Lateral stability, (about the longitudinal axos), is governed by three factors. Dihedral angle, sweepback angle, and the keel surface above the centre of gravity. (Dihedral angle is the angle at which the mainplanes are inclined from the lateral axis.) Almsot invariably the angle is upward (positive) although a few aircraft are designed with a section of the wing downward (negative). Should an external force cause one wing to drop, the centre of pressure moves over toward the lower wing. But the weight always acts vertically downward. The result is that the machine side slips. (The relative airflow now comes from the direction of the slip as well, as from the front, giving the lower wing a larger angle of attack than the high wing.) Therefore, there is more lift on the lower wing, which raises the letter, returning the machine to its normal attitude of level flight.

Sweepback assists the lateral stability as follows. As a wing "drops" a side slip will result as previously explained. The lower wing new presents a relatively increased span to the surface.

As the aircraft side slips, the keep surface will have a force exerted on it by the new relative airflow. Any surface above the centre of gravity, such as the fin will receive a pressure that tends to correct the aircraft. However, any part of a surface below the centre of gravity receives a pressure that tends to aggravate the conditions of instability. This is particularly the case with flying boats, where the nose of the hull gives a great keel surface below the centre of gravity.

High wing monoplanes have what is sometimes termed as PENDULUM STABILITY. This term is not quite accurate. The centre of gravity is low when compared to the centre of pressure on this type and the force on the mainplanes during a side slip allows the weight to pull the fuselage back to the normal positon of laterally level more rapidly.

(Directional stability around the vertical axos) is governed by the keel surface area BEHIND THE CENTRE OF GRAVITY. As with either stabilities, if the machine is distrubed from its normal forward direction, inertia carries it on in the original direction momentarily. (This presents the keel surface at an angle to the airflow) All of the keel surface aft of the centre of gravity thereby receives a correcting force, all the surface ahead of this point receives a force tending to aggravete the unstable condition. If the corrective force is greater than the aggravating force the machine will return to its normal altitude. (The fin area is of great importance in this respect as it increases the keel surfae in the desired place and has large mechanical advantage using the centre of gravity as its fulcrum and the length of the fuselage behind as the lever. It should be apparant, therefore, that a small fin on a long fuselage is an effective as a large fin on a short fuselage.

Control

It is, of course, necessary that the pilot be able to move the aircraft about any of the three axis at will. (Rolling about the longitudinal axis is controlled by the Ailerons.) PITCHING about the vertical axis is controlled by the RUDDER.) Each of these control surfaces is mounted as far as is efficiently possible from the centre of gravity, to permit as small a surface as possible, to give maximum control. The ailerons and elevators are operated remotely by the control column, and the rudder by the rudder pedals. These controls are instinctive, i.e. pulling the control column back raises the elevators and the nose of the aircraft inclines upward. Moving the control column to the right, operates the ailerons in such a manner that the aircraft rolls to the right etc.

To climb backward, pressure on the control column raises the elevators into the airflow. The air passing the upper surface of the elevators decreases its velocity placing a down lead on the tail and raising nose of the aircraft. This porcess is reversed to force the nose down. Similarly, depressing the right rudder pedal pulls the rudder to the right andinto the airflow causing an increase in pressure on the righthand surface of the rudder and forcing the tail to the left, the nose to the right. The roll is governed by an aileron mounted at the tailing edge of each wing extremity. As the control is moved to the right, the right aileron is raised into the airflow causing an increase of pressure on the upper surface which depresses the right wing. Simultaneously, the left aileron is lowered into the airflow, causing an increase of pressure on the upper surface which depresses the right wing. Simultaneously, the left aileron is lowered into the airflow, causing, in effect, an increase in wing camber, increasing the lift of the left wing and raising it. This results in the aircraft rolling about the longitudinal axis.

AIDS TO CONTROL

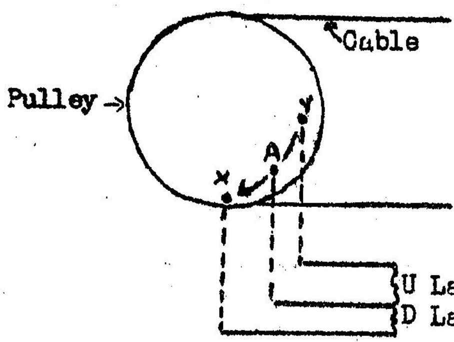
Considerable force is exerted on control surfaces. This is particularly true of large aircraft or of these with high speeds. The effort of operating such controls would be fatiguing to the pilot. Many devices have been developed to make control movement easier to the pilot.

Aerodynamic balance is any device designed to assist the pilot to move a control surface with the use of aerodynamic force. This can be accomplished by designing the surface to have the hinge line back from the leading edge. If the pilot whishes to depress a control, the portion ahead of the hinge line moves in the opposite direction, on which the airflow erects a force to assists the pilot move the bulk of the control. This type is usually found on ailerons andis known as an INSET HINGE AILERON. Another type is the HORN BALANCE usually found on elevators and rudder. This is similar to the inset hinge in operation and consists of a portion of the control at the extremities, being designed ahead of the hinge line. A BALANCE TAB, or BOOSTER TAB is commonly used. It is a small aerofoil mounted at the trailing edge of a control, hinged to the latter. A lever interconnects the tab with the main aerofoil (not the control), in such a manner than when the control is depress, the tab automatically raises and vice-versa. The resulting force on the tab assists the pilot to move the control.

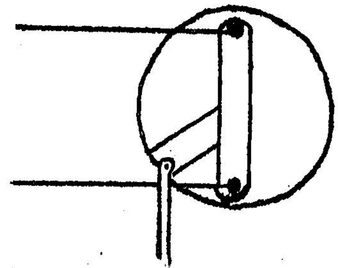
MASS BALANCE

(This is in an addition of weight on a controlling surface ahead of the hinge line.) It can be mounted externally or internally. (See any hinged surface tends to excillate up and down rapidly when it is moving beyond a certain speed. This speed depends on the area and the weight of the surface and the aerodynamic lead on it. On aircraft this is termed FLUTTER. By placing a weight ahead of the hinge line the inertia of the control is increased and the speed at which flutter will commence will be beyond the normal top speed of the airplane. (Thus, it is said that mass balance is added to postpone flutter.)

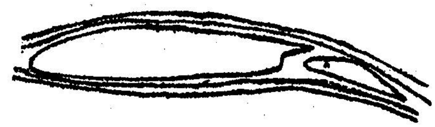
Differential Pulley



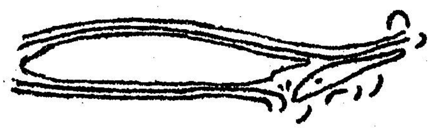
Differential Bell-crank



Aileron neutral

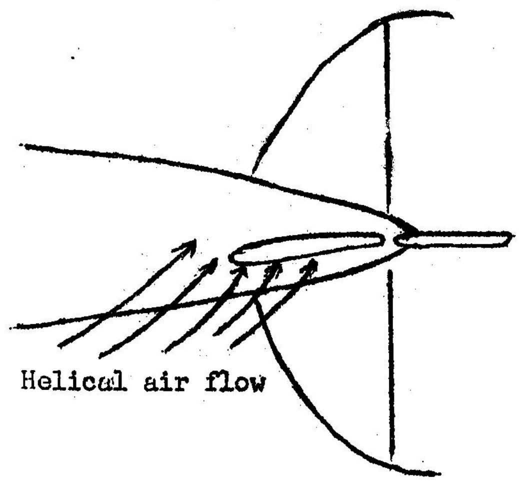


Aileron down - smooth flow



Aileron up - turbulence and drag

FRISE AILERON



Offset Fin

TABS

There are various tabs and combinations thereof. The trim tab is a small aerofoil mounted in the trailing edge of a control surface. Some are merely adjustable on the ground, others are adjustable on the ground, others are adjustable from the cockpit so that the pilot can change their setting easily whilst in flight. (The latter are known as controllable trimming tabs.) Their function is to adjust minor rigging faults or compensate for changes of centre of gravity whilst in flight. E.G. if an aeroplane was flying slightly tail heavy, the pilot would have to fold the control column forward to keep the elevators down, to prevent the machine from climbing or even stalling. This would be fatifuing to the pilot. By adjusting the tabs upwards at the trailing edge, a downward load is exerted on the tab in flight, which being transmitted by the hinge point to the elevator would hold the elevator down aerodynamically, thus relieving the pilot of unnecessary work. A balance tab has already been discussed. There can be any combination of tabs. By adjusting the rod on a balance tab, thus changing its basic setting, it can also be used as a trim tab. By adjusting the rod remotely from the cockpit by cables and a threaded drum, a balance tab can have its basic setting changed easily in flight, in which case it would be called a balance-cum-trim tab (or controllable-booster tab.) An elementary type of adjustment of this type is the spoiler strip was attached to the upper surface of an aileron at the trailing edge, the airflow will be slowed down over the top, resulting in an increase of pressure and depressing the aileron.

Differential Controlon Ailerons

When an aircraft makes a turn, the wing tip on the outside of the turn travels faster than the inside tip. The drag on the outside tip will be appreciably greater than that on the inner tip, since drag increases with the square of velocity. This difference in drag between the two wing tips will have a tendency to yaw the machine back to its original course against the influence of the controls. This may be overcome in a number of ways, one of which is the differential aileron.

Observation of some aircraft will show the fin mounted at a slight angle to the longitudinal datum line (axis). The reason for this lies in the behaviour of the slipstream, not the relative airflow, air from the propellor rotates in a spiral around the fuselage as it passes down the latter it strikes the fin at a slight angle. Normally, this continual side force would create unequal pressure on the fin surfaces and cause the aircraft to have an undesirable, constany yaw. The fin, therefore, is mounted at a slight angle to be parallel to the angle at which this air flow strikes it. The action of the properllor and engine tends to rotate the aeroplane in the opposite direction of the former (Propellor torque), dep-ressing one wing. This may be corrected by having a slightly greater drag on the other wing, causing yaw. The offset fin will now have a slight, corrective, permanent ruddering effect. A similar effect as the offset fin is obtained by cambering the fin on one side only.

Landing Flaps

Safety in flight is very dependent on wing area, the shape and the velocity at which is drawn through the air. The larger the wing and the greater the camber (up to a point), the greater the ligt. Likewise, the higher the velocity, thegreater the lift. However, it is obvious that high speed on landing is hazardous and undesirable, therefore, a lower speed is essential. It should be clear that if the speed is to be decreased, the wing camber and/or area must be increased to compensate for the loss of velocity. This condition is control. With this system, the aileron being raised moves through a greater distance than the one being depressed, causing the lower, slower wing to have more turbulence, dran and oss of lift. The aileron being depressed (outer) moves much less (sometimes only ½ the distance), creates negligible turbulence, increases the camber of the wing which increases the lift, and increases the drag very little. The result is a smoother turn.

FRise Ailerons

These are designed to assist in a smooth turn, similarly as differential aileron control, i.e. by increasing the drag and partially destroying lift on theinside (sloer) wing and increasing the lift on the outer wing without too great an increase in drag. These ailerons are so designed that the leading edge of the aileron being raised projects into the airflow under the wind, creating a great deal of turbulence and without creating turbulence.

Observation of some aircraft will show the fin mounted at a slight angle to the longitudinal datum line (axis). The reason for this lies in the behavious of the slipstream, not the relative airflow air from the propellor rotates in a spiral around the fuselage as it passes down the latter. It strikes the fin at a slight angle. Normally, this continual side force would create unequal pressure on the fin surfaces and cause the aircraft to have an undesirable, constant yaw. The fin, therefore, is mounted at a slight angle to be paralled to the angle at which this air flow strikes it. The action of the propellor and engine tends to rotate the aeroplane in the opposite direction of the former (Propellor torque), depress-ing one wing. This may be corrected by having a slightly greater drag on the otherwing, causing yaw. The offset fin will now have a slight, corrective, permanent ruddering effect. A similar effect as the offset fin is obtained by cambering the fin on one side only.

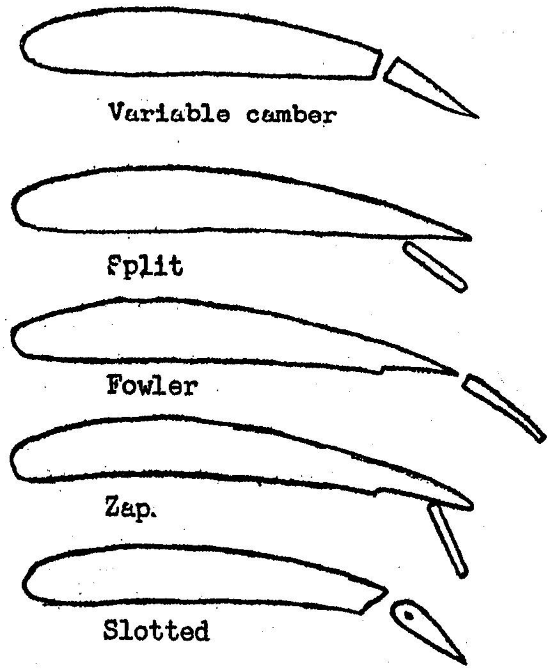
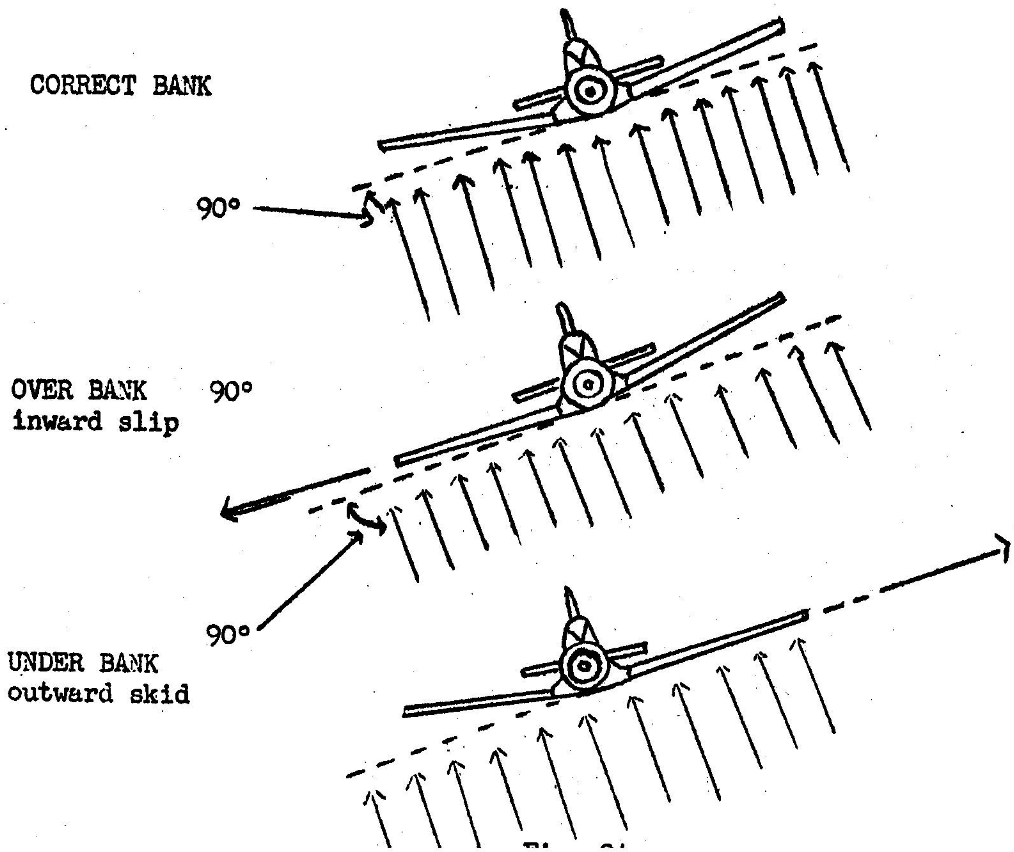


Fig. 23 Flap Types



Landing Flaps

Safety in flight is very dependent on wing area, the shape and the velocity at which is drawn through the air. The larger the wing and the greater the camber (up to a point), the greater the lift. However, it is obvious that high speed on landing is hazadous and undesirable, therefore, a lower speed is essential. It should also be clear that if the speed is to be decreased, the wing camber and/or area must be increased to compensate for the loss of velocity. This condition is is achieved by the use of landing flaps. The VARIABLE CAMBER FLAP increases the camber of the wing but not the area, when lowered for landing. The FOWLER FLAP, however, increases both the area and the camber when lowered. The SPLIT FLAP, gives the effect of an increases angle of attack, without imparing the efficient smooth airflow over the upper surface of the wing. The SLOTTED FLAP is a variable camber flap designed to have a venturi slot between its leading edge and trailing edge of the mainplane. This allows it to be used to a greater extent, as the slot increases the velocity of the air over the upper surface of the flap, similar to the Handley Page Slat, which allows for a greater angle of attack without stalling the flap. A slight angle of a flap may be used to increase lift for take off (usually 15 to 20 degrees). For the landing approach, however flaps may be used to their full travel to steepen the angle of glide and thus shorten the landing run.

(X) THE FLIGHT OF THE AEROPLANE

Air and ground Speed

The speed of an aircraft relative to the air through which it is passing is its AIR SPEED. The speed relative to the ground is the GROUND SPEED. There is an important difference. To the aircraft the air always approaches from the front, regardless of the external wind forces. If an aircraft is flying with an airspeed of 100 mph and the wind is travelling in the same direction with a velocity of 20 mph the ground speed is 120 mph. If, however, the aircraft is flying against the wind using the same figures, the ground speed will be 80 mph but its airspeed is still 100 mph. This is the reason for taking off and landing against the wind. If a machine, with a stalling speed of 60 mph lands against a wind of 40 mph, its ground speed will only have to be 20 mph making the landing easy. If, however, the landing is attempted with the wind, the ground speed will have to be 100 mph calling for a great deal of skill on the part of the pilot and long runways.

WING LOADING

The total (gross) weight of a aeroplane divided by the wing area (in square feet), will give the load supported by one square foot of the wing area. This is known as the wing loading. This varies on each type of aircraft. The higher the wing loading, the higher the stalling speed and consequencyl, the higher the landing speed.

Turning

The turning of an aircraft is opposed by what is known as Centrifugal force. The aircraft resists this change in direction so a force must be applied equal to the centrifugal force, this being called the CENTRIPETAL FORCE. This force is applied by banking the aircraft, so that the lift acts inward as well as upward. By banking the aircraft at the correct angle, the wings are presented at right angles to the desired force and the mechine will not "skid" outward as in the case of under banking, nor "slip" inward, as in the case of overbanking. Newton's laws state that the greater the change in speed or direction, the greater the force must be applied. Therefore, at high speeds or sharp turns, the steeper the bank must be, to supply a greater inward force of the lift. During a bank turn, the wings must supply sufficient lift to support the aircraft and also an inward force to execute the turn. Therefore, there are greater loads imposed on the wings in a turn than in level flight. During sharp turns, the control surfaces perform unusual functions; in a vertical bank, the rudder has to be used to keep the nose on the horizon (or above it), consequently momentarily acting as the elevator, whereas the elevators are moved upward to hold the machine in the turn and temporarily act as a rudder. This condition exists in any turn requiring a bank of 45 degrees or more. Flat turns, i.e., turns without banking, may be executed, but this results in violent outward skidding. They are, moreover, difficult to perform because the outer wing travels faster, creating more lift and tends to bank the machine automatically.

Climbing

If an aeroplane is in level flight with a certain throttle setting, and the throttle is increased, the thrust and lift will increase. The drag will increase until it equals thrust, but since the weight is constant, the increase in lift will cause the aircraft to ascend. To remain in level flight therefore, the tail must be raised to decrease the angle of attack of the wings and thus prevent an increase in lift. At full throttle themachine cannot be made to climb by increasing the speed, but can by increasing the angle of attack. This is accomplished by raising the angle of attack on the wing. Due to the increase in drag, however, the forward

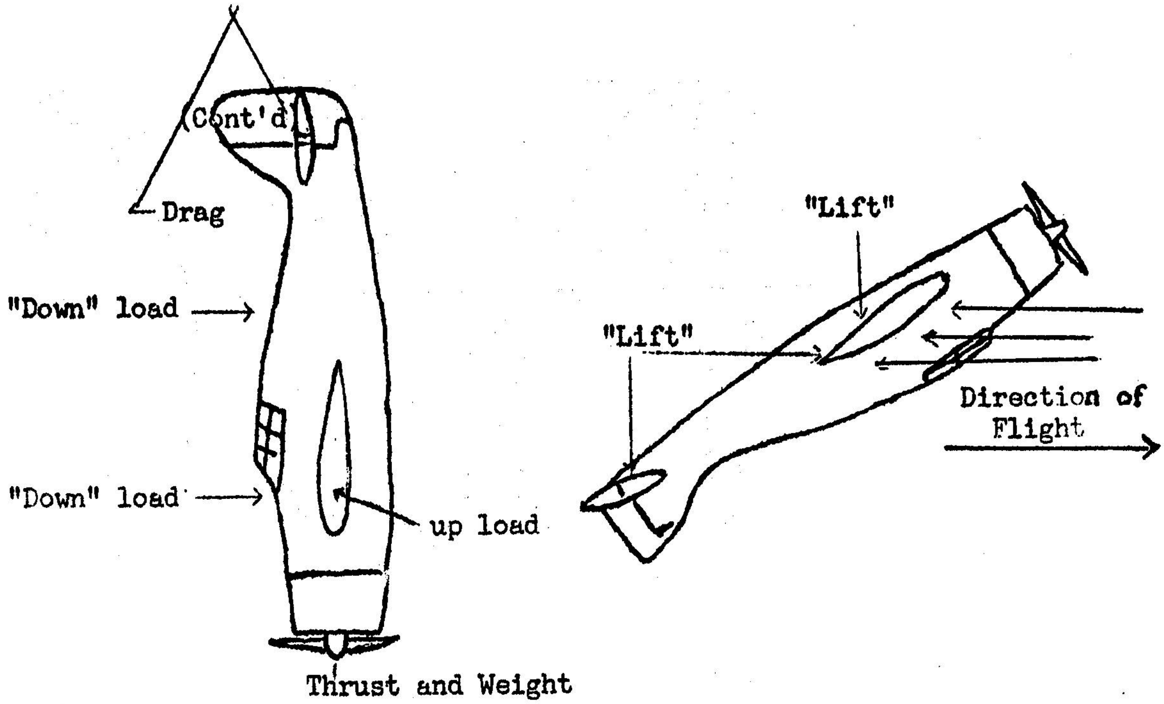
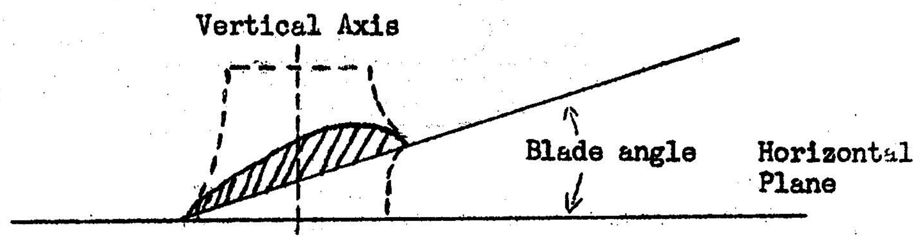
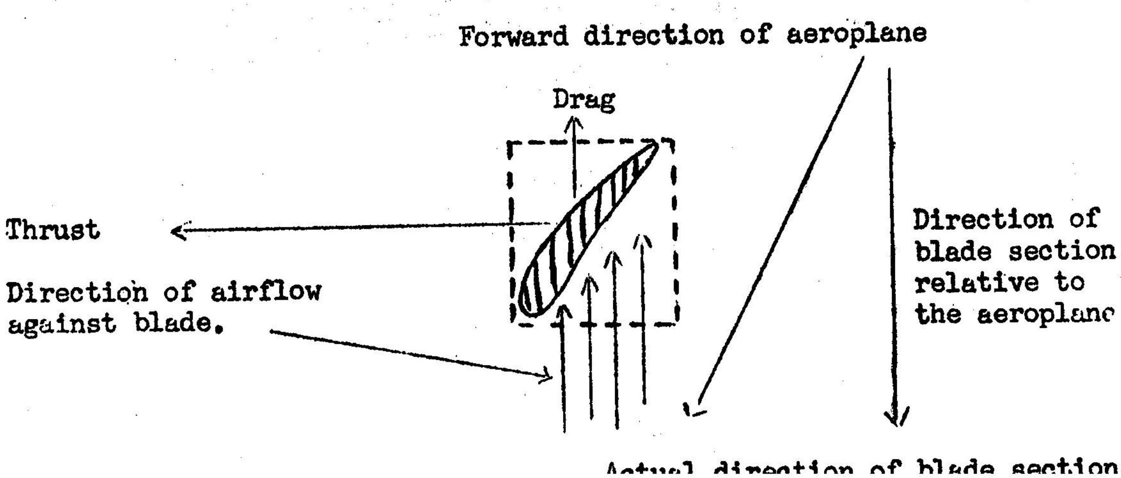


Fig. 25



Blade Angle



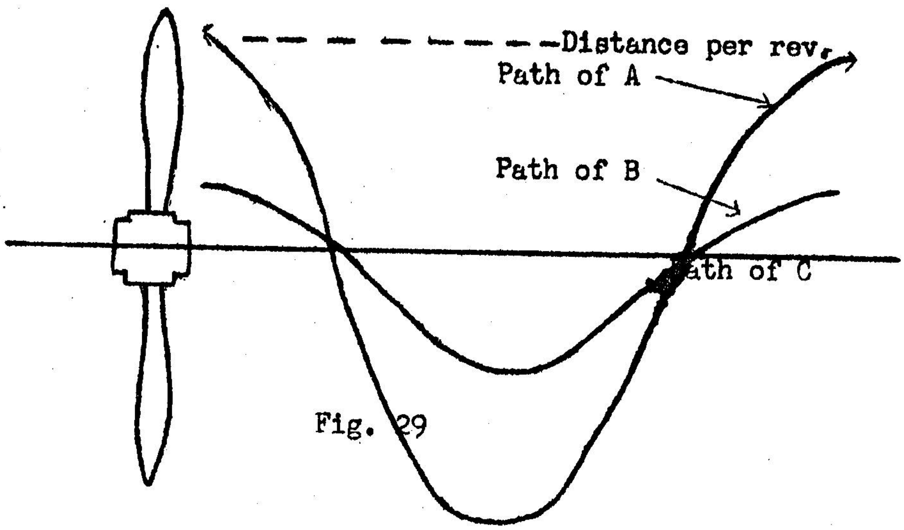

Distance per rev.
Path of A
Path of B
Path of C

Fig. 29

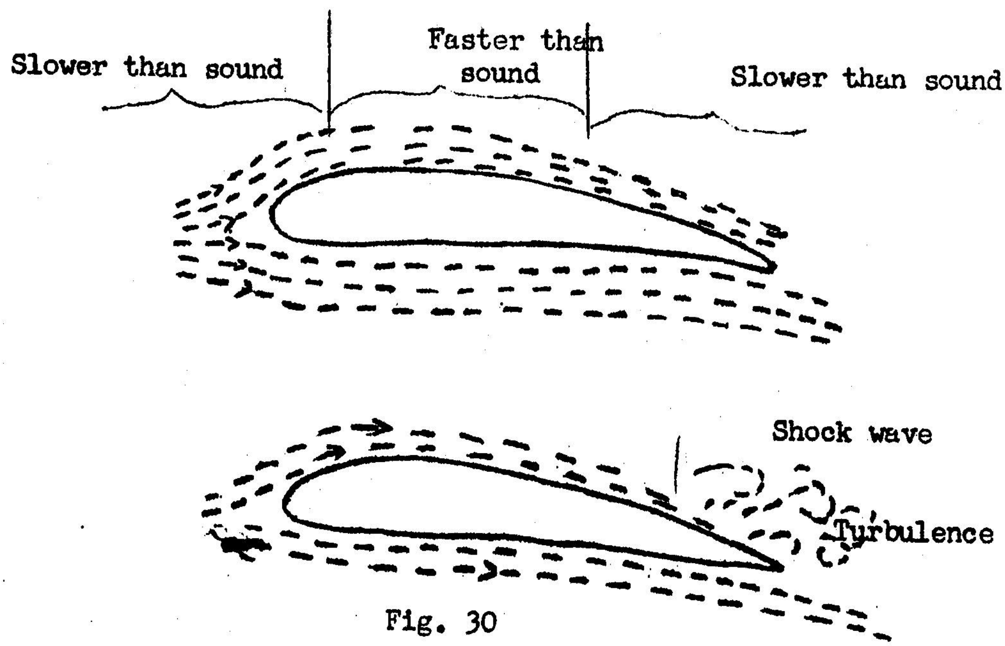

Slower than sound
Faster than sound
Slower than sound
Shock wave
Turbulence

Fig. 30

speed will decrease, but the increase in lift will cause the aircraft to climb. Increasing the angle of attack brings the aircraft to a point where the rate of climb falls off as well as forward speed. The angle immediately before this is the best climbing angle. The maximum power output of the engine obviously greatly effects the climbing ability of an aeroplane. It is possible that the engine may develope sufficient power to permit raising of the nose from level to vertical flight, but the thrust now has to oppose weight and drag combined and this manoeuvre cannot last for long with the present engines.

Nose Dives

In this manoeuvre, drag opposes weight and the aircraft increases speed until drag equals weight plus thrust. This maximum vertically downward speed is called TERMINAL VELOCITY and the heavier and more streamlined an aeroplane is, the greater the terminal velocity will be. In a vertical dive, the angle of attack is slightly negative (as is the case for level flight at full throttle) and there is a "download" on the front of the wing with "up" load at the tailing edge. The twist tendsto turn the aircraft on its back, but is opposed by a strong "down" load the tailplane. This sets up very strong structual stresses.

INVERTED FLIGHT

This flying is possible if the engine is equipped for this flying position. Symmeterical airofoils will function as weill, either inverted or in the normal position. Since the majority of mainplanes, however, are not symmettical, the aircraft must assume a position which to the aircraft gives a negative angle of attack to the mainplanes, which causes a lift toward the underside. This is done in normal flight by lowering the elevators, thus raising the tail. Since the aircraft is inverted, however, the tail will be lower than the mainplanes.

(XI) PROPELLORS

The purpose of the propellor is to convert the rotary power of the engine into a pull or push, in a straight line; the Thrust. If the propellor is mounted ahead of the engine it is called a TRACTOR, if behind, it is called a PUSHER. The propellor blades are of airofoil section, and in flight, each section follows a helical path, that of its own revolution travel plus the forward travel of the aircraft to which it is attached. Since the tips of the blades travels faster and farther than the parts near the boss, they are set at a smaller angle so that they will move the same distance forward in one revolution. This angle of the blades is referred to simply as the BLADE ANGLE and is measured from the horizontal, if the propellor hub is resting on the horizontal.

As the propellor rotates, the aerofoil sections meet the relative airflow at an angle of attack and create both lift and drag. The lift component is in a forward direction which is known as THRUST. The drag component acts at right angles to the lift and contributes to propellor torque.

Gemmetric Pitch

If the propellor was imagined to rotate in some solid substance the distance it would move forward in one revolution is called THE GEOMETRIC PITCH.

Effective Pitch

However, since the air is not solid, but a gas, and the drag of the aeroplane resists the forward motion of the propellor, it moves a shorter distance than it would with the theoretical pitch; this actual distance is known as the EFFECTIVE PITCH. The difference between the geometric pitch and the effective pitch is the SLIP. The effeciency of this figure is quite high with some types, at certain speeds as high as 80%. The decrease in blade angle toward the tip is important to the propellor's efficiency. If the blade angle with its angle of attack was the same throughout the entire length, the tipe, travelling faster would create more "lift" and the blade would tend to bend forward at the tip.

Variable Pitch

When the aircraft engine is run up on the ground, the blade angle is also the angle of attack; this angle should be such as to give maximum thrust for take off. During flight, however, a fast machine moves so far forward in one revolution of the propellor, that this blade angle would give no "bite" against the approaching air. This would result in no "lift" and no efficiency. This might be overcome by increasing the speed of the propellor but the tip becomes effected by the compressibility of air as any other aerofoil, which limits the tip speed of a propellor. If, however, the blade angle was set large enough to give efficiency at high aircraft speeds, it would be so great that the blades would be "stalled" when the machine was stationary, consequently very inefficient for the take off when efficiency is required most. The solution is a variable pitch for efficient and exonomical flight at altitude and high speed. The density of the air greatly effects the propellor as it does an aerofoil and with a decrease of density, on a supercharged engine, a fixed pitch propellor would cause the engine to race.

(XII) SUPERSONIC SPEEDS

The development of very high speed aircraft has, within the last few years met a serious obstacle. Namely compressibility or the SHOCK STALL. As a high speed aircraft approaches the speed of sound, it has been known to suddenly pitch into an uncontrollable nose dive, to crash or "pull out" at very low altitudes. Depending on atmospheric conditions the speed of sound is within the vicinity of 763 mph at sea level and 660 mph in the less dense air at 3500 feet. What has the speed of sound to do with flight? As an aircraft is drawn through the air it causes considerable disturbance ahead of it, as well as around it. The air begins to part ahead of the aircraft, due to pressure waves transmitted from the approaching wings. These pressure waves travel at the same speed as sound waves. If the aircraft travels at the speed of sound, therefore, the pressure waves will not travel ahead of the aeroplane and the wings continuously strike stationary "Unprepared" air. The air, being a gas does not act as a liquid, but compresses in front of the wing. As the air is forced over the wing, it tends to expand back to its original volume, but this expansion is so rapid that the air expands to less than normal density and then snaps back to normal. This rapid action causes turbulence which destroys lift. The aircraft itself does not have to reach the speed of sound before compressibility troubles are encountered. The airflow increases its velocity over the top of the aerofoils, this action creating the greater part of lift. Thus this airflow may have attained the speed of sound before the aircraft itself has a velocity of 4/5 of that of sound. The wing to the rear of this point can no longer send forward the pressure waves which influence the smooth airflow over the wings, but move forward at the speed of sound and encounter a mass strip of air moving backward at, or above, the speed of sound. This barrier causes all the pressure impulses from the rear portion to stop on the aerofoil and creat what is termed a SHOCK WAVE. This destroys the lift as effectively as a spoiler or heavy ice formation. The aircraft, having lost its lift will, due to its inherent stability, nose down and increase speed, aggravating the condition. If this phenomenon should occur at high altitudes, where the speed of sound is less, it is possible that when the aircraft reaches a lower level, where the speed of sound is higher, the machine may come back under control. This explains why some aircraft pull out of a shock stall dive.

Corrective Methods

The main cause of the shock stall is the speeding up of the airflow over the wing, which on orthodox machines is concentrated over the highest point of camber. A wing with a thin leading edge and a small camber distribution evenly across the chord of the wing would advoid some of the compression ahead of the wind and the rapid increase in airflow velocity at one concentrated point on the wing. Such wings are the DAVIS WING installed on the "Liberator" and LAMINAR FLOW wing on the "Mustang". Flaps have been developed which help the situation. They are fitted to the underside of the wing toward the leading edge, and are claimed to prevent the "stretching" and "snapping" of the compressed air as it flows aft on the underside. Moreover, the flaps will withstand the pressure of being lowered at high speeds and will slow the aircraft to below the critical speed and permit recovery from the abock stall dive by use of ordinary control. These flaps are not entirely corrective, but reduce the risks involved at high flying speeds. Terrific drag forces are encountered at the supersonic speed range and very destructive buffeting. Experts agree, however, that if this critical speed range could be passed, buffeting would cease and the drag at 1400 mph would be no greater than at 600 mph. But the aircraft would have to pass through this range during acceleration and deceleration and the problem has remained unsolved until the last few years.