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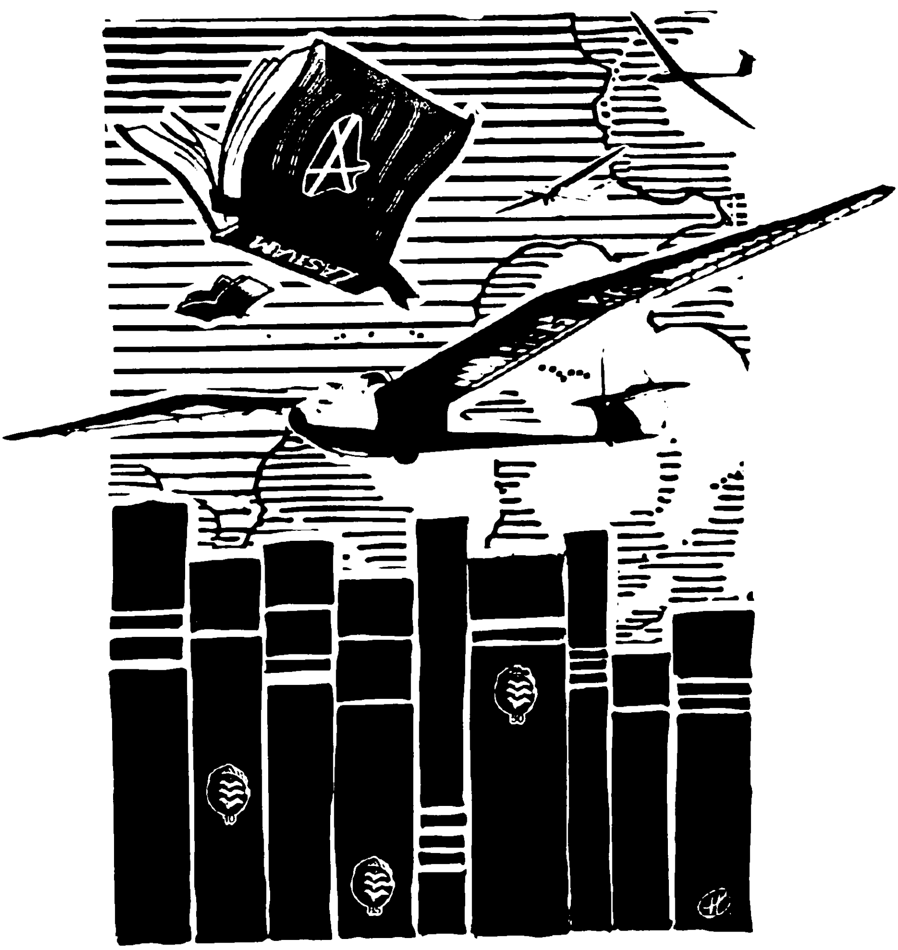

From the Gliding Library of

Wally Kahn

GLIDING AND SOARING

By the same Authors

THE FLYING SOLDIER

GLIDING AND SOARING

by

MAJOR ALOIS SITEK

and

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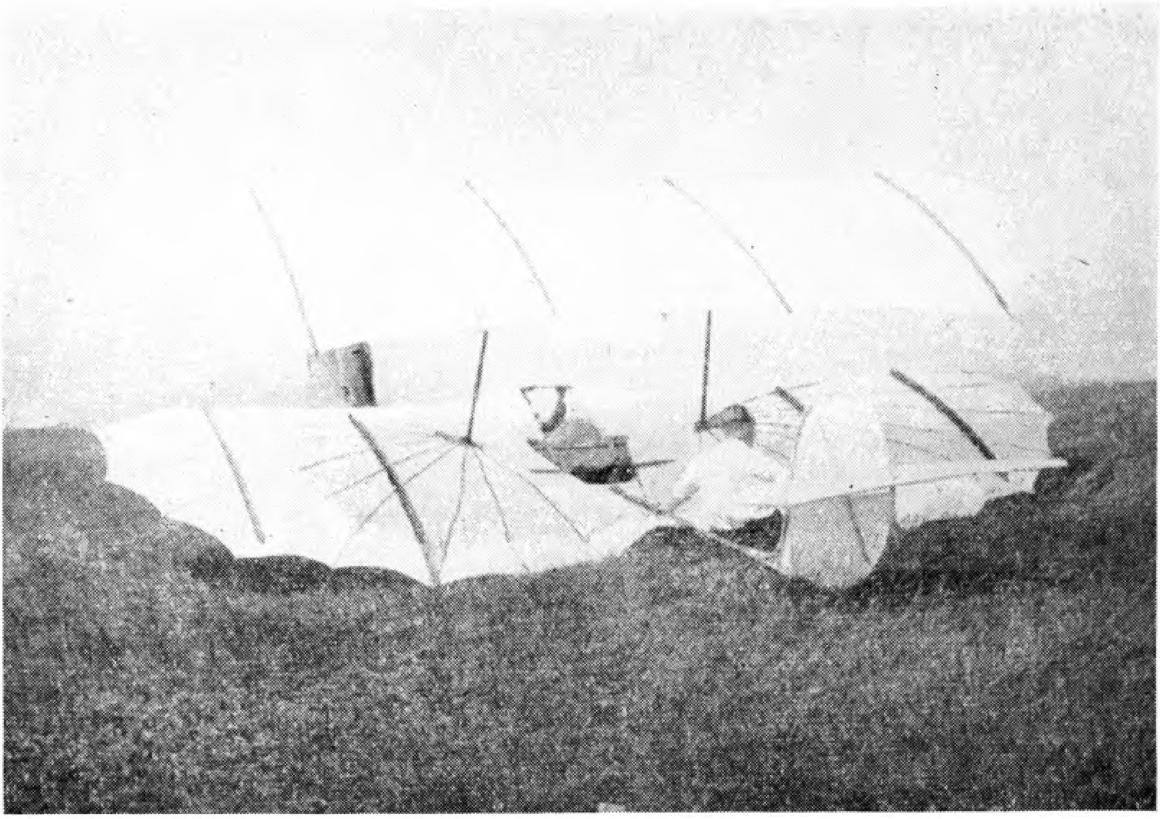
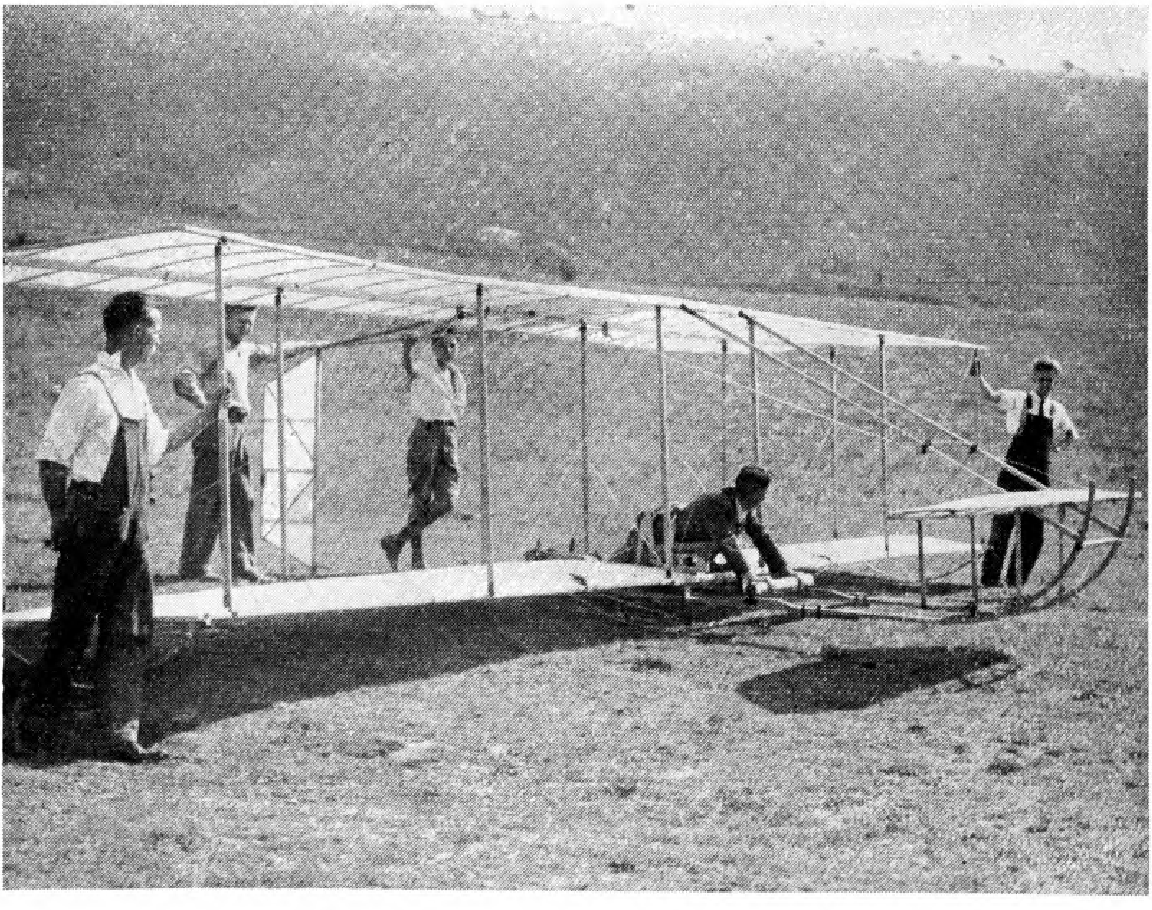
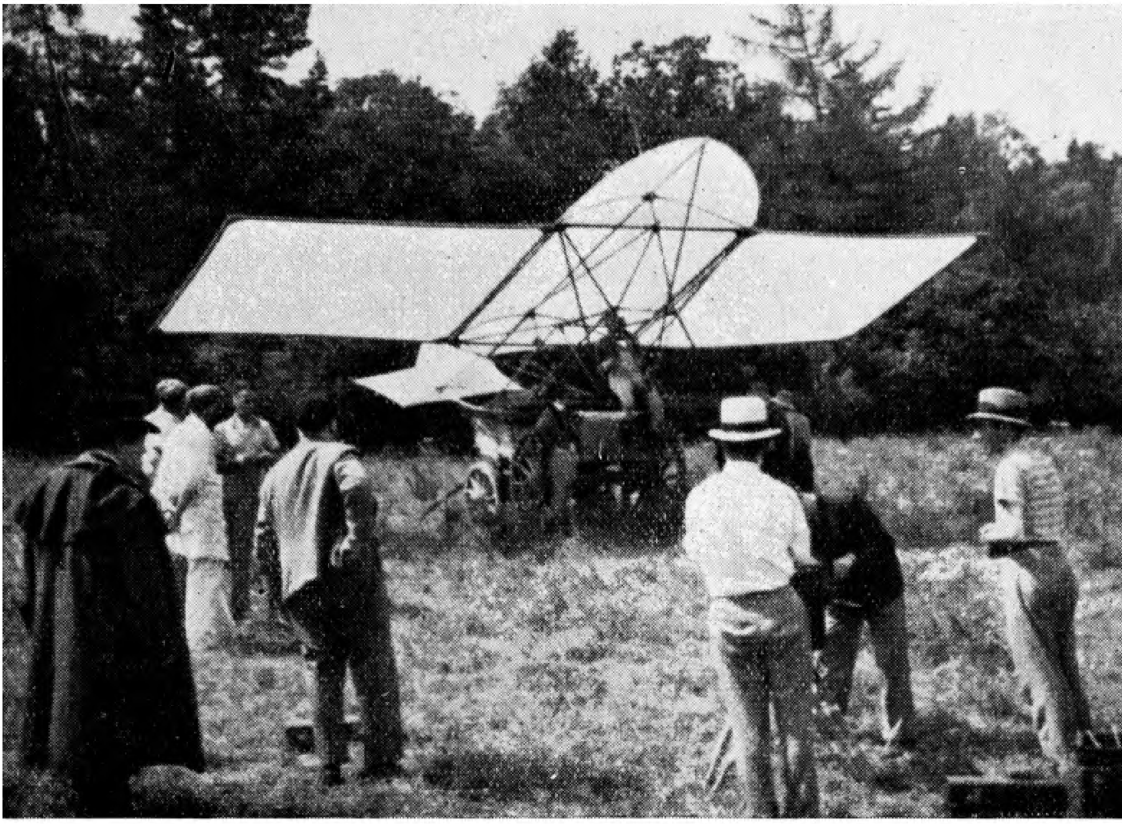


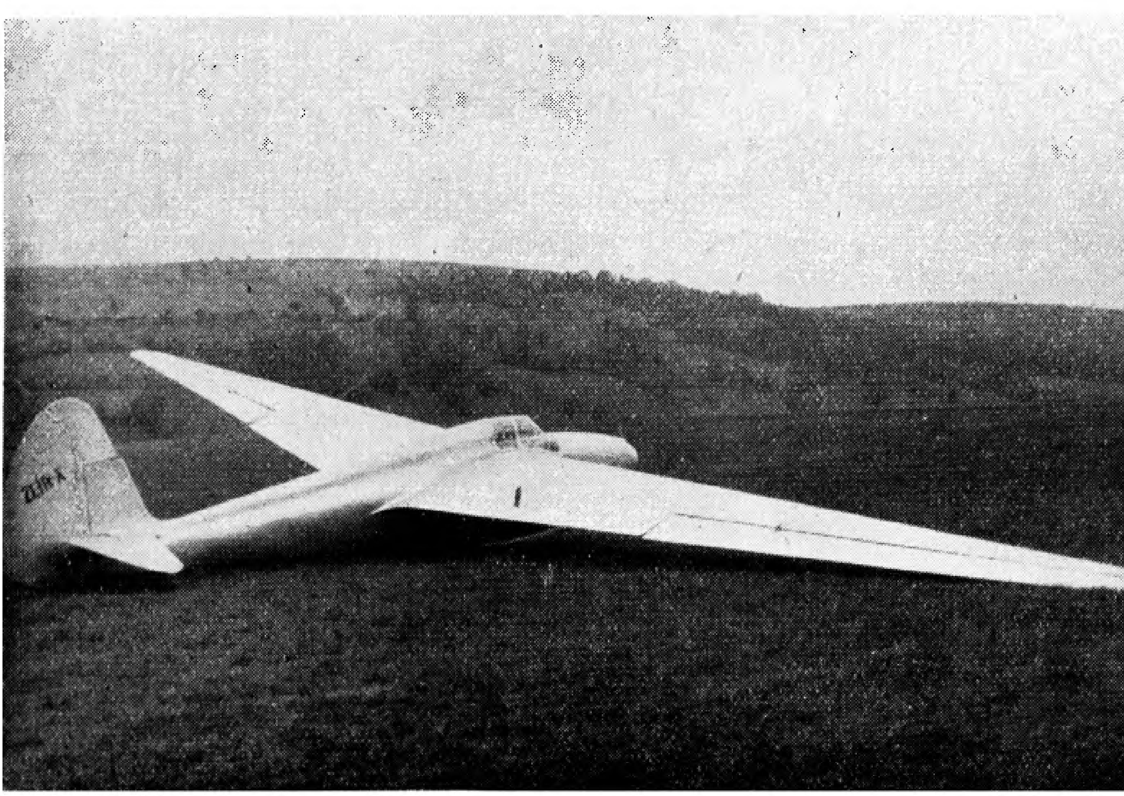
A replica of the Lillenthal early type biplane glider which was manufactured by Messrs. Zander & Weyl, of Dunstable, for London Film Productions, Denham



Replica of Wright biplane glider built for London Film Productions, Denham, by Messrs. Zander & Weyl, of Dunstable



Jumping off a farm waggon. Early type attempt at gliding



Major A. Sitek's high performance sailpane

I

INTRODUCTION

ONE of the most startling developments of the war has been the increasing use of glider aircraft. These, which in the very beginning, were no more than a sporting toy, have now become a vital part of modern airpower. They have become a deadly instrument of modern war, and it is not difficult to see that the practical use of gliders both in war and peace may bring about a development of the world which will be comparable to those changes which occurred with the growth of railways and the invention and production of the automobile. Up to the outbreak of war the art of soaring, that is, using motorless aircraft and relying upon air currents for power, had been put to the following practical purposes :—

Experimental.

(1) The retesting of prototype model aircraft, which have already been tested in a wind tunnel. However good wind tunnels there may be, they cannot create the same atmospherical conditions as are met with in actual flight. It is not generally known that Sikorsky, the famous American aircraft designer of the " Clipper " trans-atlantic aircraft, developed it from a glider.

Development of Slots and Flaps.

(2) Glider pilots and soaring craft have been responsible for such practical improvements as slots, which prevent aircraft from "stalling," and flaps, which act as airbrakes.

Meteorological Exploration.

(3) The use of sailplanes (as they are called for sporting purposes) in meteorological exploration of the atmosphere has provided data more accurate than that provided by motor driven aircraft. The reasons are that instruments mounted in the glider are able to note atmospherical conditions with the utmost accuracy, they are not disturbed by engine vibrations, and since the pilot depends on air currents he must and does observe natural phenomena closely.

Learning to Fly.

(4) The basis of flight is being airborne, and this is much more easily learned in gliders than in power driven aircraft. Gliders are cheaper to produce and to fly, and thus it is possible for a great many more people to learn to fly in gliders than will ever be possible in power aircraft.

Long before the present war the German Lufthansa (civil air line) compelled all pilots of her airline to fly gliders and thus gain experience of atmospherical conditions. This reduced the percentage of crashes due to storms, bad weather, etc. By such means and by the development of soaring clubs, Germany was able at the outbreak of the war to put into the air the world's largest number of efficient and irreplacable flying personnel. This helped her to gain those initial victories in the air on all fronts which have led to her present formidable position.

Not only this but the gliders and sailplanes were the prototypes of aircraft which the Luftwaffe eventually used with such devastating effect. For example the German sailplane Habicht became parent of the Stuka type bomber, having carried out vertical dives at 300 miles per hour. Gliders which proved their worth in aerobatic flying were so cleanly designed and so well constructed that on them is based the design and construction of the Messerschmits and Heinkel fighters.

(5) In war, gliders have been used by both sides for the transport of troops and war material.

It will be remembered that on the invasion of Belgium the forts at Eben Emael were attacked by troops landed on the forts by glider aircraft, which had been released over German territory and silently glided to their objective, thus effecting the maximum surprise. The guns of the forts were put out of action before the air raid sirens had sounded.

To the Russians belong the credit of having recognised the importance and use of gliders long before the present war, and they have devoted great sums of money and effort in the development of and experimentation with gliding and soaring aircraft. The Russians were the first nation to put the gliders to practical use by towing them behind aircraft. They were loaded with mail or material, and were able to land where it was impossible for aircraft to do so. This has been extended in U.S.A., and gliders can now be "picked up" by tug aircraft.

The Russians were also the first to use gliders for paratroops and even for bombing operations during manoeuvres.

It is clear that the glider has achieved a most important position in our organisation for war, and in time to come its functions may become more and more indispensable.

The uses to which it may be devoted in peace are even greater than those which war has demanded of it.

II

BRIEF HISTORY

EVER since human beings possessed imagination, they have tried, by one practical idea or another, to lift themselves into the air and fly. Greek mythology relates the sad stories of Daedalus and Icarus whose early attempts to fly were defeated by the elements. The wings of Icarus it will be remembered, being fixed to his shoulders by wax, were supposed to have been melted by the heat of the sun as he flew high in the air towards it.

Such also was the fate of many others who attempted to move from their natural elements of land and water into the freer air.

In modern times at the beginning of the last century, Sir George Cayley mathematically examined the conditions of flight in the air and thereafter constructed little models of gliders with which he carried out a great number of successful experiments.

In 1855 the French captain Le Bris constructed a glider in which he made a number of successful flights.

About the same time another Frenchman, Mouillard, studied the conditions of gliding and also make a few flights.

In 1891 the brothers Lilienthal accomplished the first successful piloted flight. Their gliders were either mono or biplane, from which the pilot was suspended by his elbows. They got into the air by running down a slope against the direction of the wind. The pilot steered the craft by throwing his weight from one side to the other. One of them was killed in 1896 in such a flight.

Lilienthal had many followers of which we would like to mention the names of Pilcher in England, Ferber in France, Chanute and Wright in U.S.A.

The first gliding club was founded in New York in 1894 by Mr. Carl Steinmetz. In 1902 the Wright brothers built a glider which made over a thousand flights. It was the first glider to be equipped with rudder and elevator, and reached a height of approximately 600 feet in 26 seconds. The Wrights, however, constructed their own motor in 1903 and ceased to develop gliders.

At the same time Montgomery, in California, undertook many successful gliding flights, but, unfortunately, in 1905 he changed over to hot air balloons and ceased to occupy himself with gliders. To the Frenchmen, Ferber and Voisin belongs the honour of having first attempted to tow a glider by motor car, but with the improvement of the internal combustion engine it became possible to mount engines into gliders which now become power driven aircraft, and from then on, until Germany was disarmed in 1919, the glider was forgotten. Once, in 1911, Orville Wright used a glider again in order to test a new type of stabiliser. His flight on that occasion of 9 minutes 45 seconds remained a record until 1921. At the same time experiments in motorless flying were made in Germany. By chance a very suitable area was found at the Wasserkuppe in Rhineland where Gutherman flew about 1,000 yards in 1 minute 52 seconds.

During the period of the first world war, experiments came to an end except for a few military attempts which do not appear to have achieved anything.

Immediate after the war in 1918 a German, Ursinus, editor of the journal " Flugsport " took up gliding again, and as Germany was forbidden by the Peace Treaty to have an air force, it was clear that it was important to develop training in gliders. This the Germans did and built a large number of gliders which they flew once more on the Wasserkuppe.

Klemperer in 1920 constructed the well-known " Schwarze Teufel," and in 1921 the " Bloue mouse " gliders, which were thought to be technical miracles. By means of an elastic cable these gliders were started from a hilltop. The first flights of 13 minutes were soon surpassed by others of 15 minutes. Martens and Hart flew a " Wampyr " for 21 minutes. The technical institute of Hanover and other high schools helped to supply the necessary calculations and produced the formulae for their construction.

In 1922 Martens reached the one hour mark, Henzen flew two hours, and a few days later three hours. These successes astonished sportsmen all over the world.

From 1923 sailplane pilots in England, U.S.A., Russia and other countries took up the new sport of motorless flying with enthusiasm.

In the same year Thoret, the Frenchman, switched off his engine and glided for 7 hours; whilst a little later Maneyrol and Barbot did the same thing for 8 hours and 5 minutes. At that time the greatest height reached by a glider was 2,000 ft., which a Frenchman, Descamp, achieved at Biskra.

By this time " slope " soaring had reached such a degree of development that even a slightly experienced pilot could soar along a slope in sufficient wind and keep on gaining height. The Czechoslovak Gliding Club was founded in Brno in 1923. A number of gliders were built and frequent flights were made in the Medlanek hills.

A thunderstorm in 1926 enabled Schulz and Kegel to reach a greater height than had yet been reached by gliders, and to double their distance record of the year before. Nehring undertook a successful circular flight to Milseburg and back.

About this time most important work on the atmospheric conditions favourable to soaring was done by Professor Georgii, president of the Rhön-Rossiten Gesellschaft. As a result of his intense work and experiments in cloud flying under cumuli, in 1928 the Austrian Kronfeld starting on the Wasserkuppe, made use of a thunderstorm and got on his way. Flying from cloud to cloud he found he could make distance. In the following year from the same airfield and on the top of a storm cloud he reached a height of nearly 8,000 feet and covered 80 miles. These new exploits greatly revived enthusiasm in gliding and resulted in the formation of the international soaring society, the Istus.

Another new soaring club was founded at Rossiten in East Prussia. In 1925 Schulz carried out a flight which lasted for 12 hours, and covered 16 miles.

The Germans began to develop soaring to the utmost and spared neither time nor money for experimental flights all over the world under the aegis of the German Exploration Institute. As a result it became possible to " mass produce " gliders and soaring 'planes, which in turn had a profound effect upon the development of the German civil and military aircraft industry.

In America the method of starting by being towed by an auto had been introduced. The first towing flight was carried out by Professor Franklin, who was towed in a glider by a power-driven aircraft. Other towing flights, however, were carried out by Espenlaube on the Wasserkuppe, but the method was not developed any further.

In 1930 one of Professor Franklin's gliders was towed across the American Continent. In America, also in 1930, Bowlus soared for 9 hours, and Bartow for 15 hours. The German, Klemperer, who in the meantime had joined the Goodyear Zeppelin Works at

Akron, Ohio, set up a new American record at a distance of 16 miles. The same year a good soaring area was found at Elmira, near New York, where Klemperer, Wolf, Hirth and O'Meara carried out their first long distance flights by the aid of clouds and hills, and covered about 55 miles.

In 1931 at a meeting on the Rhön flights of 70 miles were made by this method by Hirth, Kronfeld and Groenhof. In the same year Kronfeld started from Munich and landed in Czechoslovakia after a flight of 170 miles. During tests in Honolulu, V. Cooke soared for 22 hours. In 1933 this record was broken by Kurt Schmidt who flew for 36 hours 35 minutes. A height record was set up at Rio de Janeiro by the German, Dittmar, who reached 12,000 feet. Hanna Reitsch soared for 10 hours in the same year, covering 60 miles at a height of 7,500 feet.

In 1932 a soaring society had been founded in America by an experienced pilot Warren Eaton. O'Meara flew over 60 miles, Richard Du Pont 120 miles and two years later in 1934 Levin Barringer flew from Elenville by New York to Duketown in Pennsylvania covering 150 miles.

In the same year Dittmar covered 230 miles in 5 hours at a meeting on the Rhön and many other German glider pilots set up new records. By 1935 flights of 70 miles were common place; over 200 were made in Germany alone in that year. Distance continued to expand. Oeltschner, Brautigam, Heinemann and Steinhofen started from the Wasserkuppe and landed near Brno in Czechoslovakia 300 miles away. During the journey back, in which they were towed behind a power 'plane, Oeltschner was killed in a crash. In the same year Reidel flew from Hamburg to Berlin and Kraft from Hornberg to Cologne. During the Olympic Games in 1936 the Hungarian pilot Rotter flew from Berlin to Kiel and 4 German pilots made the 450 miles circuit from Darmstadt to Wurzburg, Munich, Augsburg, Stuttgart, Mannheim, Darmstadt. The following year in 1937 meetings were held in Salzburg, which resulted in the Alps being crossed for the first time, and in 1938 a meeting on the Rhön brought new altitude records. Drechsler reached 21,000 feet. Ten other pilots reached 11,500 feet, and in the same year Ziller reached 23,000 feet. Sandler and Bodecker, using a two-seater sailplane, remained in the air for 50 hours. Many nations took part in this competition, but all the prizes were won by Germans. In 1937, for the first time, Russian pilots took part in international competitions, and in the same year Rastorgueff started from Moscow and covered 250 miles and later 400 miles. Ilschenko and Emerik flew 250 miles in a two-seater, Kartasew 400 miles, and in 1939 Miss Klepikova flew 480 miles. A Pole, Miss Modlibowska, reached a new record by soaring for 24 hours. Soaring and soaring records went ahead at enormous speed until the outbreak of the new world war put an end to record making.

The glider, however, had already reached such a degree of perfection that its importance could not be overlooked. The different armed forces took it over and its development for the most varied war purposes is now in full swing. There can be no doubt that in the beginning the Germans were much in advance of the rest of the world, and may still be so, but recent achievements in glider development by Great Britain and America would make it appear impossible that they should have as long a lead as they did at the outbreak of war.

The further use of gliders after the war is beyond dispute, and offers many opportunities for development and experiment which open up entirely new visions of world transport, not the least of which is the possibility of being able to fly long distances without mechanical power and to land in areas accessible by no other means except long and arduous journey over difficult country.

British Gliding and Soaring

By Dr. A. E. SLATER

(By permission of "Sailplane & Glider")

The history of successful gliding in Britain begins with Percy Pilcher, who experimented with gliders in the closing years of last century. Later, the advent of the aeroplane stimulated many people to build and fly gliders, but with one exception they regarded gliding as a preliminary to aeroplane flight. The exception, José Weiss, single-mindedly pursued the ideal of soaring flight until, in 1909, he produced a bird-like glider in which Gordon England rose 100 feet in an up-current and remained aloft for 58 seconds.

The next event of note was a soaring competition near Lewes in 1922, organised in reply to a similar German meeting at which flights of up to 3 hours had been made. A few British pilots did some prolonged soaring, and a French competitor raised the world's record to 3 hours 21 minutes. The only consequence of this meeting was the ultra-light aeroplane, called "motor-glider" until it grew more horse-power.

However, by 1929 soaring in Germany had developed to the stage of long cross-country and high altitude flights. This stimulated the formation of a British Gliding Association, and in the following year scores of gliding clubs sprang up. But their numbers soon dwindled, and anyhow only a fraction of them did any soaring.

There have been two schools of thought in British gliding. To one, it is merely a cheap means of getting into the air. The most active exponent of this school, C. H. Lowe-Wylde, developed the method of towing the glider behind a car, following this by the further economy of transferring the motor into the glider. So history repeated itself, and Lowe-Wylde's "Drone" became the forerunner of a fresh spate of light aeroplanes of continually increasing power.

The alternative school, which regards soaring flight as an end in itself, has brought British soaring to the high place it now holds. The process began in earnest when G. Eric Collins, in 1933, pioneered the exploitation of thermal currents in England, and was quickly followed by a select band of fellow-members of the London Gliding Club. In 1934 the British distance record was raised to 56 miles by Philip A. Wills, then to 95 miles by Collins; while

G. Mungo Buxton climbed 8,323 feet from the Yorkshire Gliding Club in a " cold front " storm and came within a few hundred feet of the then world's record.

Distribution of a Government subsidy of £5,000 a year began in 1935, a condition being that clubs receiving it must possess a soaring site. Thus was soaring flight officially recognised as the ultimate aim of gliding. Fifteen clubs were receiving subsidy when war put a stop to it; and as to its stimulating effect, more gliding certificates were issued in 1939 than in the whole of the five pre-subsidy years 1930 to 1934.

A British team took part for the first time in an international contest in Germany in 1937, and gained some useful experience, incidentally putting up an international duration record for two-seaters. Shortly afterwards the British National Contest eclipsed all previous annual events of the kind, an aggregate cross-country mileage of 1,489 being done from the site of the Derbyshire and Lancashire Club, much of it by the skilful use of " cloud streets."

Of further meteorological interest was the first use of large-scale stationary air waves in Britain, resulting in a climb of 7,100 feet over the Midland Club's site by John E. Simpson. The " evening thermal " (warm air pushed up by katabatic wind) had already been first exploited in Derbyshire in 1936. Another innovation in 1937 was the use of aeroplane-towed launches for club training; many of those who gained this experience put it to unforeseen use in building up the Glider Pilots' Regiment during the present war.

The year of greatest progress for advanced soaring in Britain was 1938. In April alone more than 2,000 miles of cross-country flying was done, and in the same month the British distance record of 104 miles, established by Wills in 1936, was broken three times: by Christopher Nicholson (120 miles), John S. Fox (145 miles), and again by P. A. Wills (209 miles from Heston to St. Austell). During the last two flights useful lift was got from the " sea breeze " effect, the use of which for soaring is almost unknown on the Continent.

Wills raised the height record to 10,080 feet in June, and in July the international two-seater duration record was regained for Britain with a flight of 22 hrs. 13 mins. by W. B. Murray and J. S. Sproule. The British duration record for single-seaters was extended to 13 hrs. 27 mins. by A. O. Pick in July, and to 15 hrs. 47 mins. by A. N. Young in August. The number of pilots qualifying for the international " Silver C " certificate for advanced soaring reached the record figure of 20 for the year, and Philip Wills became third pilot in the world to obtain the newly instituted " Gold C " badge, given for flights of 300 kilometres distance and 3,000 metres altitude.

Nor was 1939 devoid of outstanding performances, which included the first soaring flight across the English Channel, from Dunstable to Boulogne, by Geoffrey H. Stephenson on April 22. W. B. Murray set up the first official British record for an out-and-return flight : 68 miles from Leicester to Birmingham and back. A notable example of applied meteorology was a new altitude record of 10,540 feet by N. McClean, who used a stationary wave in the notorious Helm Wind to leeward of Cross Fell. Soon afterwards P. A. Wills regained the record with 14,170 feet in a cumulo-nimbus cloud.

An additional subsidy was given in 1939 to enable the clubs to provide instruction camps for Air Defence Cadets, but in this case official policy was reversed and the emphasis put on gliding instead of soaring. Thus between April and September 577 pupils were trained to fly a glider down, but none learned how to keep a glider up. The Cadets' successors, the Air Training Corps, have now received similar training to the number of 200,000.

A number of short-lived glider manufacturing firms sprang up in 1930 and 1931, but for many years after that Slingsby Sailplates, of Kirbymoorside, had most of the trade, finally producing two excellent advanced sailplanes, the " Gull " and " Petrel." A more recent firm, Scott Light Aircraft of Dunstable, brought out the " Viking," also in the high-performance class.

Taking as a criterion the number of " Silver C " certificates held, Britain at the outbreak of war stood third among the nations in the art and science of soaring flight.

III

ATMOSPHERE

THE medium in which the glider moves is the air or atmosphere. It is not possible to control the atmosphere to man's liking and hence man must adapt himself to the given conditions; that is the glider must be designed in such a way that it takes advantage of favourable conditions and avoids being affected by those which are unfavourable. A pilot has to learn how to take advantage of everything that can help him, and similarly to avoid being influenced by unfavourable factors.

The following chapter contains a brief discussion on the structure and physical changes of the atmosphere as they affect gliding. This discussion is limited to superficial information for the benefit of those who are not already informed on the subject.

Atmosphere.

It has been calculated by the scientist and meteorologist, Edwin Houston, using Young's calculations that the earth's atmosphere which covers its surface reaches approximately to the height of 200 miles, but there are remnants of the lighter gases which reach up to about 500 miles. This is deduced from the fact that meteors on their way to the earth from the outside universe on reaching the resistance offered by these gases to their passage begin to fuse and burn at this height from the earth's surface. Above this height there is probably a vacuum which reflects the radio waves. This ceiling will most likely become the limit of future altitude records.

Air is a mixture of gases; 78% nitrogen, 21% oxygen, 0.9% argon, the rest being composed of hydrogen, xenon, neon, crypton and helium (Fig. 1). There is also a certain amount of carbon

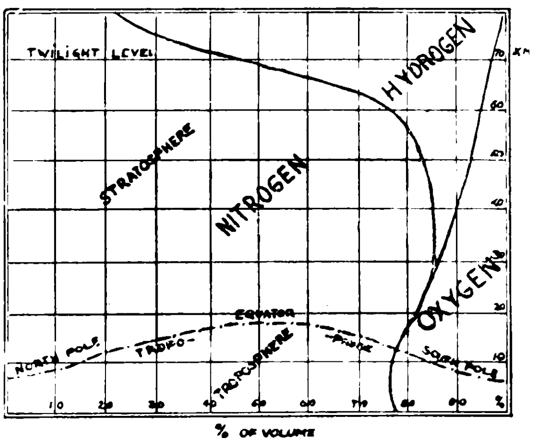


FIG. 1

AIR STRUCTURE CHANGES WITH ALTITUDE

dioxide, moisture and minute particles of organic and inorganic structure, that is dust. Because the atmosphere is comprised of gases of different atomical weights, its structure will change with increasing altitude.

Pressure.

All static and moving materials are influenced by the weight of the atmosphere above them, which is called barometric pressure. At sea level at a temperature of 0^0 centigrade this pressure amounts to about 1 kilogram per cm^2. The same pressure would be caused by a water column 10.33 m. high or a mercury column 760 mm. high. Measuring pressure in millibars (MB), 1,000 MB equals the pressure of a mercury column 750.1 mm. high. (Footnote comparative figures in inches.)

The astronomer and physicist J. A. Clark writes in his " Mechanics of Gases " : " Molecules of the air above move about freely with enormous speed. They strike the walls of their container in so great numbers that their impact produces a continuous pressure, the space which they occupy being limited only by the size of the vessel containing them. A mass of gas is said to resemble a swarm of bees, each molecule flying hither and thither in the course which is decided by its collision with other molecules " ; there is to be added only that the speed of the electrons circling round the nucleus of each atom (molecule) varies, decreasing in cold and increasing in warm temperatures. An air molecule revolves in normal temperature and pressure 5,000 million times per second. At the absolute zero temperature (-273° centigrade) the molecules will have no speed and the gas must change its form.

Instruments constructed for the measurement of atmospheric pressure are called barometers (showing the momentary pressure) or barographs (registering the pressure changes).

Density.

The density of the air is very important in flying : it is measured in grams of air per cubic metre. One cubic metre of air at the temperature 0°C. will be heavier than the identical air at 30°C.

Temperature.

The atmosphere is continually moving. This is caused by the heat of the earth and the sun (Fig. 2). A sun-ray being an electromagnetic wave 0.0008–0.00004 cm. long having travelled a distance of 93 million miles from the sun, hits the earth with a speed of 186,000 miles per second and warms it.

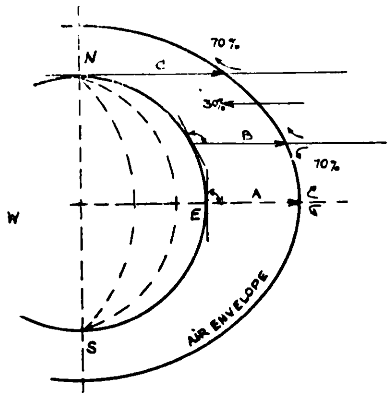


FIG. 2
AIR ENVELOPE: UNEQUAL TEMPERATURE CAUSES UNEQUAL AIR PRESSURE AND CONSTANT AIR MOTION

Let us now consider the phenomenon which the earth with its atmosphere presents in relation to the sun which is this great distance away. The rays coming from the sun, because of the great distance of their source, compared with the diameter of the earth are, to all intents and purposes, parallel. At the Equator at noon they fall vertically to the earth breaking through the atmosphere whose thickness is shown as (*a*) in Fig 2.

In the moderate zone the atmosphere is represented by (*b*) and the Polar zone by (*c*). Because the ray is to some extent influenced by absorption, transfusion, diffusion and reflection, it will therefore reach the earth at different places with different effects. Not at all places will it be vertical to the surface, and, for example, at the Poles it will have to pass through an atmosphere twice as thick as that through which it has to pass at the Equator. At the Poles the atmosphere will absorb a great part of the rays, especially in overcast weather. Consequently, the temperature transmitted to the earth through the atmosphere will vary from Pole to Equator because of these physical characteristics of the earth's atmosphere in relation to its surface.

The atmosphere is measured by degrees of Celsius (centigrade), Fahrenheit, or Reaumur. Fahrenheit fixed the freezing point of water on his scale at the figure 32, Celsius and Reaumur by 0, whilst Fahrenheit put the boiling point of water at the figure 212, Celsius at 100, Reaumur at 80. Fahrenheit's scale, therefore, left a difference of units of 180 from the freezing to the boiling point, whilst Celsius left 100 and Reaumur 80.

Temperature decreases with increasing altitude by approximately 0.6°C. per 100 m. (Fig. 3) nearly regularly at low altitudes (except

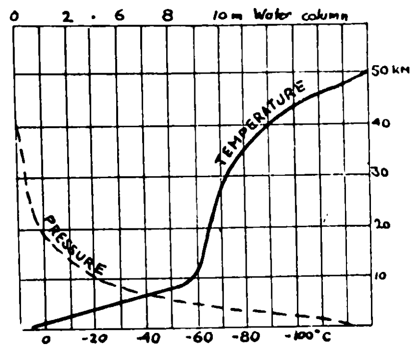


FIG. 3

DECREASE OF PRESSURE AND TEMPERATURE WITH HEIGHT

where there is ground reversion) and at higher altitudes more irregularly, nearing –273°C. in the stratosphere (Fig. 4).

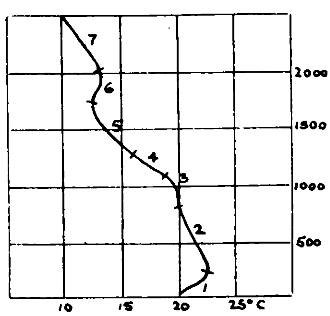


FIG. 4

TEMPREATURE CHANGES IN LOW ALTITUDE

1 Ground inversion
2 Rate of decrease
3 Influence of isotherms
4 Superadiabatic decrease
5 Adiabatic decrease
6 High inversion
7 Constant decrease

Temperature and pressure being directly inter-dependent cause a perpetual circulation of air from the Equator to the Poles and back. This is because a hot gas has a less density (less weight per given volume) than the same gas when cold. Since the earth rotates from West to East, and since the rotating speed at the Pole and at the Equator is obviously not the same, the air above the earth's surface is caused to deflect irregularly, so that the cold air instead of streaming from North to South in the northern hemisphere is streaming from NE to SW, and the hot air instead of streaming from S to N is streaming SW to NE (Fig. 5). In the southern hemisphere conditions are reversed.

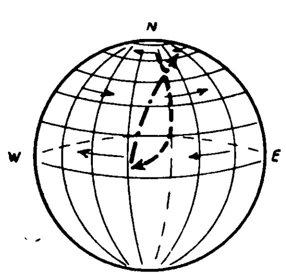


FIG. 5

CIRCULATION OF AIR AND INFLUENCE OF EARTH ROTATION CAUSES DEFLECTION OF GEOSTROPIC WIND

Passate ——————— (Trade Wind)
Antipassate —.—.— (Anti-trade Wind)

The pressure gradient and the earth's rotation cause a speeding up or slowing down of the wind in certain geographical latitudes, this wind being called geostrophic wind. Contrary to this, the cyclostrophic wind moves on a circular track of a certain radius with an increasing speed towards the centre. This is the phenomenon which is the origin of all kinds of revolving storms, such as tornadoes and hurricanes.

In the narrow belt of the Equator is the boundary of the air which streams alongside the so-called zone of equatorial calms. These air currents we call winds; the wind blowing from the Equator to the Pole is called "countertrade" (*antipassate*) whilst that from the Pole to the Equator is called "trade" (*passate*). These winds meet in the central zone thus forming currents of air. So we know three zones: the polar and equatorial zones with eastern wind prevailing; a zone in between them with a western wind and numerous currents which form the low pressure zone resulting in bad weather, rains and storms (Fig. 6).

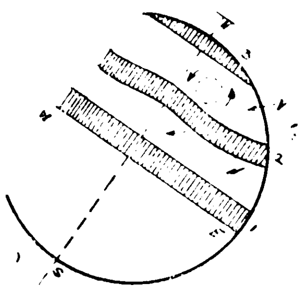


FIG. 6

EARTH ZONES:

1 Equatorial high pressure
2 Subtropical high pressure
3 Polar high pressure
V Variable Vestrelicies

The wind always blows from high to low pressure regions. The low pressure indicates bad weather, high pressure fair weather. Translated into terms affecting sail flying, a pilot should therefore try and make use of this phenomena. (We will discuss this later when we come to discuss Ballot's rule in the Art of Gliding.)

He will, therefore, remember Buys Ballot's rule to use a tail wind, he will also endeavour to keep to the right of high pressure zone and to the left of the low pressure zone. He will find this out by facing away from the wind (Fig. 7).

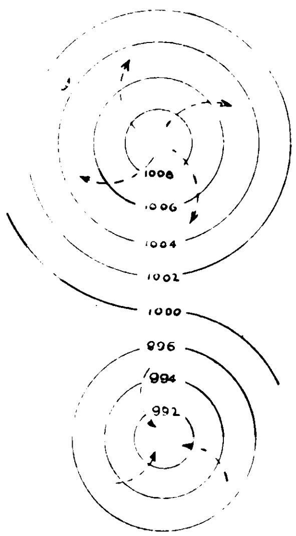


FIG. 7

BUYS BALLOT'S RULE: TO RECOGNISE THE LOW AND HIGH PRESSURE TURN BACKWARDS TO THE WIND, RIGHT HAND IS HIGH, LEFT IS LOW PRESSURE

Wind is subject to different changes in different altitudes. Close to the ground the friction of the uneven surface of the earth acts as a brake, which is not observed of course above the sea. The following table gives the average relative speed of wind in different altitudes in the temperate zone:

		SPEED OF WIND IN KILOS PER HOUR			
		At surface	At 3,000 ft.	At 6,000 ft.	At 9,000 ft.
		k.p.h.	k.p.h.	k.p.h.	k.p.h.
Seasons:	Spring...	5	9	10	13
	Summer	4	8	10	12
	Fall ...	4	9	11	13
	Winter...	5	11	13	13

For flying purposes the speed of wind has been divided into four groups:—

(1) From 0–4 m/sec—Slight wind.
(2) From 4–8 m/sec.—Moderate wind.
(3) From 8–15 m/sec.—Fresh wind.
(4) From 15–20 m/sec.—Strong wind.

Soaring in strong winds, especially in squally weather, should only be attempted by very experienced pilots.

Other categories of winds are those which are irregular and accidental. They rise unexpectedly under special atmospherical conditions, and therefore are very fierce and dangerous. According to the locality of their origin on the earth's surface they are called Hurricane, Monsoon, Typhoon, Tornado, Harmathan, Simoon, Khamsin, etc. They originate mostly between the 10th the 30th meridian, circulating round a certain base whose speed of movement over the earth's surface is usually about 70 to 100 miles an hour. They have a very destructive effect on life and material.

The common factor of all winds is that they are capable of being deflected by the structure of the earth's surface as well as by the rotation of the earth, to as much as 40% from their original direction. For the purposes of international recognition of wind strength, all winds were measured in metres per second and subdivided in a scale devised by Beaufort varying from 0 to 12.

Instruments used for measuring the speed of the wind on the earth's surface are called anemometers. For measuring wind velocity in the upper air, observations of the speed of a free balloon or explosion of a shell from a gun is made, using a theodolite.

Speed of wind in miles/hour	Name	Beaufort's number
0– 1	Calm	0
1– 3	Light air	1
4– 7	Light breeze	2
8–12	Gentle breeze	3
13–18	Moderate breeze	4
19–24	Fresh breeze	5
25–31	Strong breeze	6
32–38	Moderate gale	7
39–46	Fresh gale	8
47–54	Strong gale...	9
55–63	Whole gale	10
64–75	Storm	11
Above 75	Hurricane	12

We must now introduce the reader to the first simple influence of wind on aircraft. Aircraft are bodies like a chair or any other body. If pushed from behind they go forward, if pushed in a backward direction they go back, from the side they move sideways. If they are already moving and are subject to pressure from behind in the direction in which they are moving they travel more quickly, and if this pressure is applied from in front against their direction of flight they are slowed down, whilst if pressure is directed from the side, and they are moving, they are deflected from their line of flight. Usually a combination of both occurs and this effect must be eliminated by changing the direction of flight. This is the

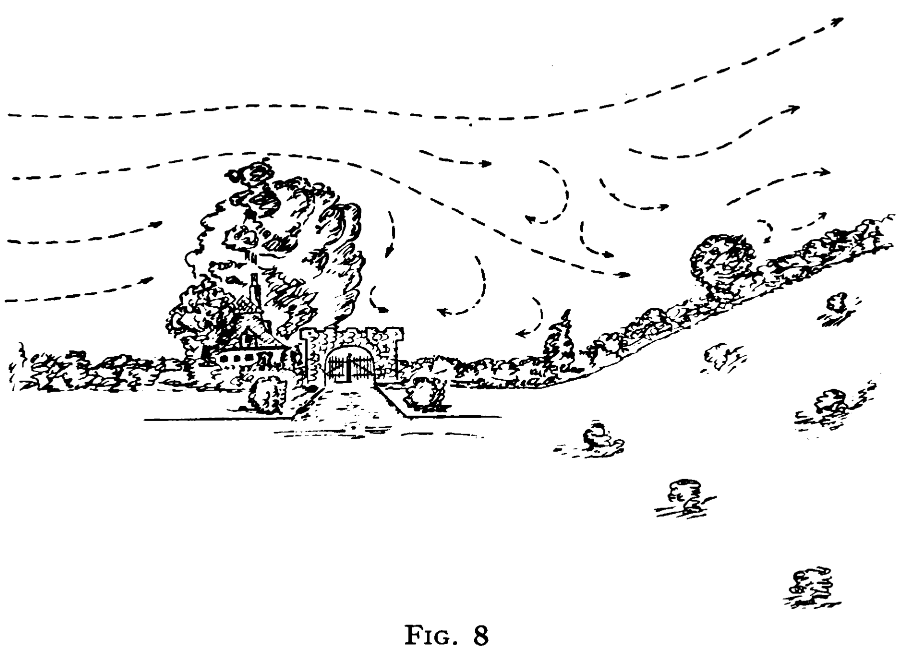


FIG. 8

COMPACT OBSTACLE CAUSES BIG WIND EDDIES

basic principle on which soaring and sailflying are founded, but it will be extended in a later chapter. It is mentioned here in order to stress the importance of a thorough grasp of the remainder of this chapter on air currents.

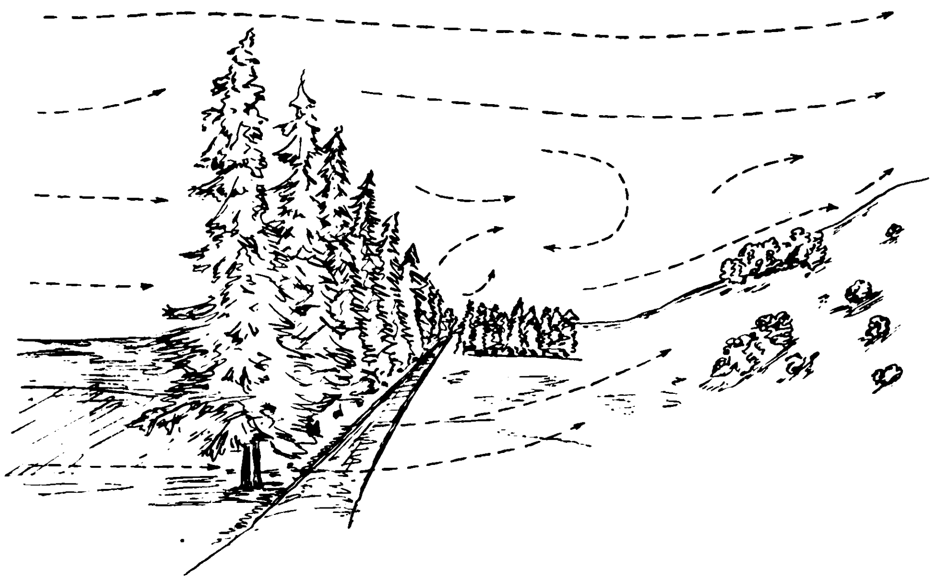
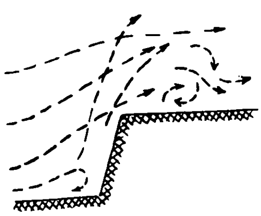


FIG. 9

THIN OR DISPERSED OBSTACLE CAUSES FEEBLE WIND EDDIES



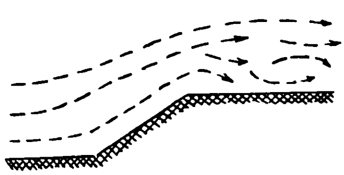
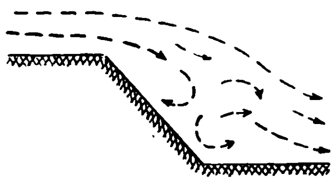


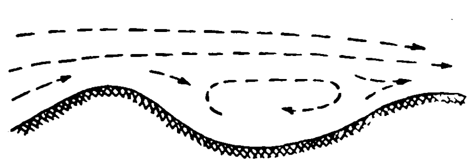
FIG. 10

WIND EDDIES ABOVE A STEEP SLOPE

WIND EDDIES ABOVE PLATEAU

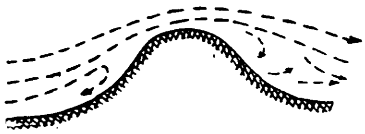


WIND EDDIES BEHIND SLOPE

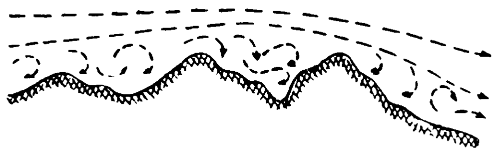


ROTATION OF WIND EDDIES BETWEEN HILLS

At low levels wind undergoes changes in direction and in speed which are due to both artificial and natural obstacles (Figs. 8, 9 and 10).



Low mountains eddies



Between and behind many hills or mountains the wind blows irregularly, causing many dangerous eddies

Figures 8 to 10 show the impossibility of an exact theoretical measuring of wind direction, kind and strength. Both observation and empirical methods are necessary. If the wind blows against a solitary hill a considerable portion of it evades the hill, only part slides up the slope (Fig 11). For sailflying (soaring) such a

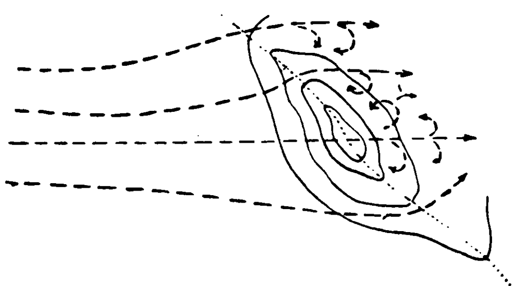


Fig. 11
Some part of the wind has a sidewise tendency to the solitary hill

terrain is unsuitable. Long slopes facing the prevailing wind are much better. (Fig. 12.) The take-off is at the most

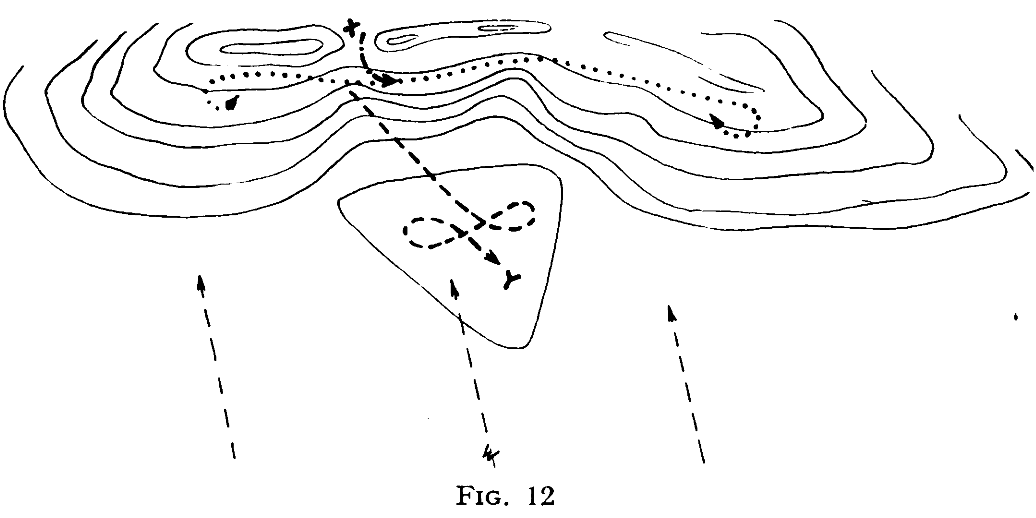


Fig. 12
Prevailing wind W
Take off point X
Taking off course —.—.—
Direction of soaring . . . . . .
Landing course — — — — — — —
Landing ground Y

convenient place, which is not necessarily the highest, the pilot therefore continuing his flight by the use of the up wind on the slope. How this slope wind is then turned to account will be developed in a later chapter.

It is important for the pilot to realise the correct position in regard to the hill and the wind if he is to engage in slope flying. The limits are shown by the thick black line in Fig. 13.

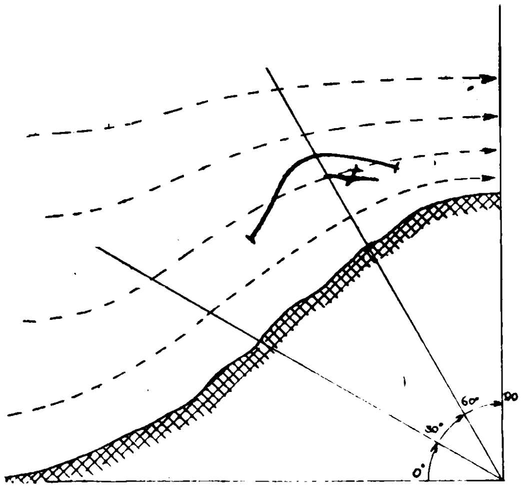


FIG. 13
HEIGHT PROFILE OF SLOPE SOARING

Another group of atmospherical movements are the vertical currents. They are originated by the unequal heating of the differently re-acting surfaces of the earth. We call them thermic or thermal. Figures 14 and 15 sufficiently explain their origin,

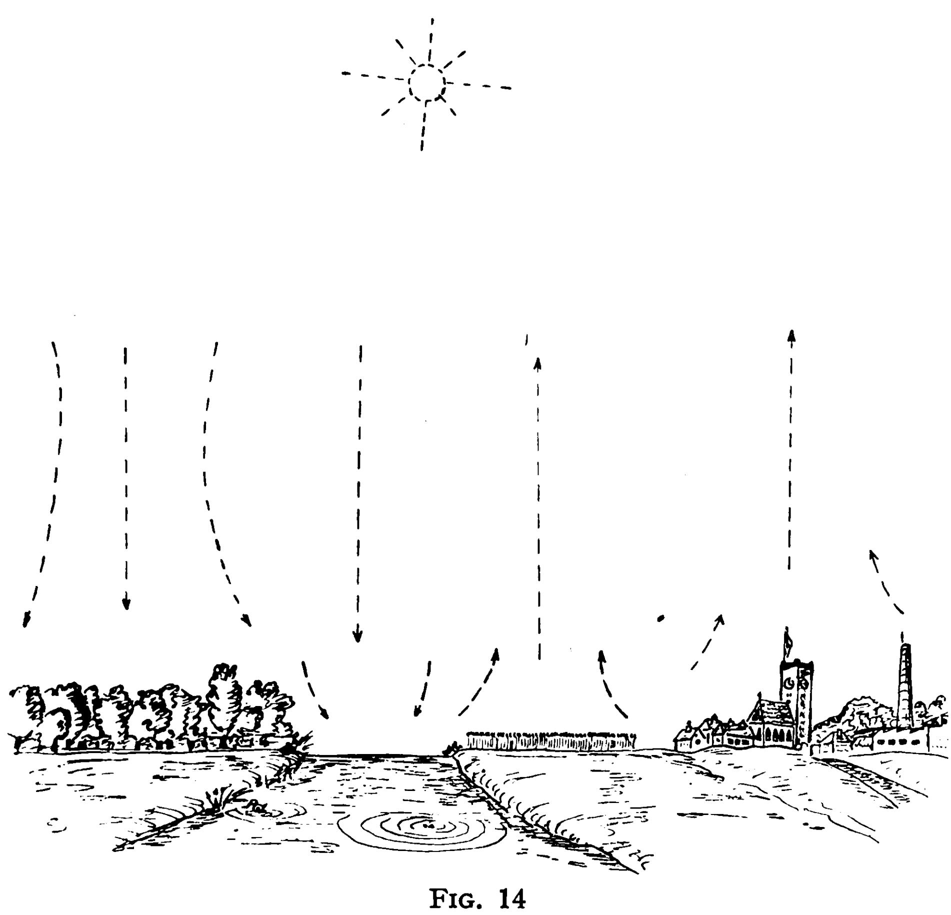


FIG. 14
AIR MOVING DURING DAY CAUSED BY UNEQUAL HEATING OF THE DIFFERENTLY REACTING SURFACES OF THE EARTH

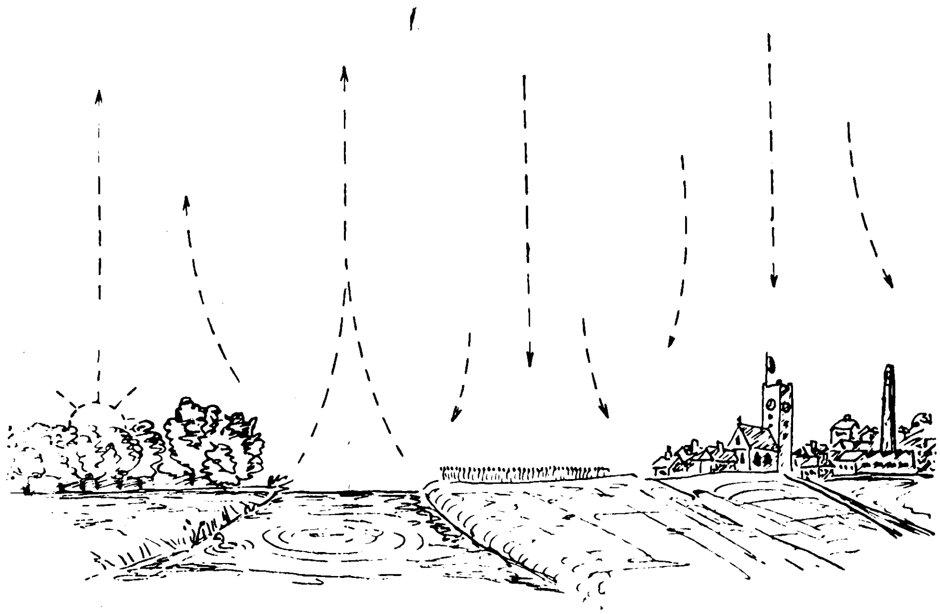


FIG. 15

AIR MOVING DURING NIGHT CAUSED BY UNEQUAL HEATING OF THE DIFFERENTLY REACTING SURFACES OF THE EARTH

movement and influence. Some areas are warmed up by the sun more quickly than others, and consequently radiate the acquired

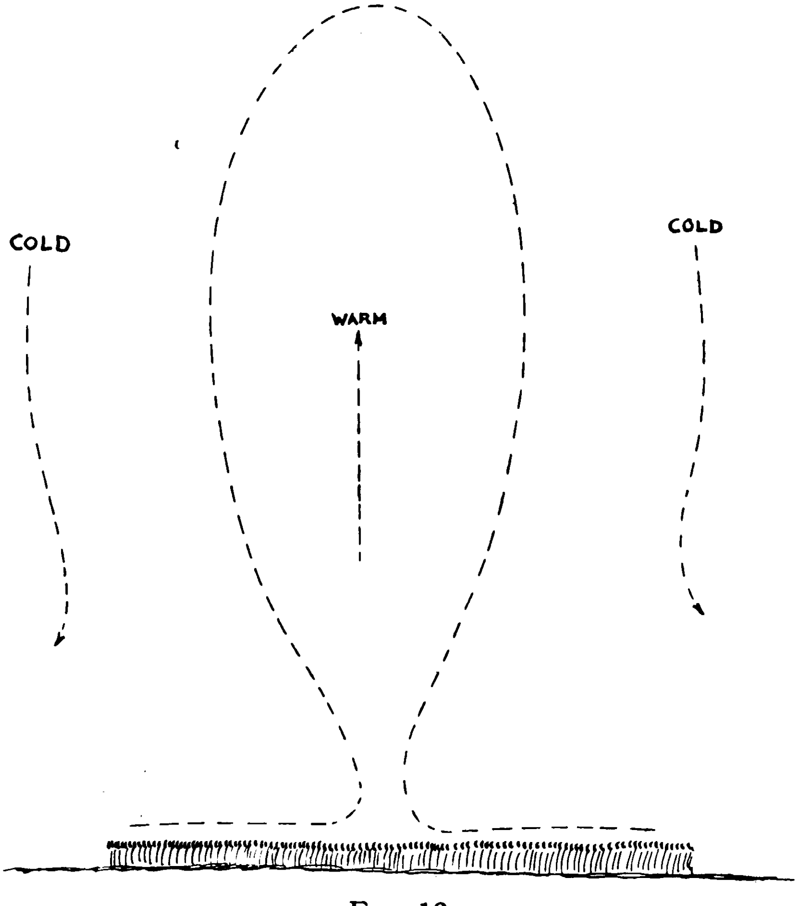


FIG. 16

RADIATING OF WARMTH IN THE FORM OF A THERMIC BUBBLE warmth more quickly. Hence a space of warm air originates over these areas and, being lighter, commences to ascend, finally detaching itself from the surface and according to circumstances rises to different heights (Fig. 16). Its ascending speed has been known to attain between 40 and 50 miles an hour reaching to a height of 20,000 feet. As it gains height this thermic bubble as it is called, grows in size and is eventually deformed and displaced by horizontal currents of air (Figs. 17 and 18). It will be

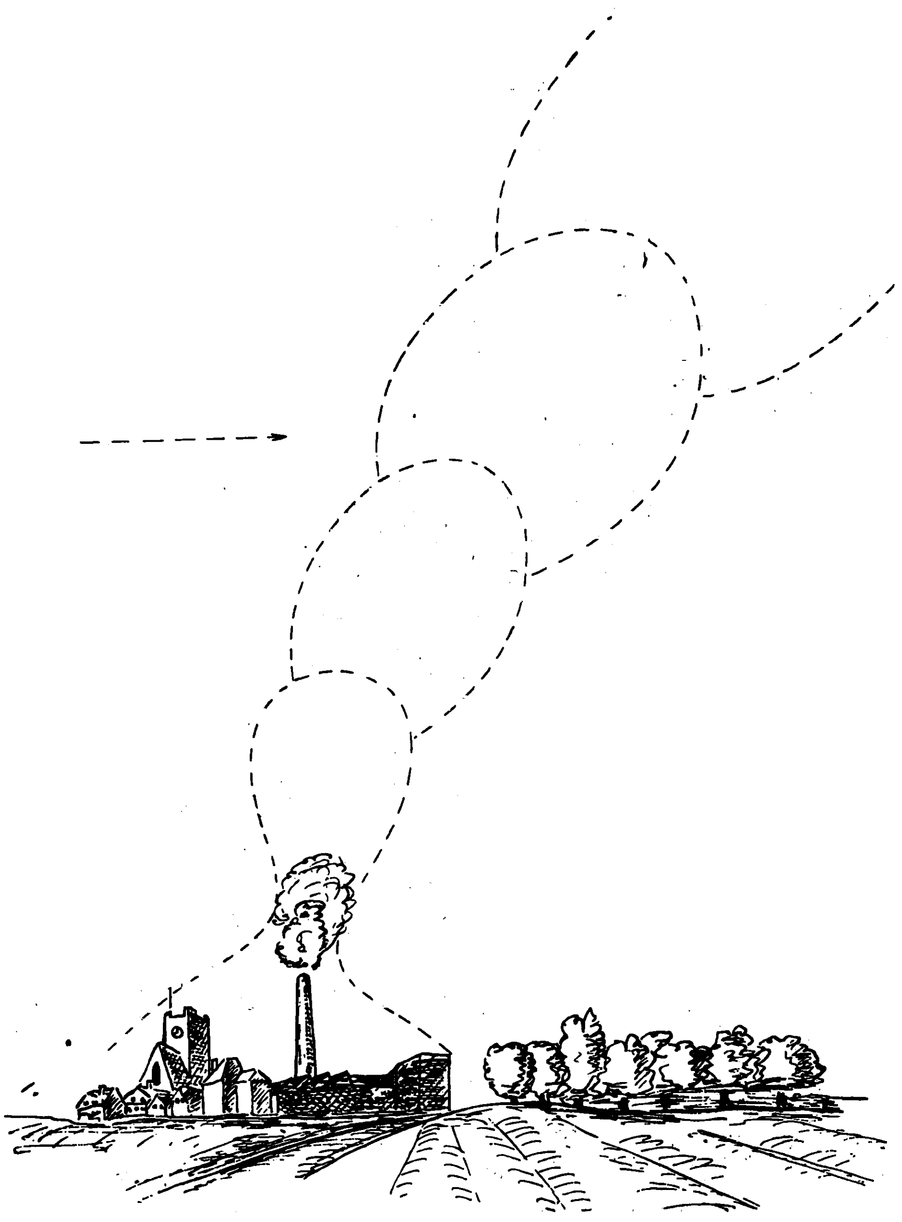


FIG. 17

THE THERMIC GAINING HEIGHT AND GROWING

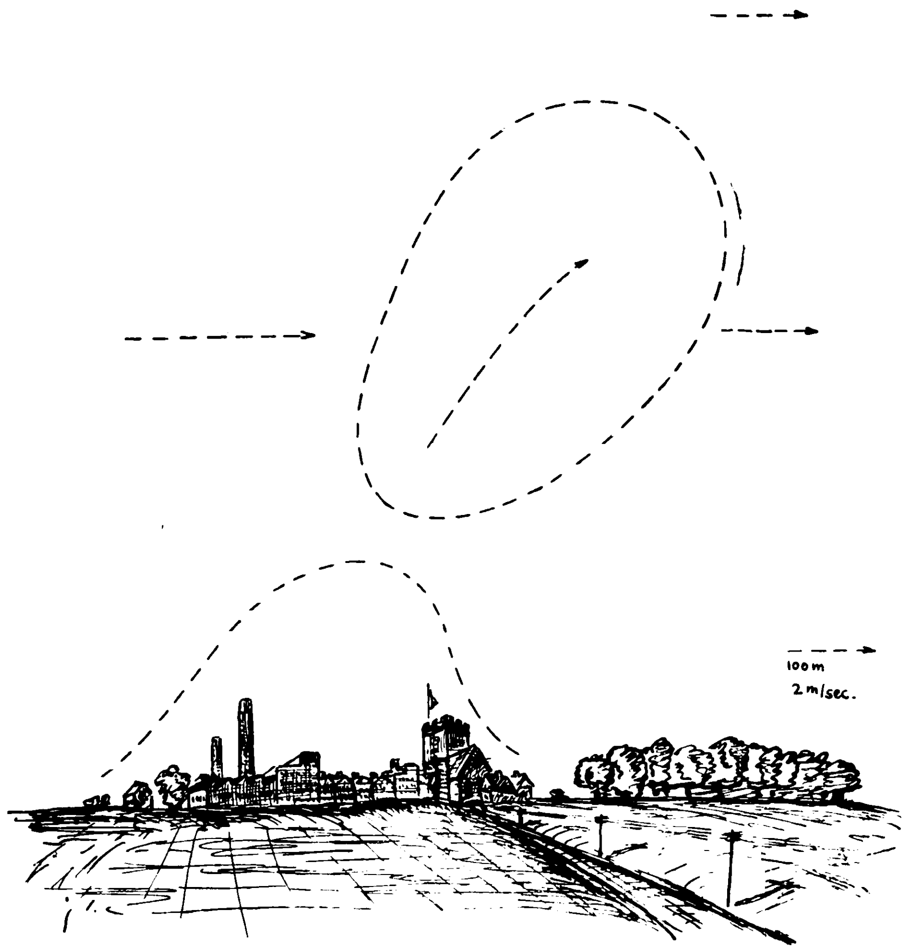


FIG. 18
DEFORMING AND SIDEWAYS SHIFTING OF A THERMIC BUBBLE

Diameter	Surface	Time ′	″
200	630	–	37
400	1,260	1	16
600	1,880	1	50
800	2,500	2	30
1,000	3,100	3	10

necessary here to anticipate somewhat the contents of a later chapter on the theory of flight in order to bring out the importance of thermal current or thermic in relation to gliding.

It is obvious that ascending currents can be made use of for soaring, if discovered in time by the glider pilot. It is extremely difficult to discover such currents by sheer physical sense, a capacity which is possessed by only a very few species of birds who have developed it after long ages of experience. Man's ingenuity constructed a special apparatus called a variometer, which immediately registers any gain or loss of altitude with precision in feet or metres per second. Such apparatus enables an experienced pilot to exploit the natural conditions, and, having discovered a thermal, to stay in it and to ascend with it to a certain altitude (**Figs.** 19 and 20). It should be added, however, that whether the

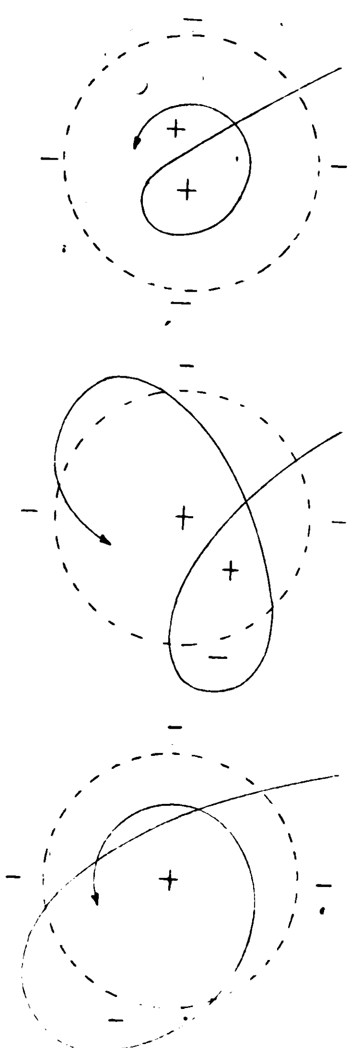


FIG. 19

SOARING IN THE THERMIC BUBBLE

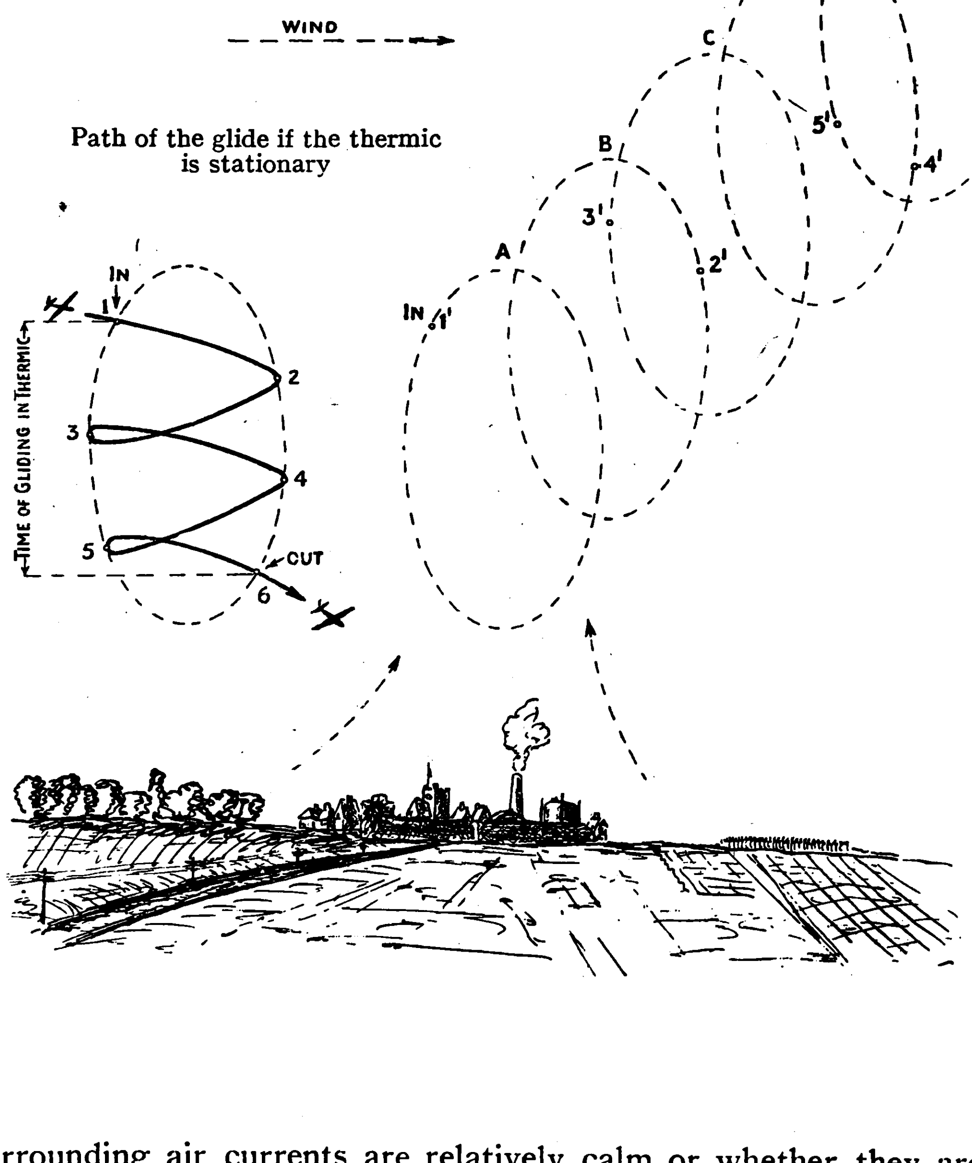
Thermic surface — — — — — —
Direction of soaring ——— ———→
Up current : climb +
Down current : descend –

Variometer indicates immediately when height is lost or gained inside or outside a thermic bubble

FIG. 20

ASCENDING OF A THERMIC AND THE PATH OF SOARING IN IT

(Numbers 1 corresponding 1′ etc.)



surrounding air currents are relatively calm or whether they are moving up or down, a glider or sail-plane whetever its construction or flying qualities, must necessarily glide. The pilot consequently either gains altitude or glides slowly downwards in his " gliding proportion " or he loses altitude more quickly than his " gliding proportion " should indicate. (Figs. 21, 22, 23 and 24). This gliding proportion is the relation between the altitude

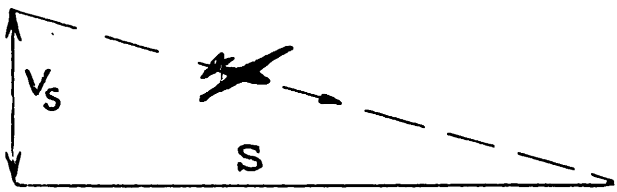


FIG. 21

GLIDING IN CALM ATMOSPHERIC CONDITIONS

Vs Sinking speed
S Distance gained
Height ÷ Distance = Gliding rate

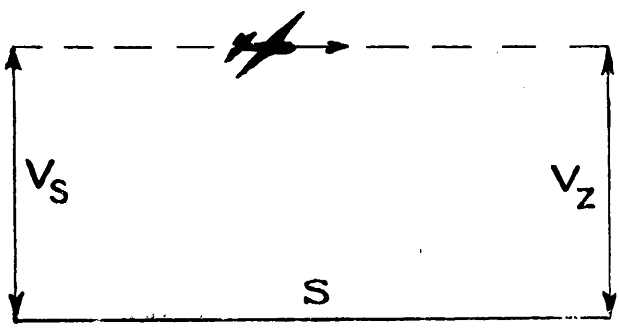


FIG. 22

GLIDING IN LIGHT ASCENDING CURRENT

Vs Sinking speed
Vz Ascending speed
Vs = Vz thus gliding (soaring) will be horizontal, while time and distance is prolonged

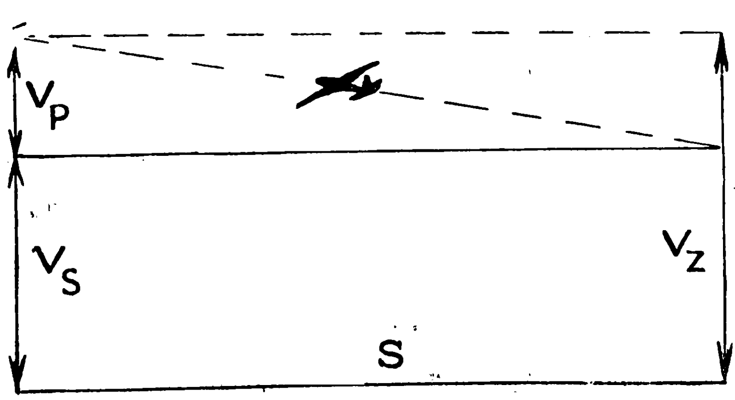


FIG. 23

SOARING IN STRONG ASCENDING CURRENT

Vz > Vs, thus Vp will be height gained
Vp = Vz — Vs

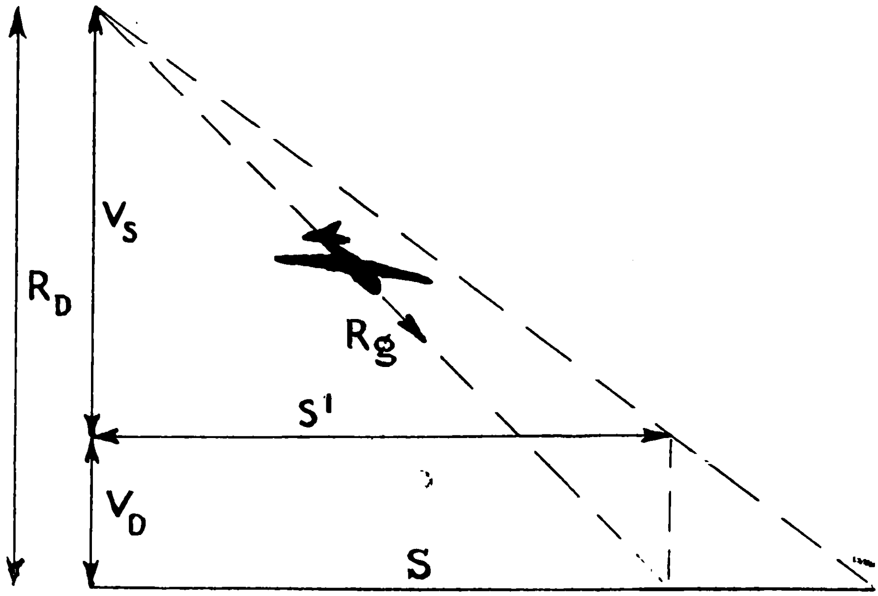


FIG. 24

GLIDING IN A DESCENDING CURRENT CAUSES A STEEPER GLIDE THAN NORMAL CONDITIONS. RATE OF DESCENT IS EQUAL TO THE $V_S + V_D$ DOWNCURRENT

Time and distance will be shortened

Rd = Rate of descent

Rg = Resultant path of descent

and the distance of the glide. Thus 1 : 20 indicates that a glider of given quality can glide in calm atmospheric conditions from 1,000 ft. height to a distance of 20,000 ft. or nearly 4 miles.

Gliding proportion of different types of gliders (Fig. 25).

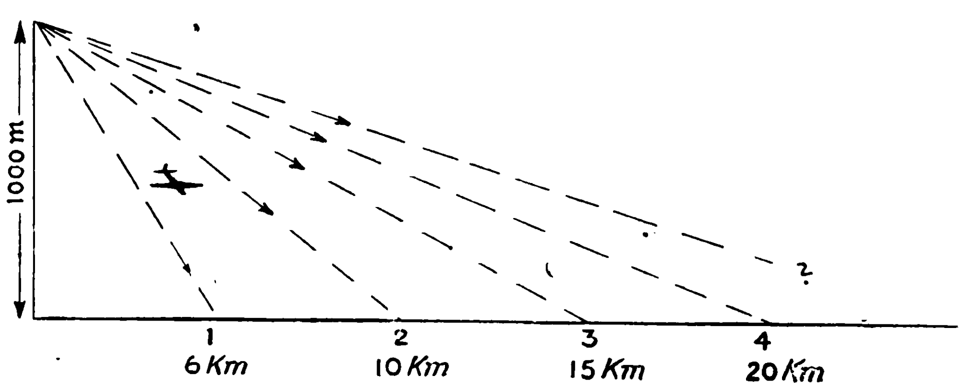


FIG. 25

GLIDING RATE (PROPORTION):

1 : 6 Primary glider
1 : 10 Utility glider
1 : 15 Sailplane
1 : 20 Performance sailplane
1 : ? (Still in development)

(1)	Primary glider	1 : 6
(2)	Utility glider	1 : 10
(3)	Sail-plane	1 : 15
(4)	High performance s.p.	1 : 20-35

These proper thermics, originating in an area of calm air, in some cases develop and combine with winds of different directions and strengths (Fig. 26). This is the cause of what are

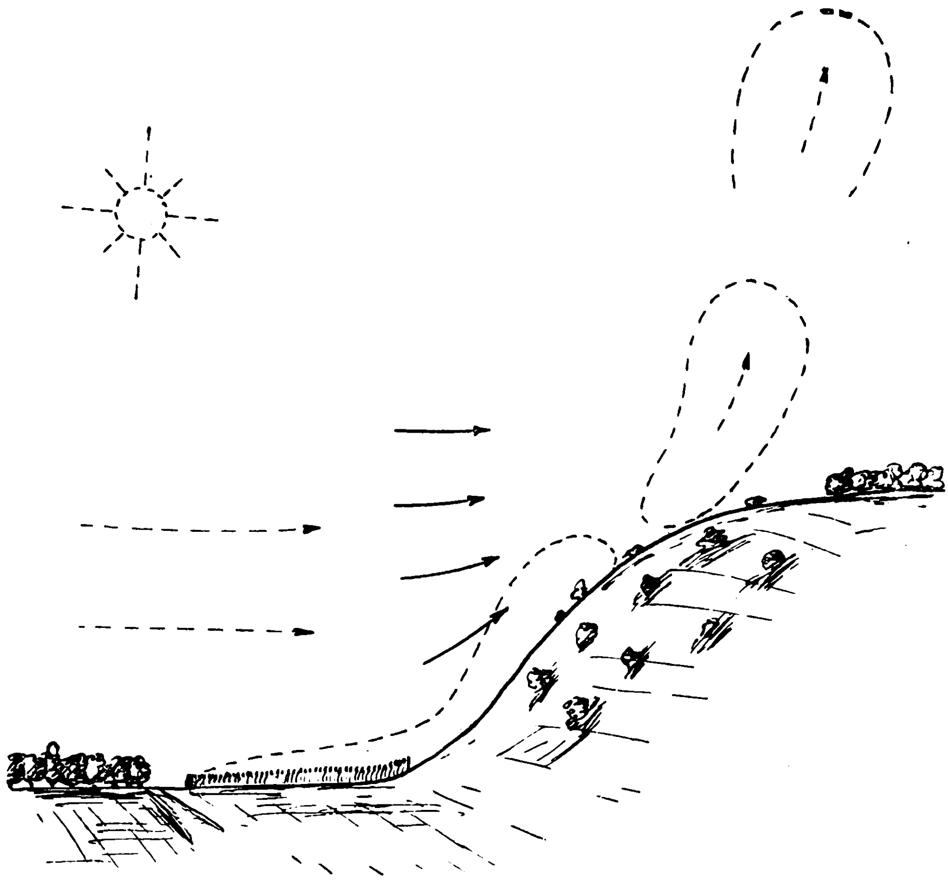


FIG. 26
ORIGIN OF THERMIC ON SLOPE COMBINED WITH WIND

known as air bumps, which result in the tossing of a glider or aircraft very much as a ship is tossed on a rough sea. This is the cause of air sickness, even with experienced pilots. But a pilot who is capable of taking advantage of these numerous occurrences can use them to gain height and bring his aircraft to considerable altitude. Having accomplished this he can assume his original course and try and find another thermic with which to repeat the manoeuvre. Thermics are frequent during day time as well as at night, at any time of the year. Clouds are a very good guide to finding them.

Humidity.

Vapour, always present in the air, is derived from vapourisation of moisture on the surface of the earth, but more especially from the vast areas of water. Quantities of vapour contained in the air are measured in degrees of humidity. This is greater above the ocean closest to the equator. Theoretically it is possible to state the quantity of vapour capable of absorption into the air at different temperatures as follows :—

Temperature in °F.	−60	−40	−20	0	+20	+40	+60	+80
Quantity of water in 1 cubic metre (in grams) ...	0,02	0,1	0,5	1	3	7	14	25

The apparatus indicating humidity is called a Hygrometer; the apparatus which indicates and registers humidity is a Hygrograph.

This percentage of humidity condenses, when subject to certain atmospherical conditions into vapour, thus forming fog and low clouds.

There are four main types of clouds :—

(1) Stratus in lower altitudes
(2) Nimbus at approximately 5,000 to 6,000 feet
(3) Cumulus from 9,000 to 21,000 feet (tops of clouds).
(4) Cirrus—more than 30,000 feet

(These are average world figures.)

but it is very rare that these are found alone. Usually they are seen in mixed structures; consequently there are :—

(1) Cumulus and Cumulonimbus—Low-level clouds
(2) Stratocumulus, Stratus and Nimbostratus
(3) Altocumulus, Altostratus—Medium altitude clouds
(4) Cirrus, Cirrocumulus, Cirrostratus—High-level clouds

Considering the altitudes in which such clouds originate, the atmosphere is to be divided into :—

(1) Space of thick clouds ranging from the ground up to 18,000 ft., rich in both horizontal and vertical air-currents.
(2) Space without considerable turbulence over 21,000 ft. where the difference of temperature between summer and winter is ± 10°C.
(3) Space of thin clouds at approximately 30,000 ft. with a temperature of − 65°C., a calm, windless space.
(4) Stratospheric space, over 40,000 ft., free of any turbulence and clouds, decreasing in temperature towards Absolute Zero.

The humidity of the air, as long as it does not reach the condensating-level (Fig. 27), does not affect the pilot's visibility.

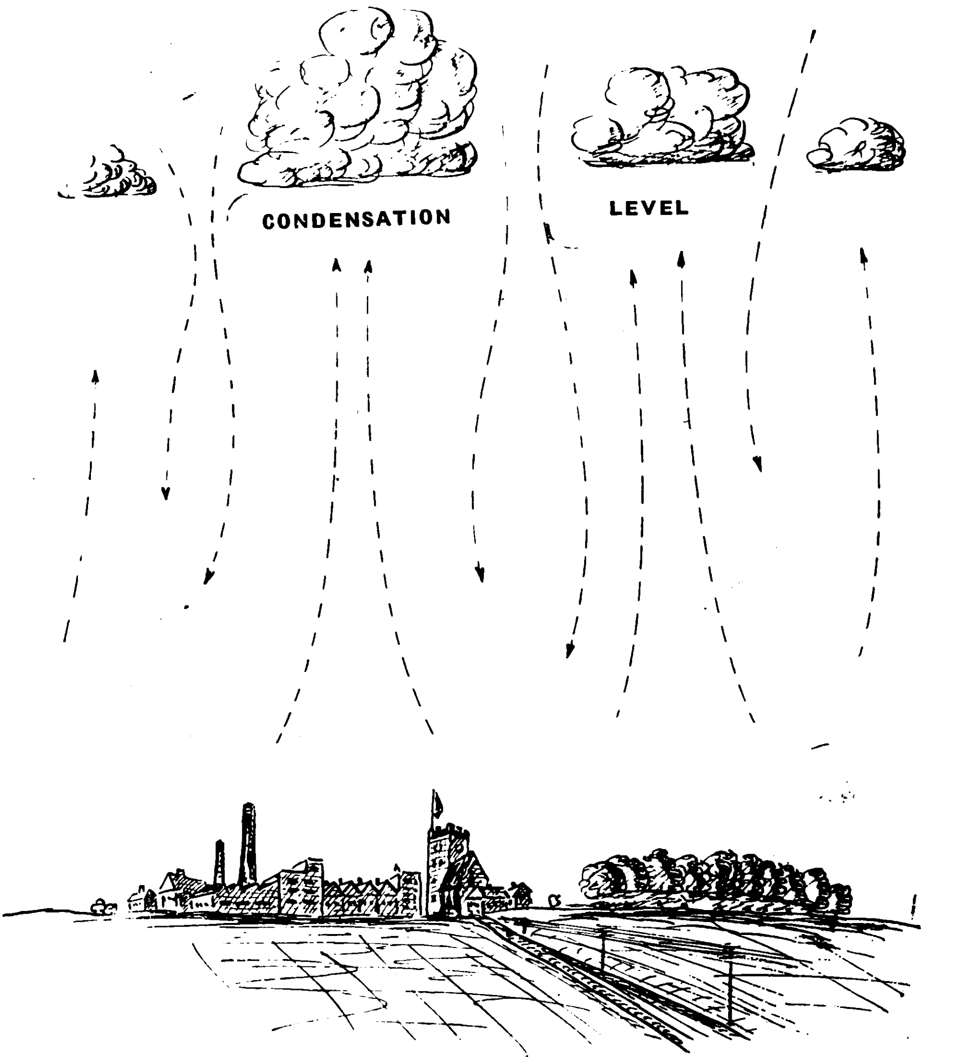


FIG. 27

FORMATION OF CLOUDS

When condensing occurs, causing fog and clouds, vertical as well as horizontal visibility is reduced.

In spite of all the magnificent apparatus invented by modern science, enabling " blind flying " (in clouds, fog and at night), visibility remains an important factor. Visibility depends on the time of the day and of the year and on the humidity. The greatest enemy of the pilot is fog, the first stage of clouds. Visibility is also reduced by rain, snow, smoke from fires and dust of different forms of sand-storms or of volcanic origin.

For flying purposes visibility is classed in the following scale:—
scale :—

	When unable to distinguish an object at the distance of	
0=dense fog	A	25 m
1=thick fog	B	50 m
	C	100 m
2=fog	D	200 m
3=moderate fog...	E	500 m
4=very poor visibility	F	1,000 m
5=poor visibility	G	2,000 m
6=moderate visibility	H	4,000 m
	I	7,000 m
7=good visibility	J	10,000 m
8=very good visibility...	K	20,000 m
	L	30,000 m
9=excellent visibility	M	50,000 m

The instruments used for measuring speed of movement and altitude of clouds are called Nephoscopes. For night movements of clouds search-lights are used and the instruments are called Alidales.

There are similar scales for rain, snow, smoke, etc. Horizontal visibility is not the same as vertical visibility under the same conditions (Fig. 28). Being right over the aerodrome, the pilot

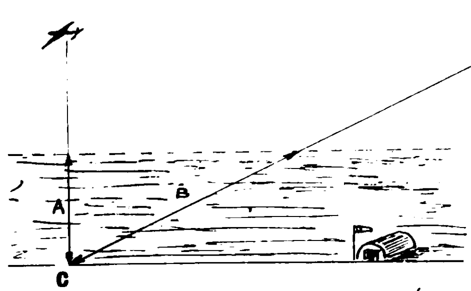


FIG. 28

DIFFERENCE BETWEEN VERTICAL AND OBLIQUE VISIBILITY. FROM THE SAME LEVEL POINT A GROUND IS VISIBLE, FROM POINT B GROUND INVISIBLE AT C.

can see it clearly, but he cannot see it just before landing as distance AC is shorter than BC.

The above description of the atmosphere and of forming of clouds makes it clear that for different categories of flight a corresponding weather is needed, *e.g.*, for an intended thermic flight the soaring pilot will choose such terrain that in his opinion gives origin to thermics, when subjected to the effect of the sun (Fig. 29). Air motion caused by changing of temperature (see Fig. 30).

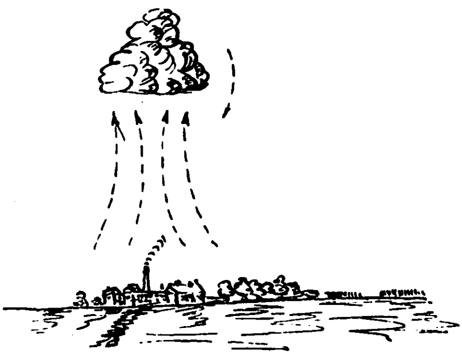


Fig. 29
Up currents create a cumulus cloud

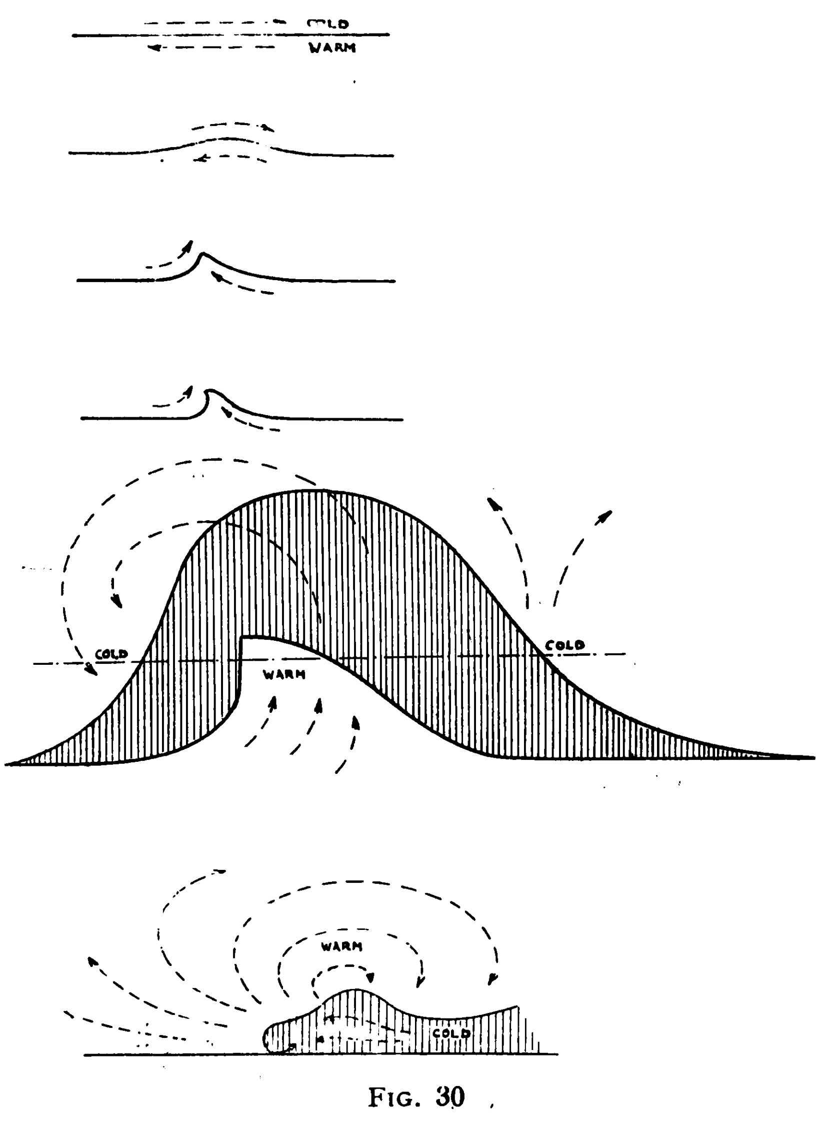


Fig. 30
Air motion caused by unequal temperature

For flying under clouds or screens a soaring pilot will choose either a single cumulus or a conglomeration of this type of clouds, or storm screens of different structures (Fig. 31). The sketch

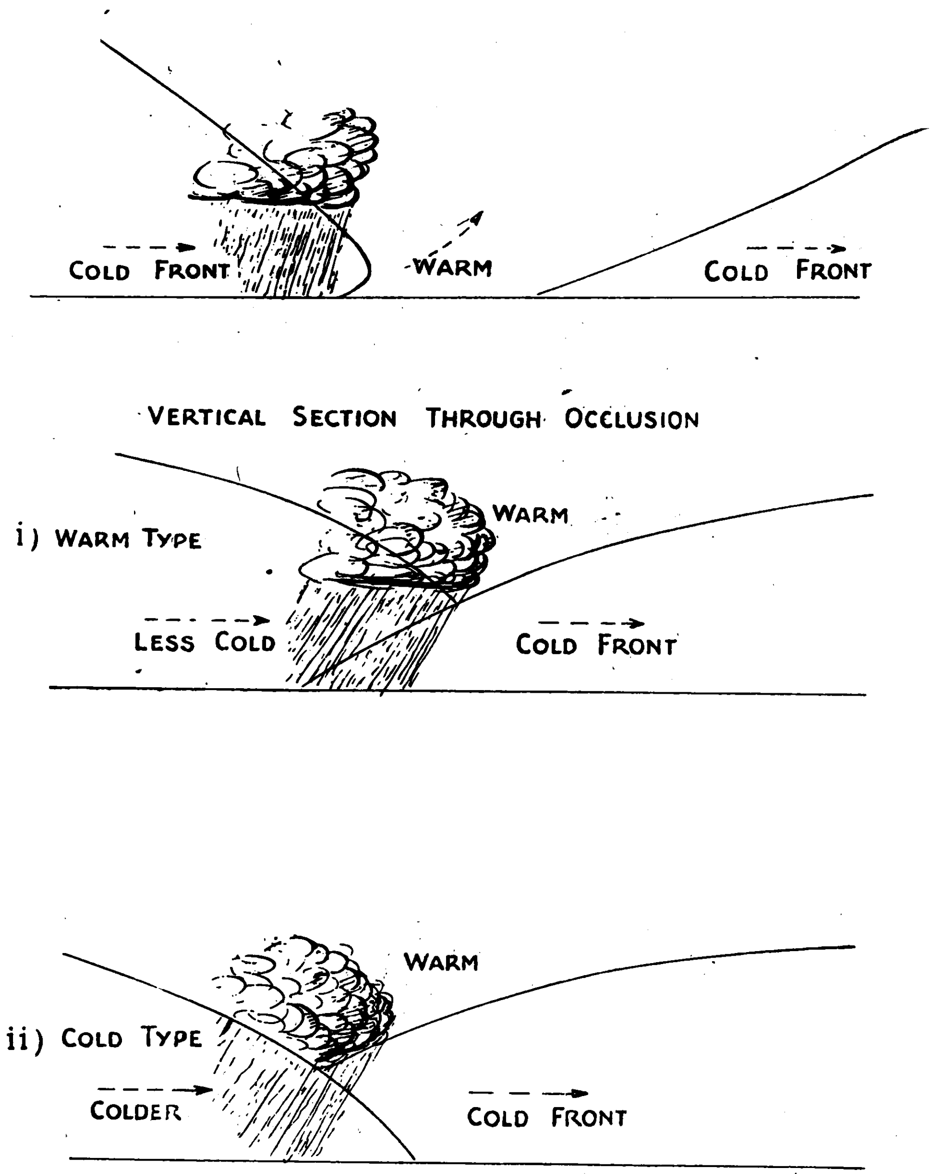


FIG. 31

VERTICAL SECTION THROUGH THE WARM SECTOR OF DEPRESSION

should make clear enough the possibilities of flying under such conditions. One of the pioneers of the soaring pilots, who demonstrated practically this kind of flying was the famous R. Kronfeld from Austria (Fig. 32).

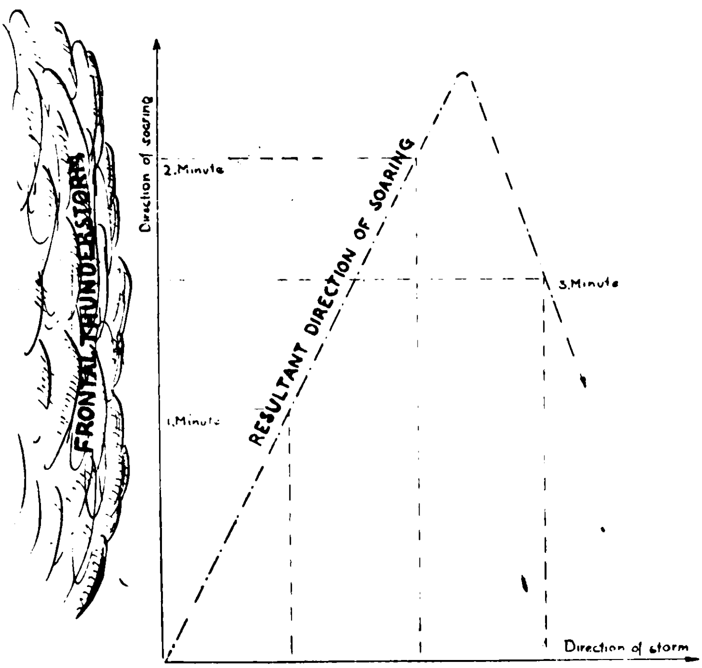


FIG. 32

THUNDERSTORM SOARING

Ascending currents under a cumulus affect lifting, so that the soaring pilot gains in altitude, time and distance (Fig. 33).

Distance flights above clouds see Fig. 34.

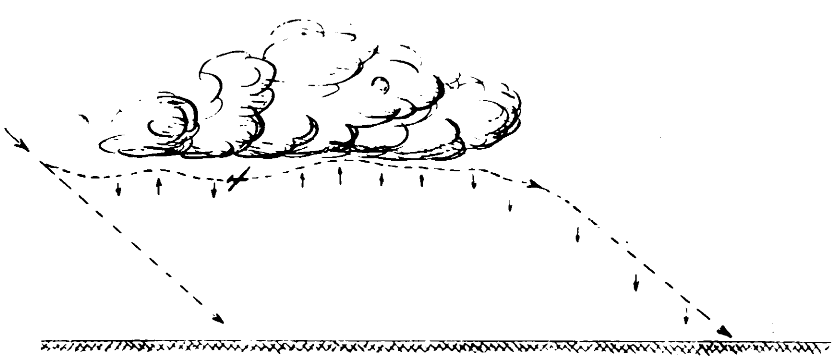


FIG. 33

ASCENDING CURRENTS UNDER CUMULUS AFFECT LIFT, THUS GAINING HEIGHT, AND THEREFORE TIME AND DISTANCE FLOWN

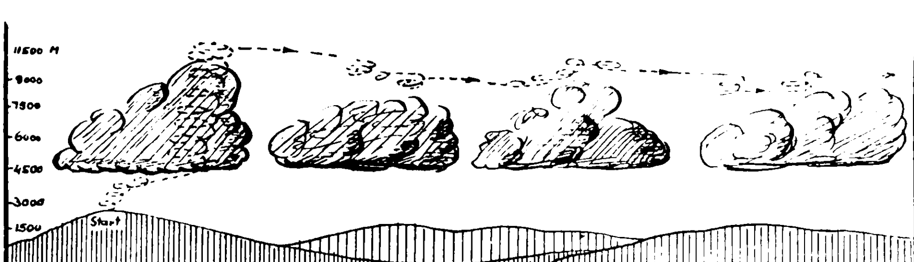


FIG. 34

DISTANCE FLIGHT ABOVE CLOUDS

Meteorological Service.

Weather conditions, with their variations, are sometimes very dangerous to flying. Therefore, long before the war, nearly every country erected meteorological institutes, to observe and study the atmosphere and to furnish military or civil pilots with barometric reports and weather forecasts. It is most essential in war-time to provide aeronauts with reports on the actual, as well as probable future weather conditions. Such information enables a course to be taken which is round or between storms or unfavourable weather conditions. The greatest obstacles are fog and low level clouds, covering the surface of the terrain over which the pilot does his reconnaissance, bombing, etc. Other obstacles are: strong wind, storms and rain, snow and possible icing in winter.

In peace time a meteorological chart can be usually found on aerodromes. It is really a normal geographical map of mountains and rivers, on which weather observations are marked and stated for the actual period. These maps include the following indications: Pressure, Temperature and Humidity of the air, direction and strength of wind in different altitudes, actual weather conditions, visibility, altitude, shape and thickness of clouds, as well as probable variations of these statements in due time. In time of war, this knowledge is, of course, of value to the enemy and is kept secret.

The lines on the chart connecting points of the same temperature are called isotherms, lines connecting points of equal pressure are isobars. These are very important for aeronautical course maps and that is why they are marked on them.

If meteorological reports are important for the pilot of an ordinary aircraft, they are more important for a glider pilot, for his 'plane is more influenced by weather conditions than an aircraft that, owing to its engines, can much more easily and quickly evade a dangerous situation in unfavourable weather.

It is therefore most important for a sailflying or glider pilot to be an expert on natural phenomena, so as to be able to make good use of some of them and to avoid others.

Perfect knowledge of the atmosphere and natural phenomena must necessarily form the basis of a pilot's training, especially where glider pilots are concerned.

It appears to have been proved in practice that the best pilots are those who start their flying career on gliders, because they have more opportunities from the beginning or becoming closely acquainted with air currents. Before this war, therefore, many countries established compulsory glider training for their air force pilots and even for pilots of the civil air lines. As a result the percentage of accidents decreased substantially in both cases, as many a crash is caused solely by the pilot's ignorance of the atmosphère and its phenomena.

IV

THE PRINCIPLES OF FLIGHT

THE early history of man's attempts to fly is a succession of tragedies and failures. This was due to two main causes; first a lack of knowledge of the structure, dangers and possibilities of the atmosphere, and secondly a lack of knowledge of the physical conditions necessary in order to become airborne.

These early failures, however, provided food for much thought which became of a more scientific nature as the instruments upon which forces could be measured became more accurate. The application of great mathematical minds to the problems of forces in the abstract eventually paved the way for that close application of science to practical experiment, and *vice versa*, which such pioneers as the Wright Brothers brought to bear upon the problems of flight. Once the principles were established flying advanced considerably.

As might have been expected the most favourable era for the progress of aviation was that of the first World War 1914-1918. The turning of a large portion of the competent resources of science and industry, together with the intelligence of those who flew, on to the problem of using aviation as a weapon of war, had an enormous effect upon the advance of knowledge of the problems of flight and the progress of their successful solution.

At the end of the war nations were much more interested in cutting down their national budgets and this fell most severely upon aviation especially in Great Britain where financial interests were so organised that there did not seem much prospect for the use of aircraft in any but military spheres, and these were restricted by the Peace Policy followed by successive governments up to 1936. The sole exception was Germany to whom engineless aviation offered the one means of escape from the restrictions upon human flying aspirations which were imposed upon them by the Versailles Treaty.

In spite of the high cost of private flying a great deal of progress was made with light aircraft in the U.S.A., Gt. Britain and Europe except Germany. The use of aircraft for communications was not much practised inside Gt. Britain where distances are small, and the time saved over journeys by fast railway systems did not justify the increased cost. On the Continent, where distances were greater, and in the U.S.A., the possibilities of commercial transport, if only for mails, came to be appreciated with the result that at the outbreak of war in 1939 there were world wide networks of air communications which were at their strongest in Western Europe and North America.

It was to be expected that Germany would be spurred on by political considerations to develop the art of soaring and gliding more than any other nation, and it has to be admitted that the art of soaring has derived its chief impetus from German endeavours. High altitude flights and long range records of the famous Kronfeld lighted great enthusiasm amongst those interested in light aircraft flying. Soaring became a most exciting, dangerous and exhilarating kind of sport. Exciting because the possibilities of danger were ever present, and exhilarating because success brought that sense of mastery over the natural elements to a greater degree than even does the ability to swim or to sail a boat in a rough sea with no other aid than skill and seamanship and courage.

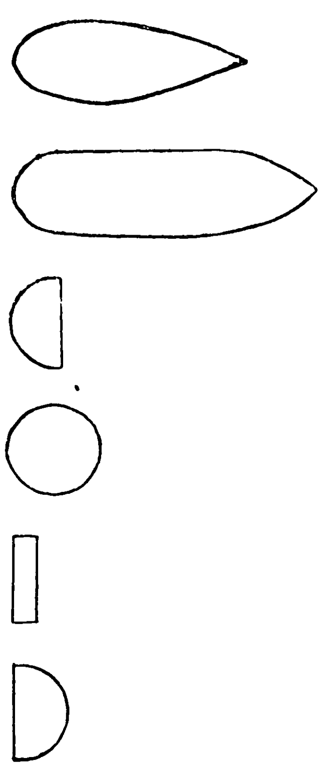
The new sport prospered, and the number of its devotees extended rapidly, so that in a few years both light aeroplane and glider clubs were established throughout the world.

How is it that a glider can not only fly but can also carry numerous loads to a great distance? The outline of the theory which follows here is not intended to be exhaustive, and those who are interested can find much more detailed information on this subject elsewhere.

The main part of the glider is the wing. It was thought at first that its best form would be that of a thin 'plane placed in a certain position or angle against the direction of the wind. One of the early promoters of flying maintained that even a barn door would fly if fitted with a sufficiently strong engine, but this was placing the onus on an engine, and there were many failures before it was realised that there was more in it than this.

The air offers a resistance to all moving objects. This resistance depends upon the form of the object and also upon the speed, the density and direction of movement of the atmosphere in relation to it, or it might be, of course, that in still air the object might move —the effect would be the same. It is the relation of these two which is the basic cause of flight. Objects of the same form and speed of movement through the air, but of a different profile, offer different resistances to that motion through the air.

Let us suppose that the profile of least resistance to air movement is that of a drop of water, and let us attach to this resistance the unit of 1. We get in comparison with other objects of a different profile, the following approximate resistance coefficient to air. By coefficience we mean the number of times greater than 1 which these resistances bear to the unit of resistance (see Fig. 35).



Streamlined Form—Resistance 1

Streamlined Stretched Form—Resistance 2′1 times greater

Semisphere—Resistance 6

Sphere—Resistance 8′3

Flat Plane—Resistance 19′8

Hemisphere—Resistance 23′5

FIG. 35
THE RESISTANCE OF DIFFERENT FORMS

We must bear in mind now the following systems by which forces are measured :—

Units.

Time : Second, minute, hour.

Linear : Inch, foot, yard, mile ; mm., cm., m., k.m. (Linear, Square, or Cubic).

Weight : lb., cwt., ton, gr., kg., cent.

Movement: Distance covered ÷ time taken = speed, which might be constant, accelerated, or decelerated.

By combining these primary units we are able to derive units of density, and of pressure, and are able to relate one unit to another in ratio.

Every force has got direction and magnitude. Magnitude is expressed in terms of mass (weight) and speed. If two forces act in the same direction the resulting force is the total of the two. If they act in directly opposite directions the resulting force is what remains if one is subtracted from the other. If they act

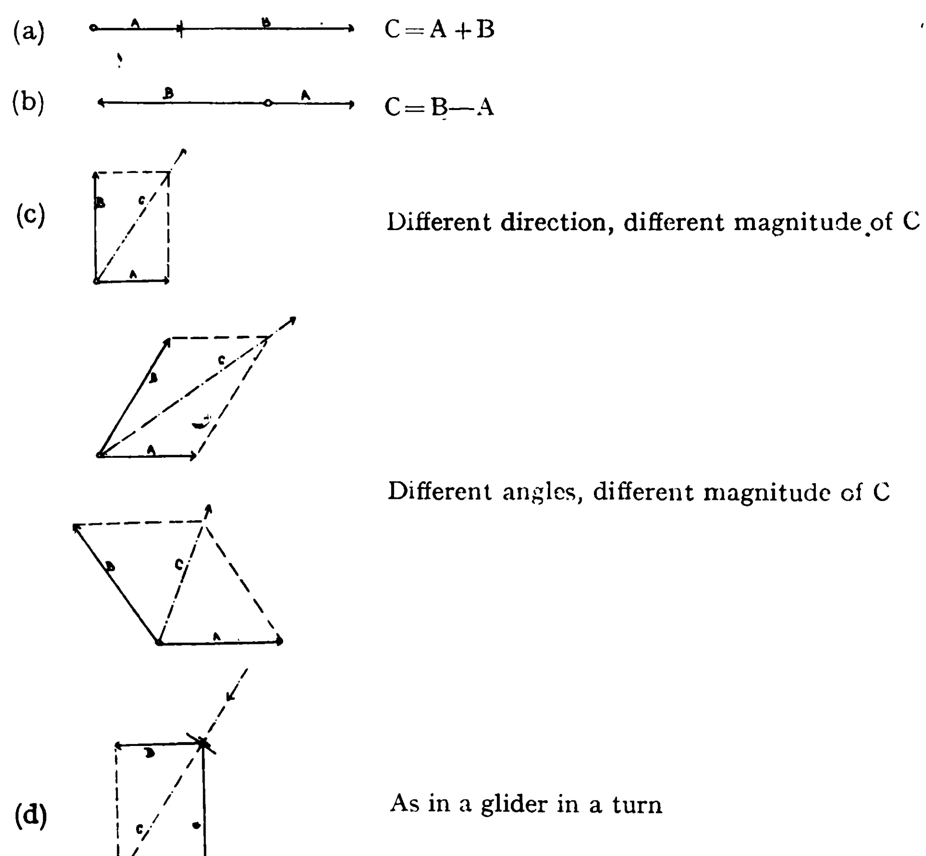


FIG. 36

THE ACTION OF FORCES

in different directions they combine into a resulting force of a still different direction. Whereas if three or more forces act in more than one plane the resulting force will be quite different from any of them but will only act in one plane, since no force can go in two directions at once, although its direction can be measured on a vertical and horizontal axis at the same time.

The Action of Forces (*Fig.* 36*a*).

Two forces A and B of different magnitudes acting in one direction result in a force in the same direction and of the magnitude of A and B.

Fig. 36*b*.—Two forces A and B of different magnitudes acting in opposite directions result in a force in the direction of the greater force B, of a magnitude = B – A.

Fig. 36*c*.—Two forces A and B of different magnitudes acting in different directions result in a force C of a different magnitude acting in a different direction. The direction and magnitude of the resultant force depends also on the angle between the initial acting forces.

Fig. 36*d*.—Thus where a glider is turning in the atmosphere we have a force of gravity, which we will call " W," acting perpendicular to the ground and the centrifugal force B acting at right angles to it. The resultant direction C is, however, cancelled by the oppositely acting lifting force of L. The glider must also be at right angles to the direction C and L. If this is not so either the centrifugal force B predominates, in which case the glider is carried outwards of the turn into what is known as a " skid " or if the angle of turning is too much inclined the force of gravity W predominates and the glider slides by its wings downwards, which is called " slipping." Either of these cases is the result of the lack of balance or inequality of forces during the flight and is faulty flying.

Objects may be at rest or moving relating to the earth. If they move, the distance covered in a given time is called their speed. Isaac Newton's law says : " An object remains in its stationary or moving state until another force begins to act upon it. Its movement is along a straight line until another force begins to act upon it, and every action is followed by a reaction."

Forces may also be expressed in terms of pressure and pressure in terms of force if they can each result in the other. Thus a pressure may exert a force and a force can cause a pressure (*e.g.* the principle of the internal combustion engine), but this is only true where the force is mass, *i.e.* we have progressed from Newton's ideal force which is only speed and direction and not mass, which we usually describe in terms of weight.

But the atmosphere possesses volume and behaves so far as forces are concerned exactly as liquids. That is the laws of resistance in a liquid also apply to the resistance of a body moving in the atmosphere.

Bernouilli, the scientist who investigated the physical properties of liquids and gases, pointed out that the resistance of air is less than that of liquids and therefore the speed of a body moving with the same force through the air is greater than that of the same body moving through a liquid. In other words, the less the air pressure the greater the speed and *vice versa*.

Aerodynamic Forces.

A glider has weight and is heavier than air. If it is to be kept up in the air a force to lift it there is necessary. This force (called lift) is caused by the movement of the wing through the air, and is the resultant force caused by the pressure exerted by the air passing over and round the wing, and the force of gravity.

The lift caused by the profile is dependent on the density of the air so that at a lower density a glider needs higher speed when taking off or landing, and accordingly a longer start. During flight, too, the glider has to keep at a higher speed so as not to lose altitude.

Newton's Law—Positive Pressure.

Following the laws of Newton and Bernouilli it has been possible to calculate and design the profile of the wing, which is also called the air foil (or aerofoil) (see Fig. 37a). The passage of the air round a body is called the air flow. The diagram 37b shows the nature of this air flow round a streamline form, whilst Figure 37c and d show its progress round a curved air foil.

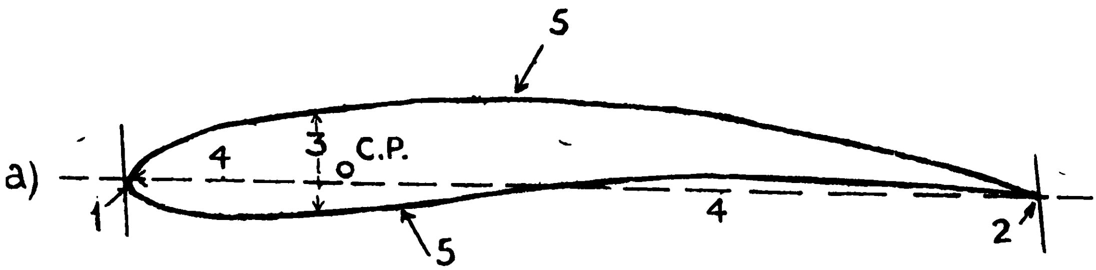
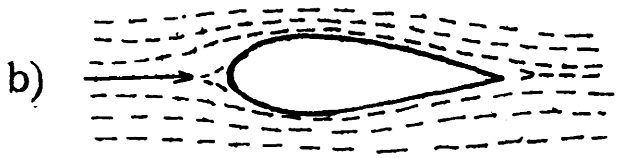


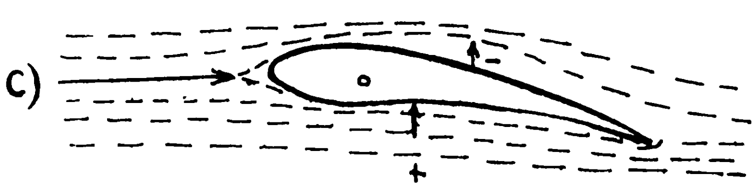
FIG. 37

1 Leading edge
2 Trailing edge
3 Thickness
4 Chord length
5 Curvature of Airfoil
C.P. Centre of Pressure of Aerodyn forces

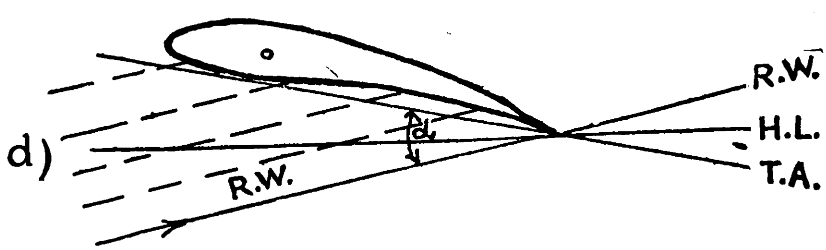


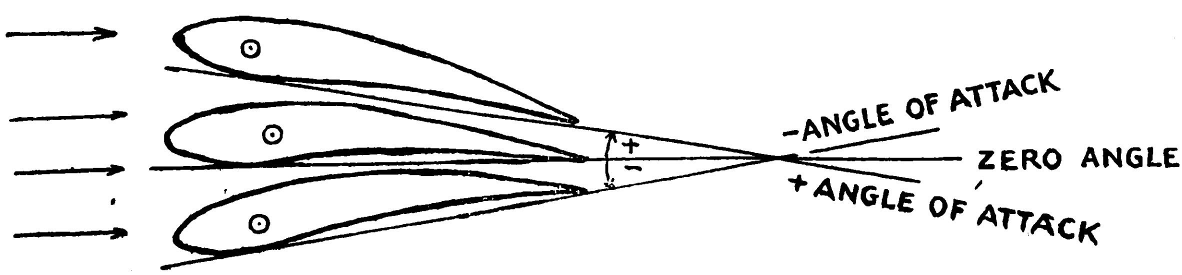
Airflow around streamlined form Above and under Airfoil equal pressure

Airflow around curved Airfoil above surface minus, under surface plus pressure



H.L. Horizontal level
T.A. Tangent of Airfoil
R.W. Relative wind
α Angle of attack between R.W. and T.A.

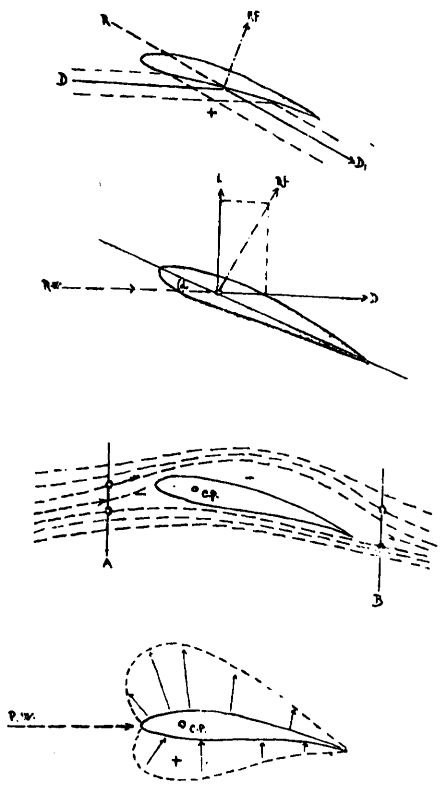




A wind flowing around the profile of a wing strikes the leading edge and divides. One part traverses the under surface and causes a positive pressure (Fig. 38a). Its direction D is changed

FIG. 38

(a) (b) (c) (d)



Positve Pressure—Newton's Law

Negative Pressure—Bernoulli's Theorem

R.W. Relative wind
CP Centre of pressure of all aerodynamic forces
↓ Direction and magnitude of forces
Plus and Negative pressure

to that of D1, thus creating a reaction R, the resultant force being shown as RF. In other words (Fig. 38b) interpreting the forces acting on the air foil we get a relative wind blowing on the bottom surface of a wing at certain angle of attack, causing a drag D in an extended direction of the wind which is perpendicular to the lift L. The final result of the forces will be as shown in the direction of the resultant lift RF.

BERNOUILLI THEOREM—NEGATIVE PRESSURE.

That portion of the wind which traverses the upper side of the leading edge of the wing is driven more away from its orginal direction by the same application of Newton's law, thus particles of wind, blowing on the top of the wing travel a greater distance from A to B than those underneath the wing. Therefore, the speed of the wind is increased and according to Bernouilli this causes less pressure, *i.e.* the density of the air immediately above the wing is less than that immediately below it. The tendency is for the wing itself to move up to fill this reduced pressure, and this causes what is called negative pressure on the wing. Combined with the positive pressure exerted under Newton's law, the resulting force is a lift L (Fig. 38c).

It is possible to calculate the magnitude of positive and negative pressures and hence the resultant lifts. In normal conditions the positive pressure amounts to 30% and the negative pressure to 70% of the total lift (Fig. 38d). The resultant acts on the centre of pressure C.P. which, as the angle of the attack of the wind changes, also moves either forward or backwards (Fig. 39a, b, c,

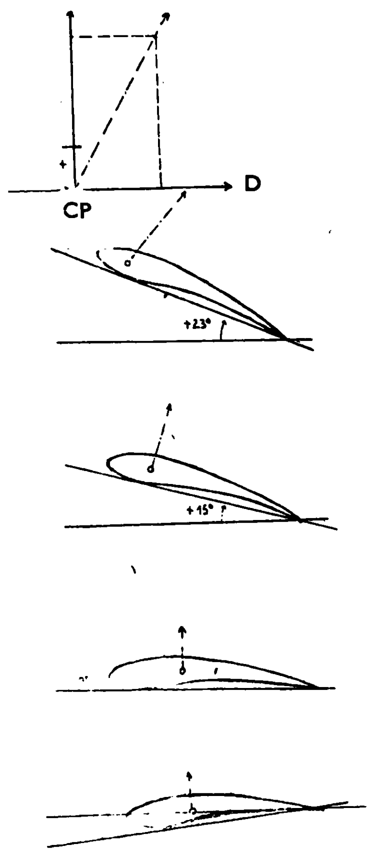


FIG. 39

(a) The combined force is as shown in the sketch—
+ Pressure underneath the airfoil } Resultant lift R.L.
—Pressure above airfoil
D=Drag
Forces act from centre of pressure C.P.

(b) At a large angle of attack, centre of pressure shifts considerably forwards to the leading edge, and the resultant lift is large, acting backwards and upwards

(c) At a small angle of attack the centre of pressure remains in the front third cord length. Resultant lift is large, acting about straight upwards

(d) At zero angle of attack centre of pressure shifts backwards. Resultant lift is smaller

(e) At a negative angle of attack the action of forces is similar as at zero angle of attack and the resultant lift is at a minimum

d, e). A change of the position of C.P. also disturbs other aerodynamic forces. It follows, therefore, that the best type of aero foil is one in which the C.P. coincides as nearly as possible at all angles of attack with the centre of gravity.

It is clear from a consideration of these theories that the resultant lift caused by the impinging of wind on an aero foil depends on the following factors :—

(1) Atmosphere. The pressure exerted by the atmosphere varies as its mass and its direction and speed. Its mass can be affected by :—

(a) Temperature

(b) Atmospheric pressure

(c) Humidity

whilst its speed and direction are variable, as currents of air not only move horizontally, but also upwards and downwards.

(2) The kind of aero foil.

(3) The area, form, location of the wing.

(4) Auxiliary devices flaps, slots, spoilers or their combinations.

If the speed of the wind remains constant, the resistance, regardless of the aerodynamic form or shape, will also vary with the dimensions of the exposed area. This, in turn, will alter with the angle of attack (Fig. 40). Where the angle of attack = Zero,

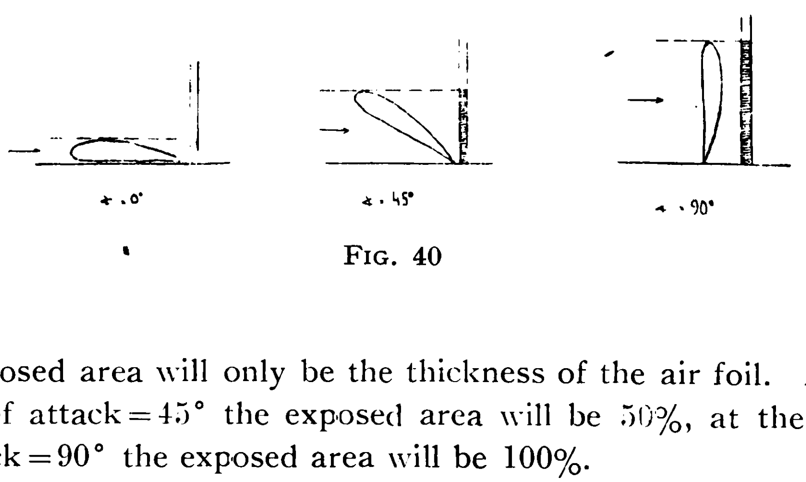


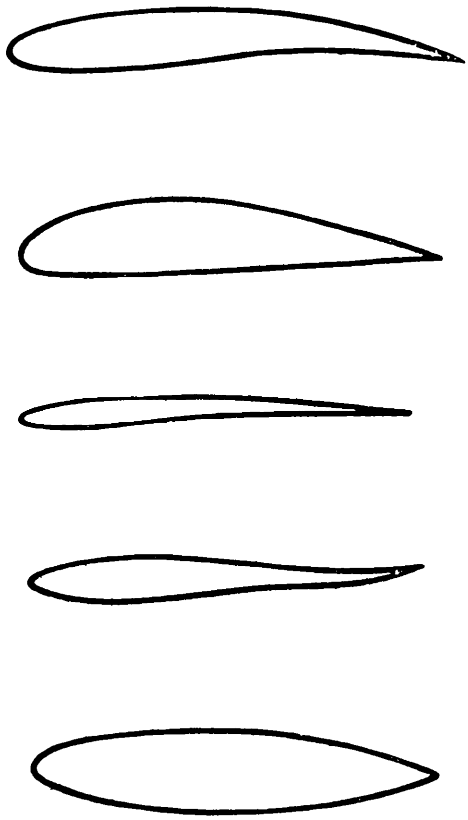
FIG. 40

the exposed area will only be the thickness of the air foil. At the angle of attack = 45° the exposed area will be 50%, at the angle of attack = 90° the exposed area will be 100%.

Selection of an Air-Foil (or Aerofoil).

An air-foil of a pure aerodynamic shape would, therefore, have a perfect airflow round the wing where the angle of attack = zero, but, in that case, the total lift will also be zero. If the air-foil has differently curved top and bottom surfaces, the lift will increase with the angle of attack. Every shape of air-foil has different qualities and characteristics which are known to designers of aircraft. These are shown at Figs. 41 to 41a.

Fig. 41



Normal profile

Profile of large lift

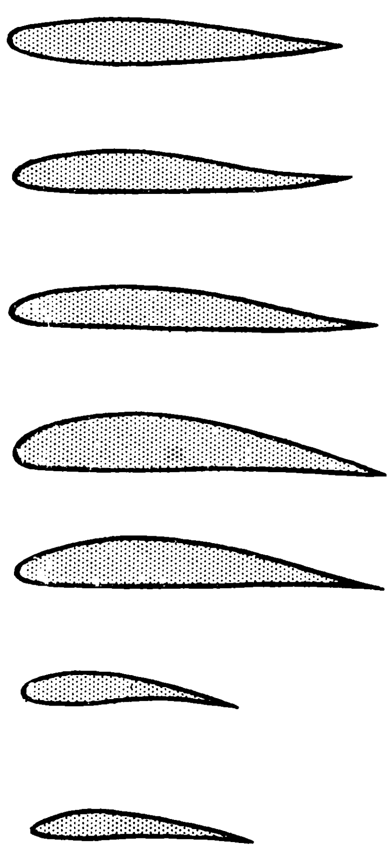
Profile of big speeds

Reflex profile

Streamline form

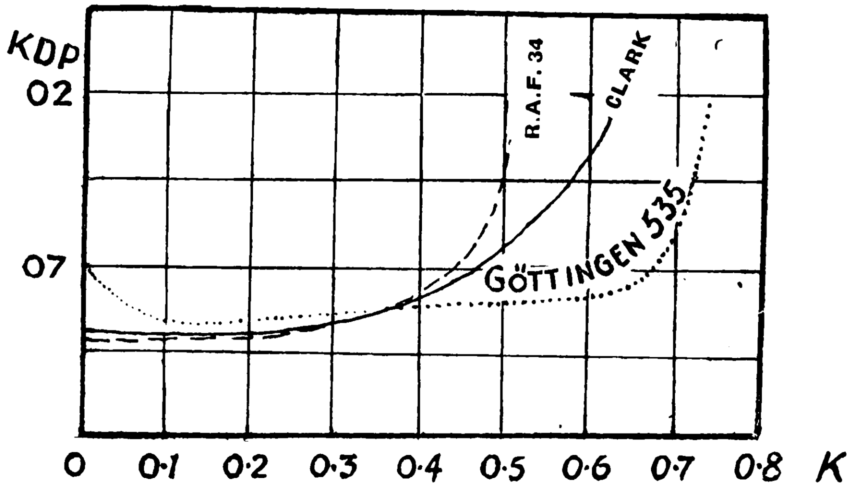
Fig. 41a

Airfoil characteristics



RAF 30 ...	Span 48 in. Chord 8 in. Vc/v = 335,500 and 252,000 Reynolds No. R.A.E. 7 × 7 ft. Wind tunnel Test 1924
RAF 34 ...	Span 48 in. Chord 8 in. Vc/v = 335,500 R.A.E. 7 × 7 ft. Test 1926
Clark Y.H. ...	Span 30 in. Chord 5 in. Vc/v = 3,570,000 N.A.C.A. Variable Density Tunnel Test 1926
Göttingen 387	Span 30 in. Chord 5 in. Vc/v = 3,470,000 L.M.A.L. Variable Density Tunnel Test 1926
Göttingen 426	Span 1 metre. Chord 20 cm. Vc/v = 410,000. Gottingen Wind Tunnel Test 1921
Göttingen 535	Span 39′37 in. Chord 7.874 in. Vc/v = 4,840,000 Gottingen Test 1926
Göttingen 549	Span 39′37 in. Chord 7.874 in. Vc/v = 4,840,000 Gottingen Test 1926

PROFILE DRAG CURVES (KDP).



Drag.

Air resistance, or drag, is exercised on all moving objects, even the best air-foil. The resultant aerodynamic forces, lift and drag, are related in an alternating ratio expressed as Lift/Drag. From the mathematical point of view lift can be expressed thus: if the speed is doubled, a double amount of air flows at a double speed, that is, the lift must be 2 × 2 = 4 (four times larger). Hence we get the formula that

lift = a constant × density of air × lift co-efficient × area of wing × speed squared.

Drag depends on the same factors:

drag = constant × a density of air × the drag coefficient × the area × the speed squared. The result is the ratio of Lift/Drag. For a fixed air-foil the ratio can be expressed in the graph as follows:—(Fig. 42). The coefficient of

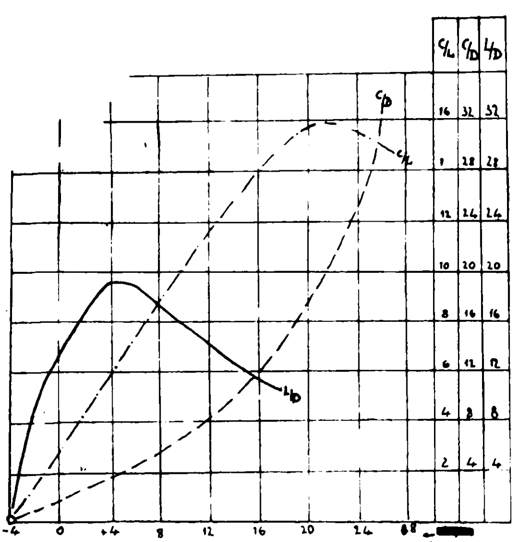


FIG. 42

C/L = Lift coefficient.

C/D = Drag coefficient

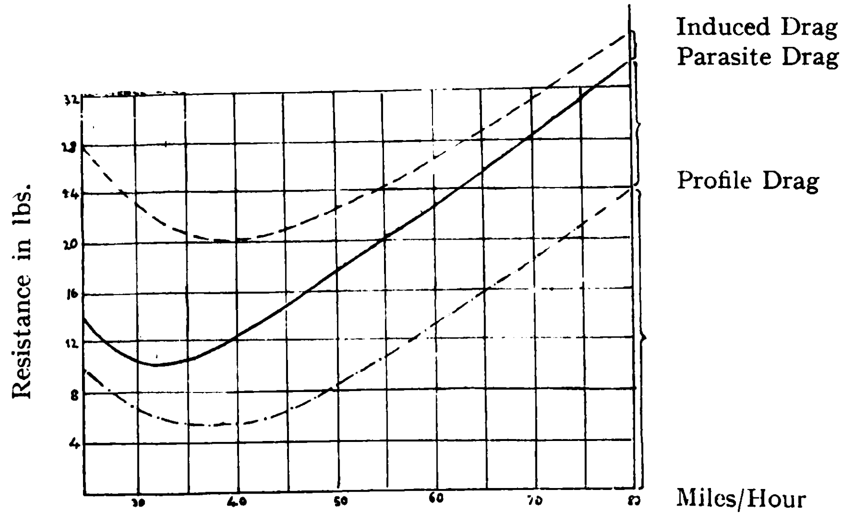
LD = Ratio of Lift to Drag

Angle of attack in degrees,

lift and drag is derived from the angle of attack. As the angle increases both lift and drag increase but the speed decreases. If the area of the wing is squared, the lift is doubled. If the speed is doubled the lift will be four times greater. By the ratio L/D is expressed the performance of the aero-foil. This L/D ratio therefore depends on the wing area, the kind of aero-foil, the relative wind and finally what is called " aspect ratio." The " aspect ratio " is the relationship between the span and the chord with rectangular wings, or between the span and the mean chord. In aircraft the normal aspect ratio is about 6, but in sailplanes is often 15 to 20. The best effect has been found to exist when the angle of attack is plus 4°, which is most important for gliders, as it is the angle of most efficient gliding which gives a lift about 2 times greater than the drag.

The best L/D ratio, therefore, corresponds to the best gliding angle, that is the angle at which the longest distance of horizontal flight is obtained from a certain altitude. This is the gliding ratio. With sail-planes, a ratio of 1 : 30 has been reached, and with transport gliders a ratio of 1 : 15 to 1 : 20. From a height of 3,000 ft., therefore, a glider will glide 1,500, 2,000 or 3,000 yards in normal weather conditions in direct line flying without turns. (If a pilot makes turns or dives he will obviously not reach as far as he will by gliding at the same angle and on the same course.) For a certain type of glider the wing area and the air resistance-pressure at given conditions are not interchangeable. If equilibrium is to be maintained during flight, the pilot may alter the angle of attack only, thus altering the speed depending on the lift/drag ratio.

FIG. 43



The drag which acts along the path of the flight (in the direction of the relative wind) consists of several components (Fig. 43).

(*a*) Profile Drag, which is caused by the friction of the air around the profile of the wing. This, as we have seen, depends upon the density of the air.

(*b*) Induced Drag, which is the result of the lift, *i.e.* the motion of the air round the wing.

(*c*) Parasite Drag, which is caused by the resistance of the fuselage, the under-carriage and the tail unit, and any other excrescences.

The various drags are not of the same magnitude and their relationship alters with the speed. A graphical reproduction for a fixed air-foil would be the relationship shown in Fig. 43.

The total drag is the mathematical total of (*a*), (*b*) and (*c*) that is the profile, the induced, and the parasite drag.

The forces acting upon the air-foil are such that profile lift corresponds to the profile drag whilst the total lift corresponds to the total drag. It will be seen that the profile drag is comparatively small, but it increases enormously with the increase of the angle of attack.

The profile drag (Fig. 44) is caused by the friction of the airflow on the surface of the wing. Since the top curvature of the air-foil

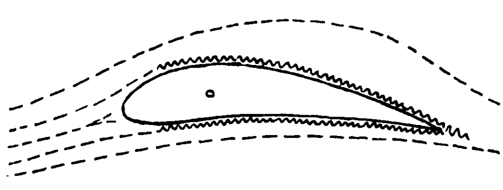


FIG. 44
PROFILE DRAG

is different from that at the bottom, the profile drag on the top of the wing differs from the profile drag on the bottom of the wing. Both drags are to be added to get the total profile drag. (Fig. 45.)

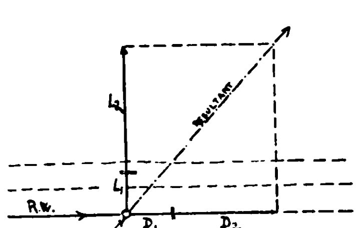


FIG. 45
$L_1+L_2 \div D_1+D_2$

The induced drag is caused by the lift and it is said to be a "taxation" for the acquired lift. The origin and action of the induced drag is explained in a chapter on the action of the total wing.

During a normal flight (ascending, horizontal flight, or descending) all aerodynamic forces acting on the glider are in equilibrium. By changing the angle of attack a glider pilot can change this equilibrium by varying the aerodynamic forces acting upon the glider. Of the remaining forces, the density of the air, the wing area, the weight, are constant on any given flight. The L/D ratio varies in relation to the angle of attack, so that the glider ascends, descends or flies horizontally.

The constructor of the glider, therefore, will aim at securing a type of aero-foil at which normal angle of attack gives the greatest lift and the smallest drag.

Almost all normal types of aero-foil are designed in such a way that even at a small negative angle of attack they give sufficient lift for horizontal or gliding flight.

If the angle of attack increases above the fixed limit, the air-flow will not follow the profile of the wing but will break off and cause eddies (Fig. 46). In this case the lift is at a minimum or

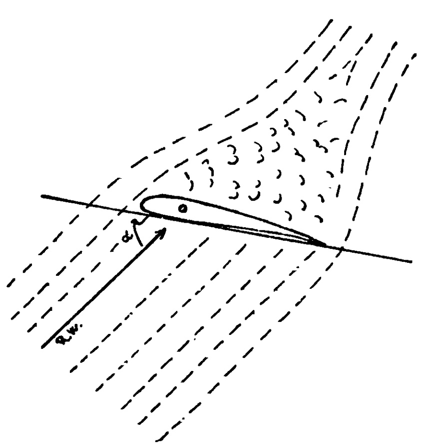


FIG. 46
SMALL LIFT + BIG DRAG

may be none at all, whilst the drag increases enormously, or the negative pressure is zero, and the positive pressure becomes large, and will therefore become a drag. Such a great angle of attack is called the "critical angle" of attack whose consequence is the loss of flying speed. In this case the force of gravity acquires its full quantity, and the result will be that the rudder and elevator will not respond and the glider will fall to the earth in a spin.

To right this situation it is necessary to return the aerodynamic forces to an equilibrium once more, that is to obtain again the necessary flying speed in order to be able to continue flying.

It will be seen that if a spin occurs so close to the ground that there is neither time nor distance in which to obtain flying speed, regain equilibrium and therefore control, a crash must occur with possibly fatal results.

The Form of the Wing.

Modern gliders are now built as monoplanes. It is more simple to consider aerodynamic forces in relation to monoplanes than to biplanes, and we will, therefore, confine our consideration to the former.

TERMS.

"*The Span*" is the distance between the two ends of the wing (Fig. 47).

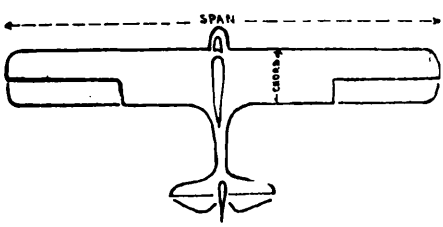


FIG. 47
MONOPLANE, RECTANGULAR WING

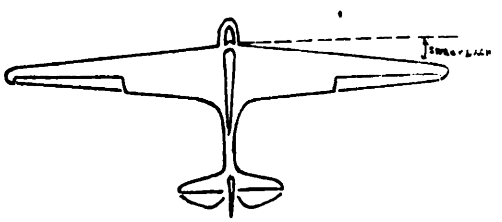


FIG. 48
MONOPLANE, TAPERED WING

"*The Chord*" is the distance from the leading edge, *i.e.* the front edge, to the trailing edge, *i.e.* the rear edge of the wing.

"*The Aspect ratio*" is the ratio of the span to the chord. This is only true for a rectangular wing. The wing which is tapered, or non-rectangular, has a chord of varying length, getting smaller as one gets nearer the wing tip. In this case it is necessary to calculate the average chord. The aspect ratio of the tapered wing, therefore, will be the relationship of the span to the average chord. The same aspect ratio may be obtained by squaring the span and dividing the result of the wing area :—

$$= \text{Aspect ratio} \quad \frac{\text{Span}^2}{\text{Total wing area}}$$

It will be seen that there will be a wide variation in the aspect ratio of wings which are short and wide and those which are long and narrow. The former will be small, the latter large. The small aspect ratio results in a larger induced drag and the smaller lift coefficient. The large aspect ratio conversely results in a small induced drag and larger lift coefficient.

The wing may be placed in relation to the fuselage, either above it, in the middle, or below (Figs. 49, 50), it may be horizontal (Fig. 49) or inclined (Fig. 50). A very convenient placing of the wing is as in Fig. 51.

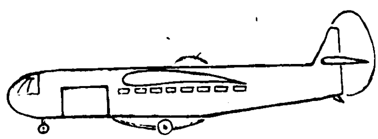


FIG. 49A
HIGH-WING MONOPLANE
MILITARY GLIDER

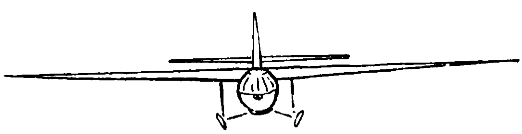


FIG. 49B
FRONT VIEW

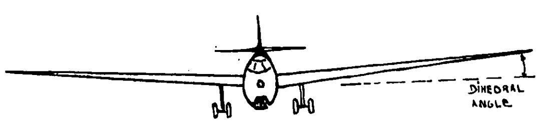


FIG. 50
FRONT VIEW

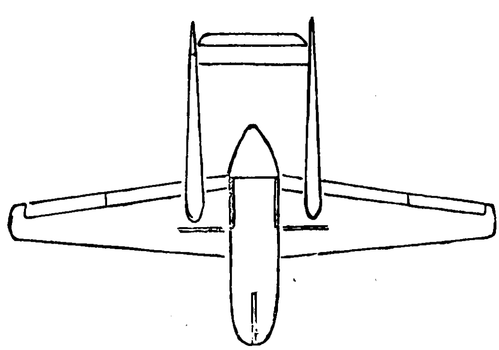


FIG. 51
TROOP-CARRIER, BI-FUSELAGE
GLIDER

During flight, the plus pressure is below the wing and minus pressure above it. This difference of the air pressure at the tips of the wing causes an airflow in the direction shown in Fig. 52. Behind the training edge vortices are created which cause induced drag (Figs. 53, 54). This induced drag will change with the

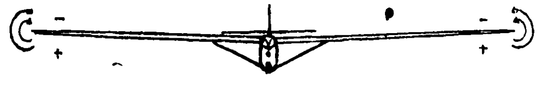


FIG. 52
AIR CIRCULATION FROM HIGH TO
LOW PRESSURE

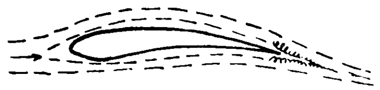


FIG. 53

ON TOP SURFACE—INWARDS FLOW. UNDER SURFACE—OUTWARDS FLOW

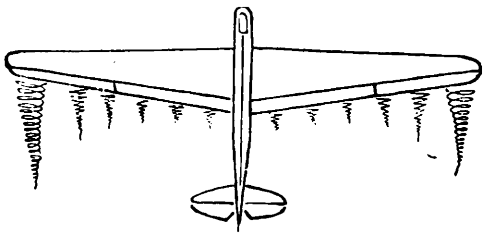


FIG. 54

WING-TIP VORTICES AND TRAILING EDGE VORTICES

change of the angle of attack, and also with the aspect ratio. Since the induced drag changes with the aspect ratio, the total drag will also change. A large aspect ratio (a long and narrow wing) has a larger lift coefficient and a smaller drag coefficient at all angles of attack. The reverse is true of a wing with a small aspect ratio. The drag coefficient will be larger and the lift coefficient smaller. It will be seen that in a glider, therefore, this aspect ratio is very important. In a sailplane it may reach as high a ratio as 20, whereas in a normal aircraft it will be somewhere about 8. It explains, therefore, why glider aircraft have long, narrow wings. The limit of the aspect ratio in gliders is affected by the factors in its construction, that is, although a long and narrow wing gives a greater span and the aspect ratio, it also has a greater weight and is less firm, and presents more difficulties of construction. It has been found that the tapered wing is the best design from a construction point of view.

Modern military transport gliders, used for carrying personnel and material, have a greater load for the wing area than any other type of glider. In order to get this weight into the air, it is therefore necessary to choose the right shape of air-foil at a certain speed, because otherwise the glider will not be in that equilibrium which is necessary for controlled horizontal flight. Since the weight, and therefore the forces of gravity are greater, and the aspect ratio is constant, it is necessary to increase the lift caused by the flow of air over the air-foil by increasing the amount of air flowing over it, that is by increasing the speed. Since a transport glider must have a higher initial speed for flying, it must also land at a higher speed. The necessity for increasing the speed is therefore a disadvantage because it is necessary to improve the aerodynamic qualities of the glider during flight. This has been found possible by the addition of what are known as slots, flaps and spoilers and their combinations. The average wing loading of gliders is 2 lbs. per square foot, training aeroplanes 5 to 7 lbs. per square foot, fighter aircraft 20 lbs. per square foot. A wing loading of 45 lbs. per square foot is not unknown. The tendency of modern aircraft design is to increase the wing loading by reducing the wing area, then raising the maximum speed, and then using flaps to reduce the speed (Fig. 55).

Slat.

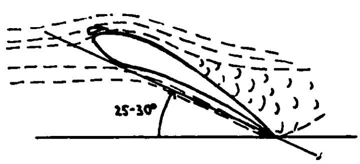


FIG. 55
WINGS WITH SLAT

The slat is a small auxiliary air-foil fitted along the entire length of the wing's leading edge. The air only flows in the gap between the slat and the leading edge at larger angles of attack. At small angles of attack the slat is not in action for the air flows by it and causes, apart from the drag, no aerodynamic forces. Its disadvantage is only the fact that the glider will be heavier in the nose. Recently, slats have been designed so that they are adjusted from the pilot's cabin, or an automatic slat is fitted which works on the principle of differences of the + and − pressures at a change of the angle of attack. Also, various combinations of slats, such as the multislat, are widely used to-day but are favoured mainly by inexperienced pilots.

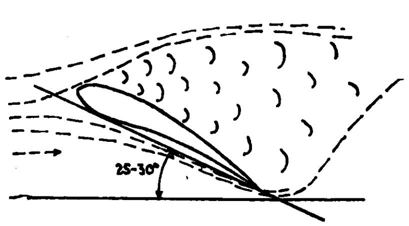


FIG. 56
WINGS WITHOUT SLAT

The purpose of the slat is to increase the lift which would otherwise decrease with the airfoil at a high angle of attack in relation to the direction of the wind. Otherwise the drag will be greater than the lift which would result in a " stall " (loss of flying speed) from which the inevitable aerodynamic result is that the aircraft falls downwards in a " spin." Slats, therefore, give a larger margin of safety to a glider at low speed. They have the same effect on engine powered aircraft. Another effect of the use of slats is that they shorten the time and distance required to gain flying speed, and enable flying speed to be relinquished on landing with the same effect of shortening the time and distance required to land.

Flap (Fig. 57).

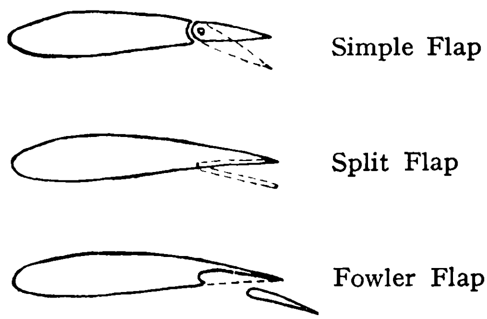


FIG. 57

A flap is an auxiliary 'plane fitted to the inner lower side of the wing, or it may be an air-foil placed as an extension of the wing air-foil. It acts in the same way as the ailerons, but it always acts simultaneously and in the same direction. It is, of course, variable in position and is controlled by the pilot. It causes a

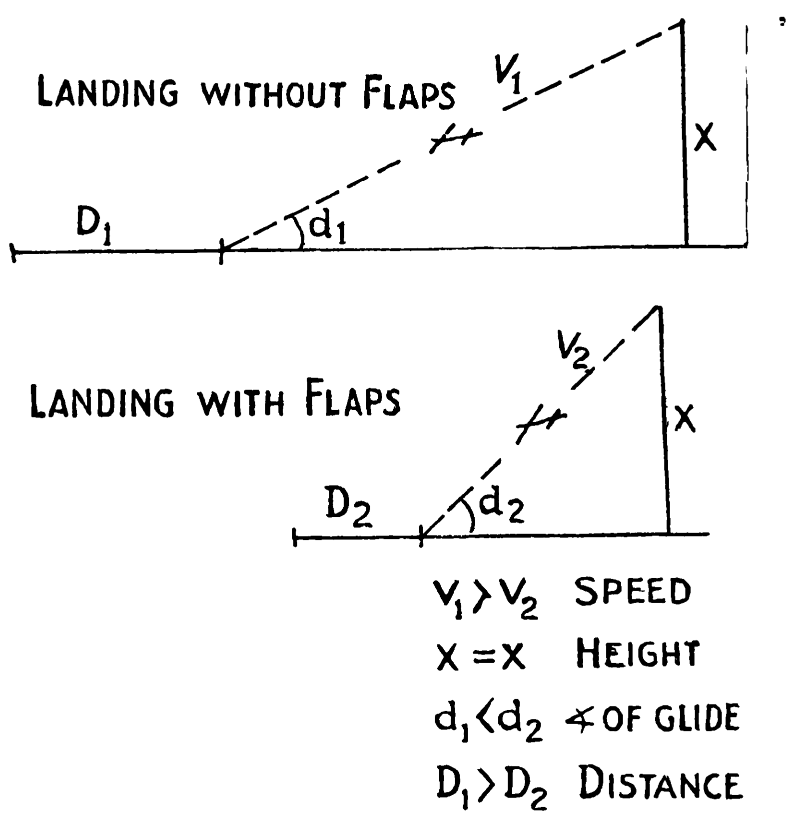


FIG. 58

change in the profile of the air-foil so that at a large angle of attack an increase of lift takes place which may vary between

50% and 90%, but at the same time an increase of drag, acting as a brake, takes place and the landing speed therefore decreases. The steeper the glide the greater the drag. It is, therefore, possible by the use of flaps to increase the gliding angle, and to shorten the landing distance (Fig. 58). This enables pilots to land in small areas, having approached over obstacles which may surround the landing space. The area of flaps compared to that of the wings may be quite considerable. There are several types in use of which the most efficient are the simple flap, slotted flap, Fowler flap and Zap flap, which may be used in combination.

Spoiler (Fig. 59.)

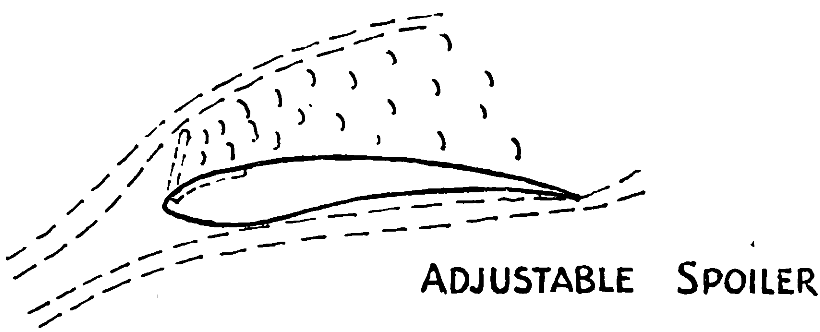


FIG. 59

A spoiler is similar in effect to a flap except that it is placed on the leading edge of the wing or air-foil. During normal flight it lies on the leading edge and offers no resistance to the air-flow. On being brought into action the plane of the spoiler is set against the air-flow direction, thus causing eddies immediately behind it, which consequently decrease the lift and increase the drag on the upper surface of the air-foil. As the angle of attack increases the effect and efficiency of the spoiler also increases. The result is a decrease of landing speed.

The Fixed Spoiler (Fig. 60) acts similarly but with less efficiency. It is a small triangular plane fitted on the leading edge of the

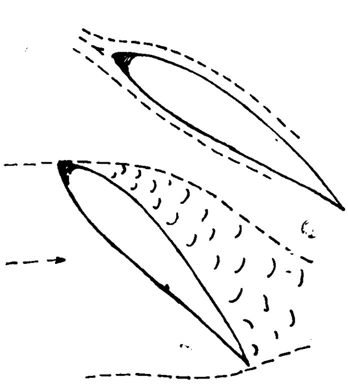


FIG. 60

Fixed Spoiler, Angle of attack Zero

Fixed Spoiler, Angle of attack Big

wing and forming a sharp front edge. Where the angle of attack is small, as in horizontal flight or moderate ascending or descending angle, it does not greatly deform the air-flow and therefore causes no special aerodynamic forces. But at larger angles of attack it acts as a deflector of the air-flow, causing eddies above the wind, decreasing the lift and increasing the drag.

It is possible to combine slats, flaps and spoilers on an aircraft, and by their use not only have the aerodynamic qualities of aircraft been increased, but by increasing the controllability of aircraft and gliders, flying has therefore become more safe.

Action of Forces.

The action of forces on the entire glider contain the principle of flight. A glider is in a state of equilibrium when all the forces acting on the centre of gravity are equal. If we take the various parts of a glider we will see that each of them is acted upon by both vertical and horizontal forces, such as gravity, drag and eventual lift (Fig. 61).

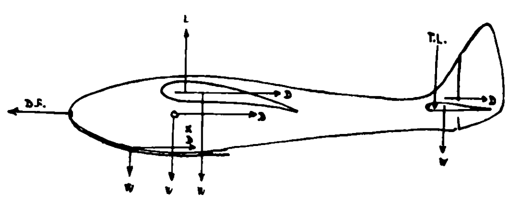


FIG. 61

D.F. Direction of flight
L. Lift
D. Drag
X. Centre of gravity of total glider
T.L. Tail load

The parts of a glider or of an aircraft are as follows :—

(1) Wings.
(2) Fuselage.
(3) Undercarriage.
(4) Tail unit.

In a glider the following forces act upon the foregoing groups :—

(1) The wing : gravity, drag, lift.
(2) The fuselage : weight, drag.
(3) The undercarriage : weight, drag.
(4) Tail unit : weight, drag.

Pure aerodynamic forces act horizontally and vertically. Speed and drag act horizontally, weight and lift act vertically.

These forces act either on the centre of pressure or on the centre of gravity of the entire glider. The changes of these forces, therefore, also alter the relative positions of the centre of pressure (C.P.) and centre of gravity (C.G.).

Drag.

Speaking in terms of aerodynamics all parts of a glider either cause lift or drag. This results from the fact that every part of a glider offers resistance to the flow of air, but it is only the wing which gives lift. That is every object, even if streamlined, causes a parasite drag if the air-flow does not streamline along the form. There is also an interference drag originated by joints of the various parts of a glider, *i.e.* where the wings join the fuselage and the fuselage joins the undercarriage. The parasite drag increases with the square of the speed. At certain speeds the forward acting force equals the backward acting force of the total drag and the velocity remains unchanged, but when the forward acting force is greater than the opposite total drag, the result will be an increase in the forward speed. The limit to this forward acceleration comes when the drag which increases with the square of the speed, equals the maximum possibility of forward force. This speed is the final speed of the object in question. It is sometimes called the terminal velocity of the object.

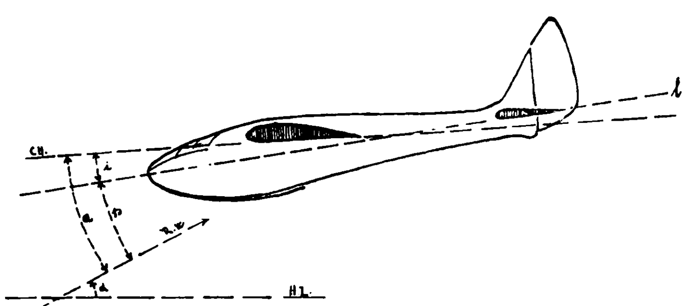


FIG. 62

R.W.	Relative wind
a	Angle of attack
i	Angle of incidence maximum L/D ratio
l	Longitudinal axis of glider
H.L.	Horizontal level
CH.	Chord line
p	Angle of pitch
α	Angle of glide

a=p+i

Angle of Attack=Angle of Pitch+Angle of Incidence

Angle of Incidence.

The angle of incidence is the angle between the chord of the wing and the longitudinal axis of the fuselage. This angle is that which corresponds to the greatest Lift/Drag ratio, which is calculated for a particular shape and kind of wing. As the position of the wing in relation to the fuselage is fixed it cannot be altered during flight and is a constant in calculation of the aerodynamic qualities of the aircraft in question.

Tail Unit.

This consists of stabiliser, elevator, fin and rudder. It is that kind of aero-foil which is effective during any kind of flying and which works in any position in relation to the glider. Like the wing, the stabiliser is fixed at a pre-designed angle, which cannot be varied during the flight. It is necessary to calculate the aspect ratio of the tail unit which must be comparatively small and should not exceed number 4.

Action of Forces During Flight (Fig. 63).

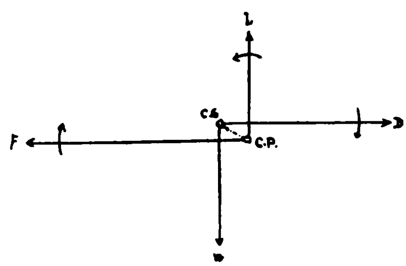
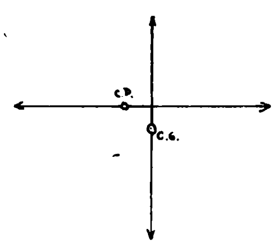


FIG. 63

C.G. Centre of gravity
C.P. Centre of pressure
—.—. Distance between C.P. and C.G. changes
F Forward motion of glider
L Lift
D Drag
W Weight

Direction of Moving C.G.



Direction of Moving C.P.

The entire weight (W) of the glider acts in the direction perpendicular to the ground from the centre of gravity of the whole glider. The lift (L) acts upwards from the centre of pressure of the wing since the C.P. changes with the angle of attack; almost in no case does it ever coincide with the C.G. The tail surface is acted upon by an upwards or downwards force according to the change of the angle of attack. The forward acting force and drag act on the tail unit in such a way during horizontal flight as to turn the glider clockwise round its centre of gravity, whereas the force of lift tends to turn the glider anti-clockwise. If horizontal flight is to be carried out the total of the forces acting on the centre of pressure must equal those acting on the centre of gravity. The aircraft then will be in a state of equilibrium.

In ascending it is necessary to increase the angle of attack which will decrease the speed and increase the drag. To overcome these forces, the forward acting force must be increased and it is this increase which will supply the necessary condition for ascent.

In descending, a decrease of the forward acting force lessens the forces acting on the centre of pressure, and thus the forces acting on the centre of gravity are greater. The result will be that the glider will move forward and downwards whilst the relative wind will act in the opposite direction to which the glider is proceeding, that is upwards and backwards (Fig. 64).

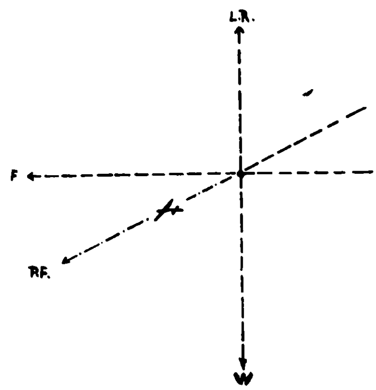


FIG. 64

F	Forward motion
W	Weight
P.F.	Path of flight
L.R.	Resultant lift

If the resultant lift (L) is perpendicularly upwards and equals the total weight of the glider, the glider will continue at the same speed along the path of flight at the minimum gliding angle which corresponds to its best gliding ratio. If the lift is greater than the weight the angle of gliding will be flatter which will result in a lower speed. Where the weight is greater the angle of gliding is steeper at an increased speed. In either case the distance flown will be shorter.

If the total drag is less than the weight the equation will be greater on the side of the weight, *i.e.* the gliding speed will be accelerated. If the drag is larger than the weight the equation will be bigger on the side of the drag, *i.e.* the gliding will be flatter and slower. The best gliding conditions will be those shown in Figs. 65 and 66 where the reaction L/R (resultant lift) is of the same magnitude and opposite in direction to the weight (W).

The lift acts perpendicularly to the gliding path and drag parallel to it but in the opposite direction to the gliding path. Since the lift and drag forces are equal to the weight and D is the total drag of the glider we may state that $W=\sqrt{L^2+D^2}$. But the lift is $W \times \cos \alpha$ where α=gliding angle. Drag also equals $W \times \cos \alpha$ and $D/L = \text{Tan } \alpha$. Thus it is apparent that the gliding angle varies with the overall drag in relation to the lift. That is if we maintain the lift/drag ratio as near unity as possible we glide the longest distance. The results in the formula by which

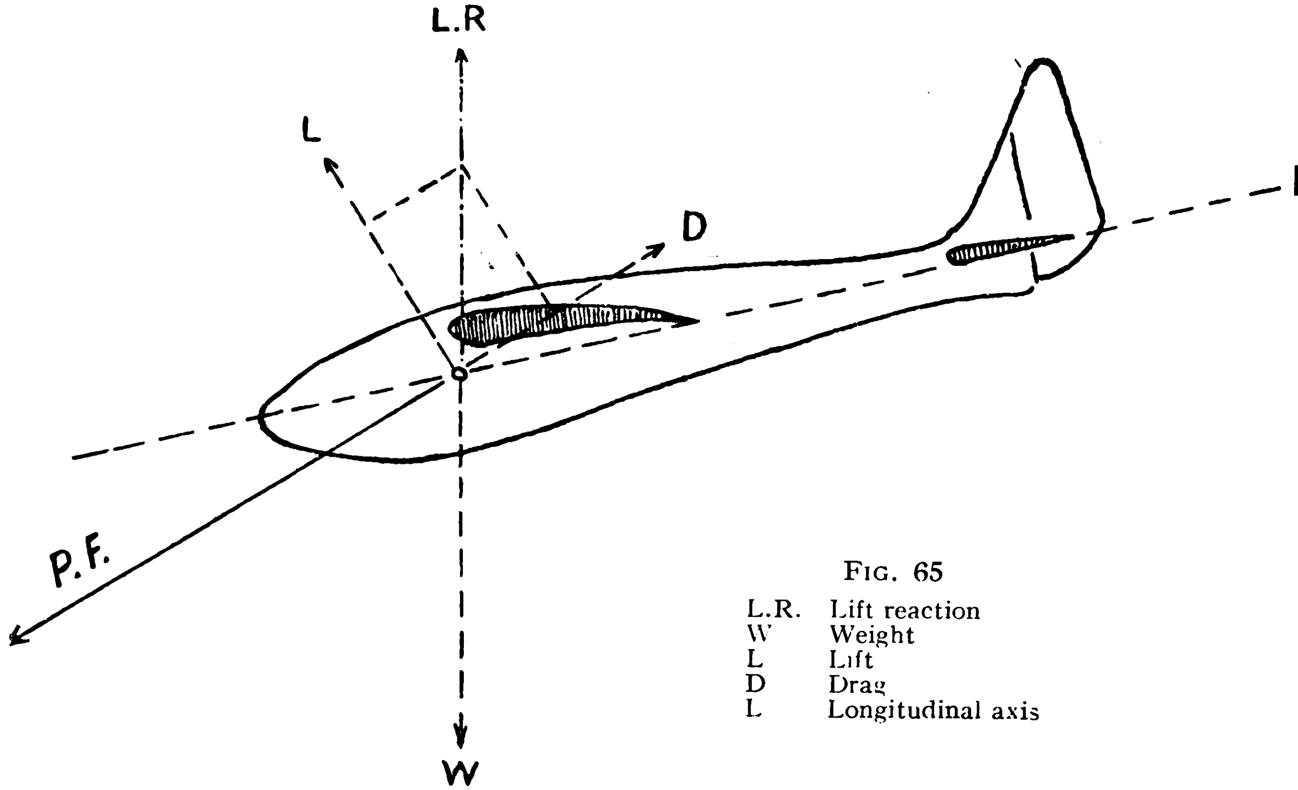


FIG. 65

L.R.	Lift reaction
W	Weight
L	Lift
D	Drag
L	Longitudinal axis

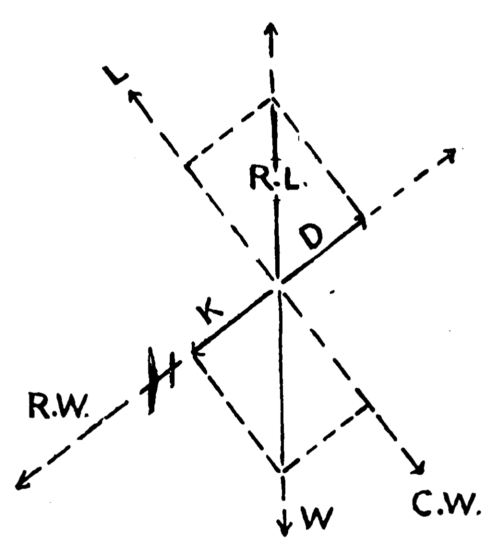


FIG. 66

1. K=D and C.W.=L. Best gliding
   W=Weight, L=Lift, D=Drag, L.R.=Resultant lift
   K=Component of weight acting along the path of flight, C.W.=Component of weight acting along the perpendicular path of flight
2. When L > W unbalanced forces will cause the glider to follow a flatter angle of glide
3. When L <W unbalanced forces will cause the glider to follow a steeper angle

And when Drag is smaller than K, glide will be faster, when Drag is bigger than K, glide will be slower. (See Fig. 67) the longest duration of gliding flight is achieved by having the minimum gliding angle. This corresponds to the minimum sinking speed.

The forces of lift and drag are related to the direction of the wind as we have stated above, *i.e.* the lift is perpendicular to the relative wind, and the drag parallel to it. In the same way the weight acts in two components, perpendicular to the relative wind (C.W.) and also parallel to it (K).

Figures 66 and 67 explain the different examples of gliding. It should be noted that gliding is a descent at a small angle of attack

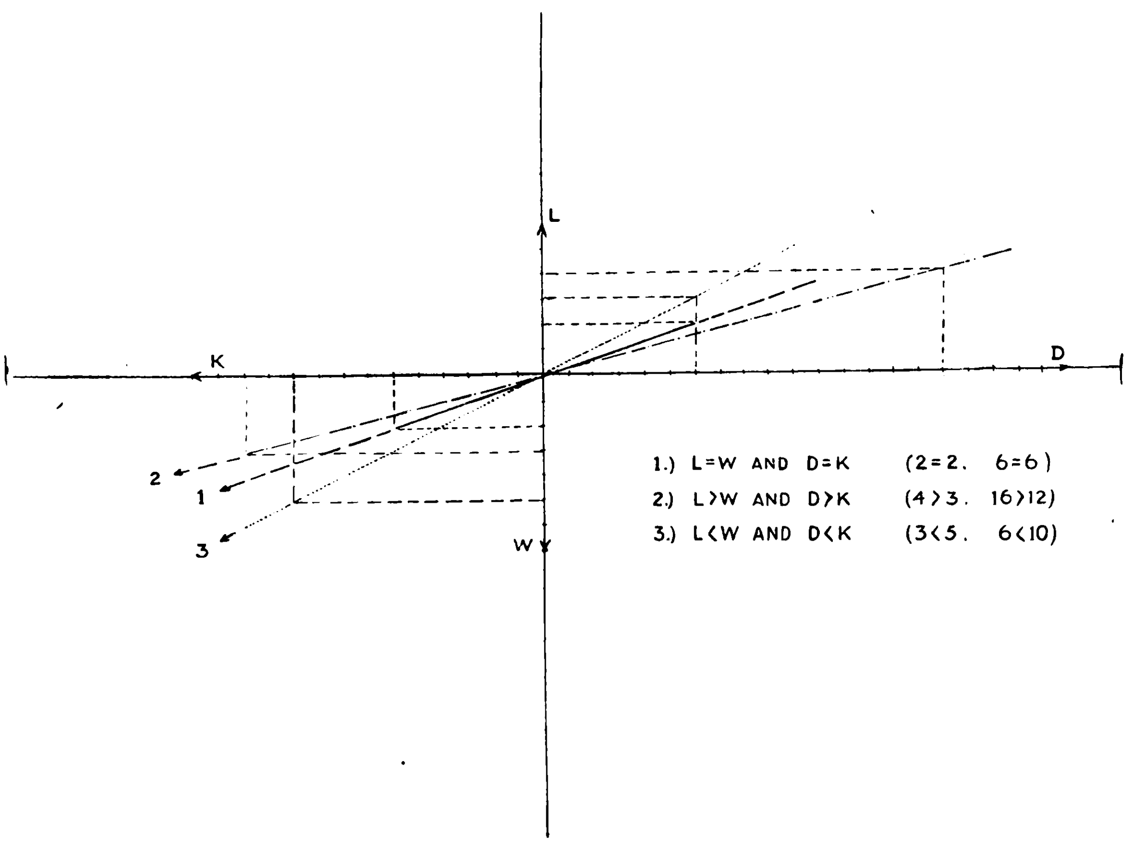


FIG. 67

at a given angle of gliding, whereas diving is a steeper descent at a greater speed and at a larger angle of gliding. In the former case the horizontal distance travelled is greater than that traversed in a steep dive.

Headlong Dive.

During a vertical downwards flight the speed of the glider will accelerate until the total drag equals the weight of the glider. Beyond this limit no further acceleration is possible, this being the final speed, or, as it is called, Terminal Velocity. At this speed the lift must be zero, otherwise the glider would tend to withdraw from its vertical headlong dive. In the " pull-out " from this dive critical forces come into operation, and these forces have to be reckoned with in gliding construction. They are discussed later on in this book.

Glider Controls.

Since the pilot of a glider must perform different movements with his 'plane in horizontal, vertical as well as lateral positions about the centre of gravity, he has to have at his disposal various devices which enable him to vary at will the aerodynamic forces acting on the glider. To perform these changes he uses elevators, rudder and ailerons. The control surfaces are parts of the air-foil of the wing or of the tail unit. The greater part of the load during flight lies on the fixed surfaces (wings, stabiliser, fin). A similar part of the air-foil is movable, being set at the pilot's will and affects the aerodynamic forces necessary for flying. The elevator causes ascent and descent, whilst the rudder causes change in direction, right or left. Both are fitted to the tail unit and act in this way only during normal flight. Ailerons which are fitted to the wings, affect the inclination of the wings about the longitudinal axis, *i.e.* affects its lateral stability.

The elevator is a fixed part of the air-foil fitted horizontally with a movable part which is hinged. The movable part is connected by wires or other methods of transmission with the control column (or joystick) which is in the pilot's cockpit. If the control column is pulled towards the body, it is so arranged that the movable part moves up, which causes downward pressure on the

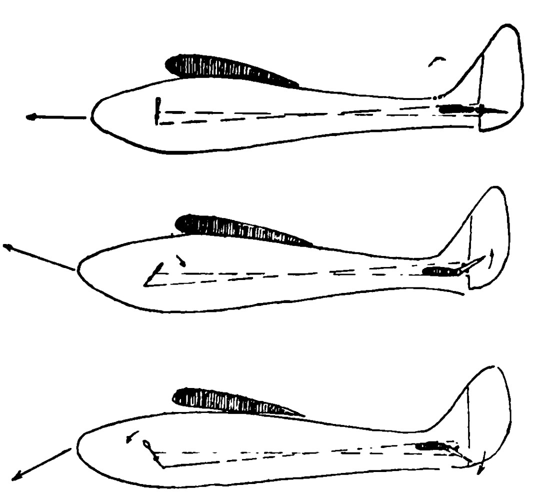


FIG. 68

Horizontal flight

Climbing

Gliding

tail unit and therefore turns the nose of the glider upwards. The reverse happens when the control column is pushed forward. By this means the motions of climbing and descending are made perfectly natural to the pilot (Fig. 68).

The rudder is a similar device except that the fitting in this case is vertical. The rudder is the movable part of the air-foil, and it is connected by a transmission with the control pedals which are situated by the pilot's feet in the cockpit. By pushing on the right or left pedal the position of the hinged air-foil is changed which results in turning the glider into the desired direction (Fig. 69).

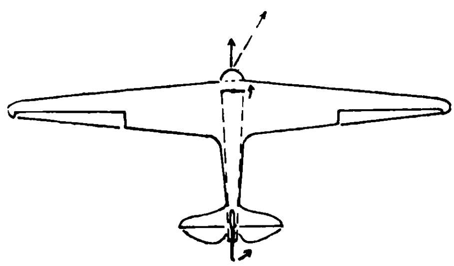


FIG. 69
Rudder changes direction

Ailerons are the small movable parts of the wings' air-foil. They are placed at the outer ends and the rear edge of both wings and are controlled by the control column in the cockpit in such a way that when the left aileron is turned up the right one is turned down. This changes the lift in the opposite direction and results in the glider turning along its longitudinal axis. As a cyclist moving at speed in a sharp curve has to incline inwards to overcome the action of the centrifugal force, so in the same way it is necessary for a glider to incline when making turns or engaging in curving flight.

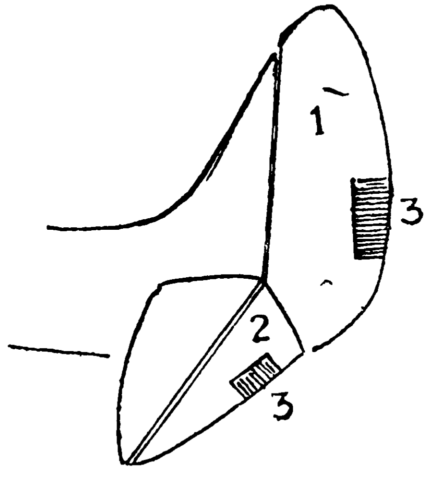


FIG. 70
1. Rudder
2. Elevator
3. Trimming tabs

Apart from all this, modern gliders have an auxiliary device called the trimming tab fitted to the rudder and elevator. Its purpose is to even the " yawing " tendency and to even the different conditions of the load of the glider at different speeds. These trimming tabs are controllable during the flight from the pilot's seat (Fig. 70).

Stability and Balance.

Stability is the greater or lesser capacity of every object at rest or moving to maintain its existing state. When this state is disturbed it is necessary that other counter forces come into action to maintain the equilibrium. The stability of a glider is its inherent ability to re-act to suitable counter forces to maintain the conditions of normal flight. This stability of the glider cannot be affected by the pilot. Because of its balance a glider tends to recover its equilibrium unless the pilot who is controlling it prevents it from doing so. For example, the pilot by using the trimming tabs can so alter the balance so that the aircraft flies nose heavy. This would enable him to glide more steeply. But should he alter the trimming tabs so that the aircraft flies tail heavy, the stability is disturbed but the balance is maintained, and a pilot with a balanced aircraft in this condition need not hold the control column, so long as the aircraft flies.

Consideration of the Three Axes of Stability (Fig. 71).

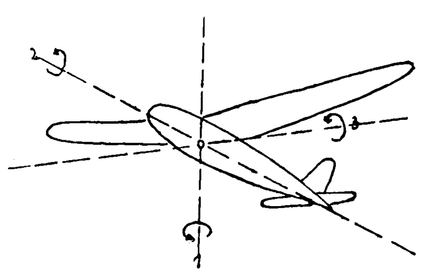


FIG. 71
1 Vertical Axis
2 Longitudinal Axis
3 Lateral Axis

As we have seen there are three axes about which an aircraft flies. They are :—

(1) The vertical.

(2) The longitudinal axis from nose to tail.

(3) The lateral axis from wing tip to wing tip.

Let us suppose that these three axes are mutually perpendicular and that they act at one point which is the centre of gravity.

The Vertical Axis (Fig. 72).

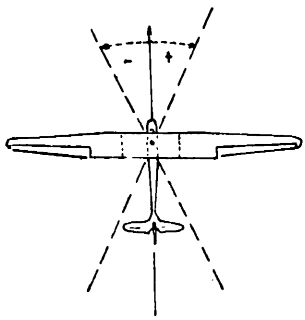


FIG. 72
+ Angle of Yaw
— Angle of Yaw

If a glider turns about the vertical axis it causes a change in its direction, this direction being called positive if the glider turns towards the right, or negative if it turns to the left. During this change the longitudinal and lateral axes move to the right or left horizontally, but the vertical axis remains unchanged.

It will be noticed that the leading edges of both wings of the glider are not usually in line. The wings usually sweep backwards at an angle (Fig. 73). The result when turning round the vertical axis is this: the direction of the relative wind is not at the same angle to both wings. Hence the wing resistance is different. If the glider turns to the left, the right wing has larger resistance than the left wing, which will mean that the tendency will be for the aerodynamic forces to press the glider

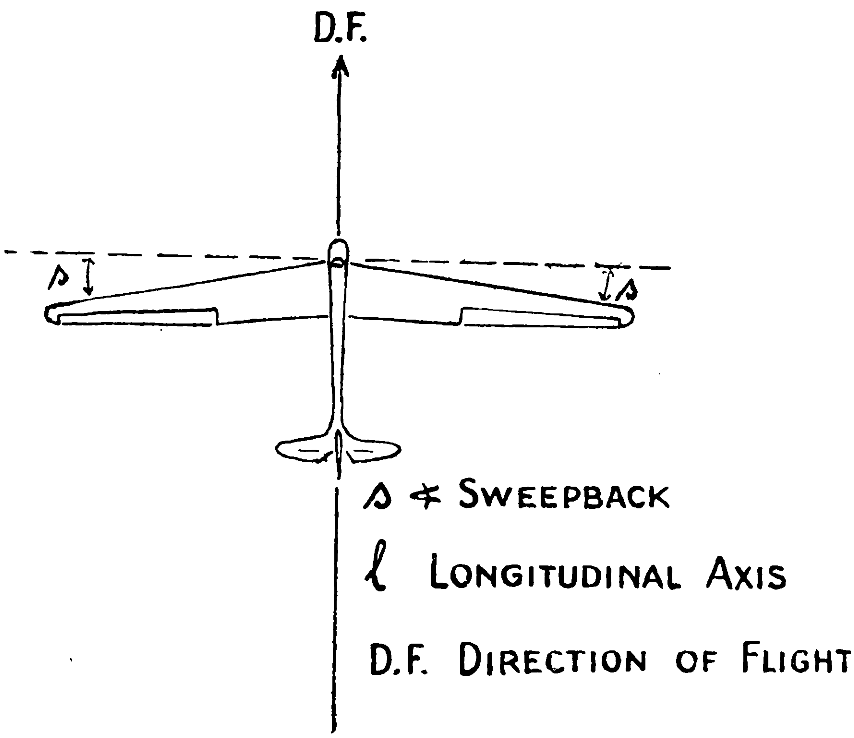


FIG. 73

into its original direction (Fig. 74). This is a test of the directional stability of a glider when flying. If the pilot depresses a pedal

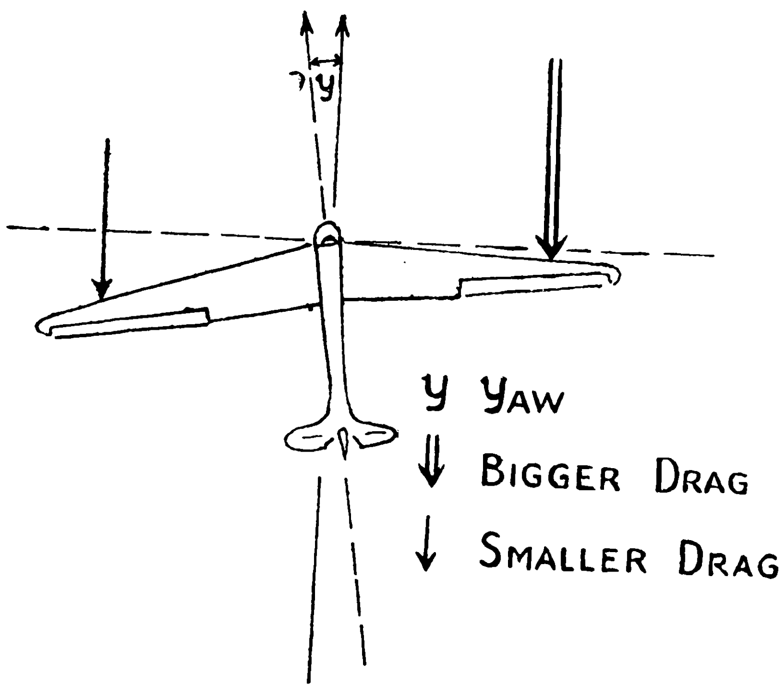


Fig. 74

and releases it immediately afterwards, the glider will tend to skid at first but will return to its original direction when the pedal is released.

Longitudinal Axis (Fig. 75).

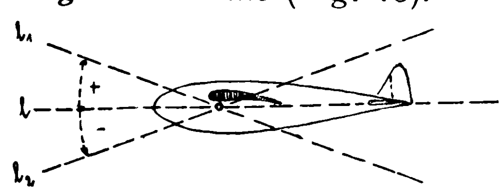


Fig. 75

l Longitudinal axis
o Centre of gravity
l_1 Upward = Positive angle of pitch
l_2 Downward = Negative angle of pitch

This is the line from the nose of the glider to its tail. Sometimes it passes through the centre of gravity. In ascending the longitudinal axis is tilted upwards in order to get positive angle of pitch from the horizontal plane; in descending the longtitudinal axis is tilted downwards to get the negative angle of pitch. In this manœuvre the vertical and longitudinal axes only are affected, the lateral axis remains unchanged.

Longitudinal stability is affected by the position of the centre of gravity relative to the wing chord. Longitudinal instability is affected by inequalities of pressures on the horizontal parts of the glider, *i.e.* the wings, the top part of the fuselage, the stabiliser and elevator. In flight the longitudinal stability is tested, when flying horizontally, by the pilot pushing the control column forward and immediately releasing it. If the glider is longitudinally stable, it will return immediately to the normal glide. It is then said that the glider is dynamically stable.

Lateral Axis (Fig. 76).

FIG. 76
H.L. Horizontal level

This axis is parallel with the wings and in some cases passes through the centre of gravity. Lateral diversions are caused by the difference of lifts between the wings. As in Fig. 77 some

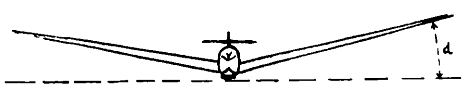


FIG. 77
d Dihedral angle

gliders do not have wings horizontal, these being inclined several degrees from the horizontal. This angle is called dihedral angle and in a turn, results in the relative wind blowing on the wings at different angles of attack, thereby causing different lifts. If the pilot flies in a straight line with the right wing lower, the forces of the lift and weight act so that the glider will not fly directly forward but will incline and side-slip towards the ground (Fig. 78). If in normal flight the glider flies with the right wing

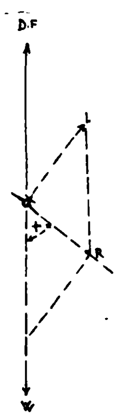
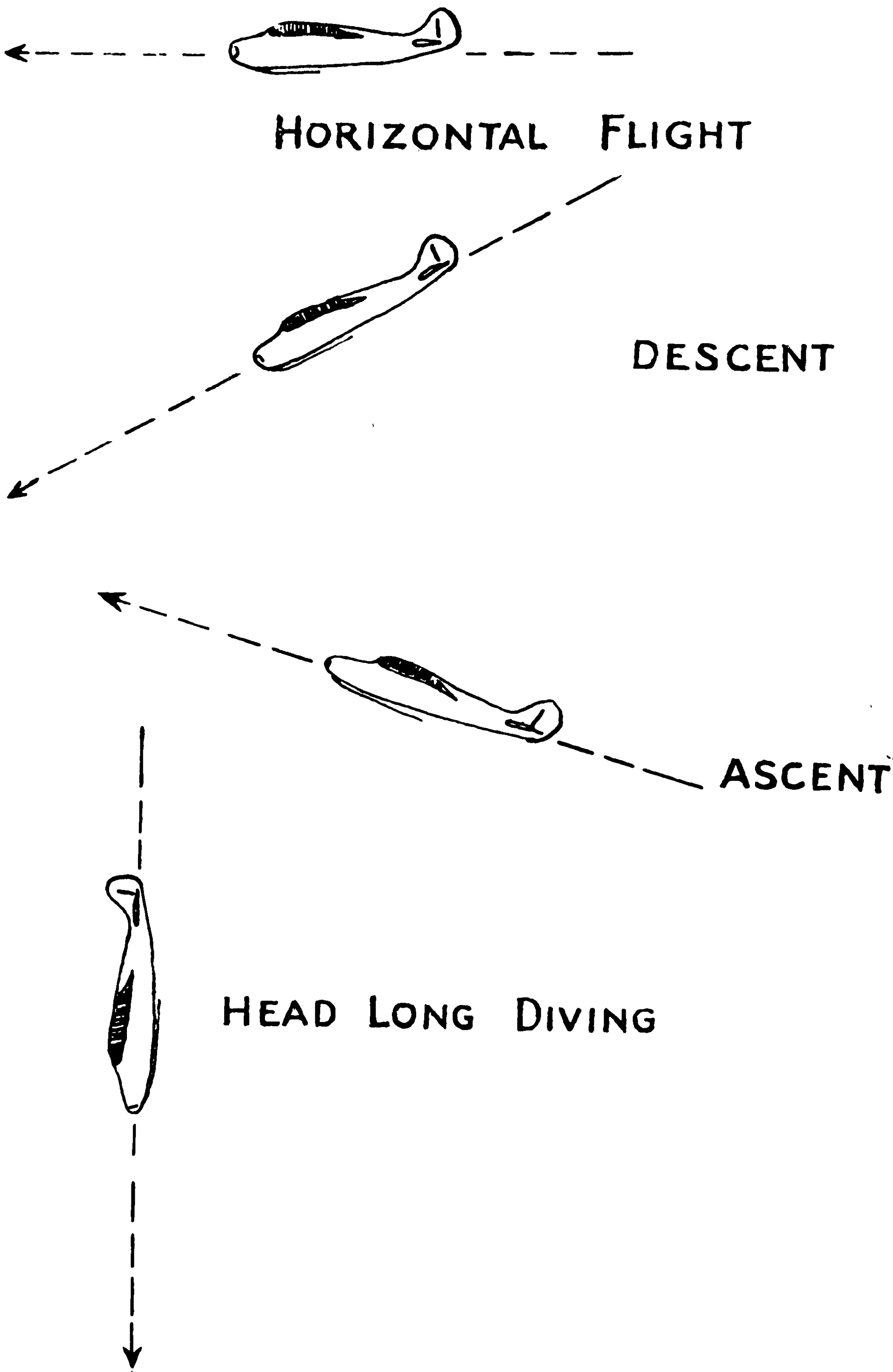


FIG. 78

D.F. Direction of flight
L. Lift
W Weight
R Resultant sideslipping
+ Angle

down it is said to have a positive angle, and a negative angle if it flies with the left wing down. As with other axes stability may be tested during normal flight by moving the control column to one side and releasing it. If the glider normally returns to its original position with the control column vertical, it is said to have lateral stability. We refer therefore to the vertical longitudinal and lateral stability of a glider.

When the forces of lift, drag and gravity act in such a manner that the pilot cannot control them, as for example when, for some reason or another—say lack of wind or lack of lift due to too great an angle of attack to the prevailing wind—the aerodynamic forces act in such a way that the aircraft loses stability, and weight and gravity taking control, the aircraft then usually proceeds towards the earth in a spin (Fig. 79). During this manœuvre the centre



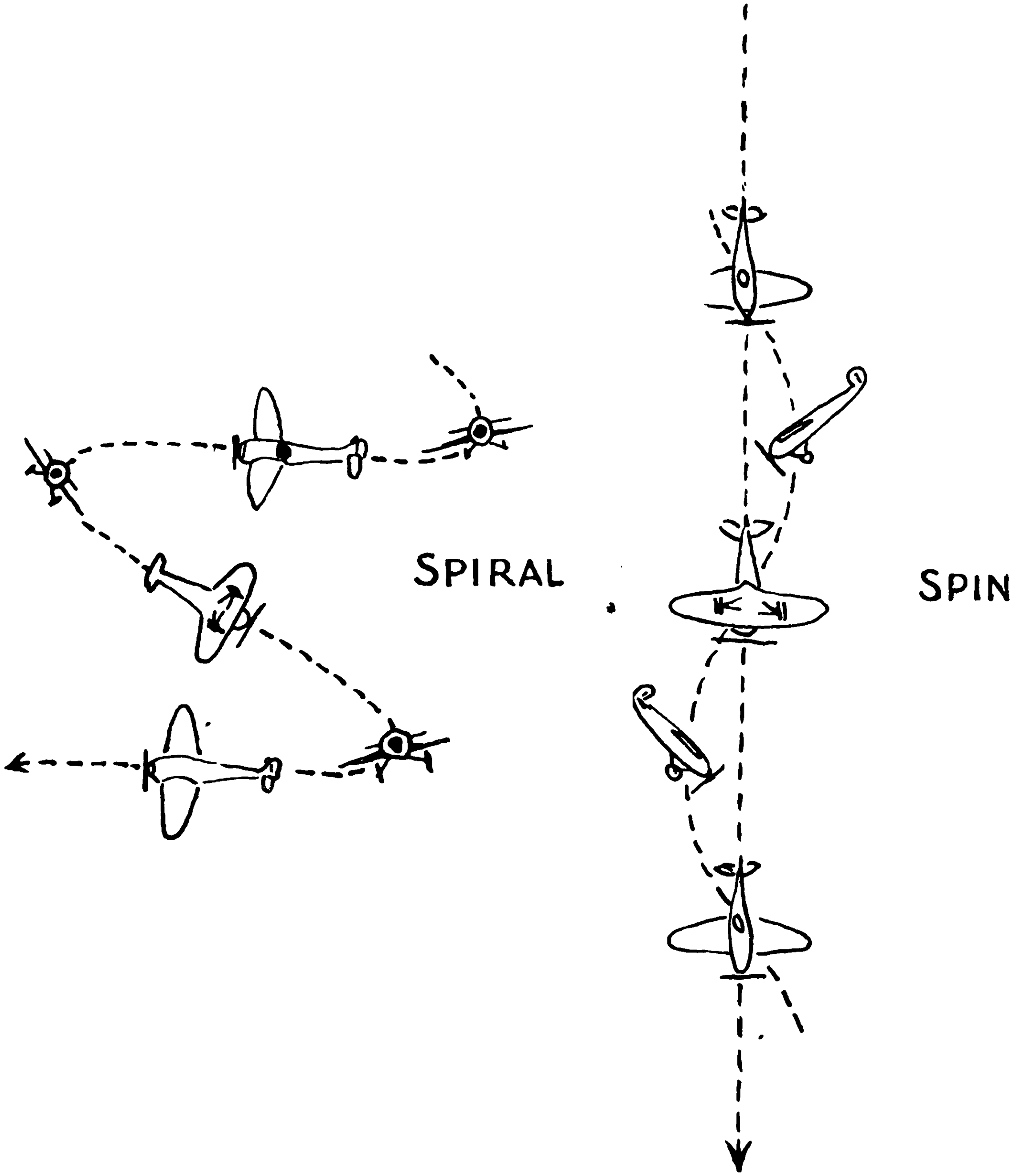


FIG. 79

of gravity traces a circle round a perpendicular line of a smaller diameter than the circle traced by the tail unit. This means that the tail unit no longer controls the longitudinal axis and therefore until it does so the aircraft is out of control. It will be seen, therefore, that a spin is very dangerous at low altitudes because a certain distance of fall is required before the wind passing over the air-foil can exert sufficient drag and lift to restore the aircraft to its normal stability. Exercises in loss of control and regaining it are therefore highly necessary to all pilots, especially military pilots, in order that they may gain confidence in their machines, and may master the elements.

Performance.

This is the characteristic property of different gliders during flight, and is arrived at by summing up all the favourable properties with a full load at the least favourable conditions. In comparison with an engine we could use the word horse-power, which is the work produced by the engine. It will readily be seen that a training glider has one performance, and a sports sail-plane another, and a heavy transport glider a third. A constructor, therefore, has to recognise the limitations of the type of glider he proposes to build, and within those limitations has to design and co-ordinate the best aerodynamic properties of all parts of the glider. Within the limitations of the work they have to do and the stress and strain they have to bear, the wings, fuselage, undercarriage and tail unit have to be designed to form a glider of the highest efficiency.

Considerations in the Design and Construction of Military Gliders.

The main factors which have to be considered in designing and constructing military transport gliders are :—

(1) Maximum load which may be carried under conditions of maximum stress (*i.e.* in bad weather or violent flying conditions).

(2) Its gliding speed, sinking speed and gliding angle.

(3) Stability.

(4) Manœuvrability.

(5) Its flying speed and landing speed.

(6) Speed whilst being towed.

These factors will be affected by, and are related to (from the aerodynamic point of view) :—

(*a*) Kind of air-foil used.

(*b*) The area, form and position of the wing.

(*c*) The local condition of the atmosphere.

Maximum Load to be Carried.

Since modern war has become a matter of engineering design, it is clear that military gliders must be designed, in general, for very special tasks. Whilst it is possible that some all-purpose craft may be built, even for these the disposable load is the measure of their usefulness in any particular kind of operation. Subject therefore to special requirements of ramps, means of entrance and exit of heavy equipment and material, the prime consideration in the construction of military gliders is the above.

It will be seen that it is of the greatest importance that a glider should be so constructed that whatever weight it carries, that weight is evenly distributed around the centre of gravity. For that reason it will be noted that large modern military gliders, such as a Horsa, have a great part of the fuselage in front of the leading edge of the wings. That is, it is so arranged that the weight factor operates evenly forward and aft of the longitudinal axis. Therefore the weight, shape and dimensions of the fuselage are the basic factors from which may be constructed the general idea of the wing structure and area.

Gliding Speed, Sinking Speed and Gliding Angle.

Of these, the sinking speed, at maximum load, is the most important calculation because the other two sub-factors, gliding speed and gliding angle, can be compensated for, in operation, by not releasing the glider from the towing aircraft until a predetermined point in relation to the landing area has been reached. But the sinking speed affects the velocity, and hence the force, with which the glider and its load will approach the land, and this has to be accounted for in calculating the stress and strain acting upon the structure of the glider coming to rest. At the same time, it is a common-sense attitude that the gliding angle shall be as economic (*i.e.* as flat) as possible and that the maximum gliding speed shall be as high as possible, but controllable, so that the landing speed can be brought within such limits that a landing in a small area is possible.

Stability.

This is the third most important factor to be considered, because a glider which is hard for the pilot to fly is going to cause too much fatigue whilst being flown, and may affect the comfort of the troops and cause the load to break loose from its moorings when in flight. It is apparently an easy matter to construct a stable transport glider, but not so easy to distribute the load it carries, so that the stability is not interfered with.

Manœuvrability.

In towed flight manœuvrability is not such a necessity nor even as desirable as manœuvrability in a sail-plane, because the forward motive force is provided by the tug aircraft and not by the use of aerodynamic forces, which can turn lift and drag into a forward motion. In view of the necessity for straight and level flight in airborne operations, the question of manœuvrability is not therefore so important.

Flying Speed and Landing Speed

The lowest speed at which a fully loaded glider will fly is, of course, extremely important, because it affects the type, engine power and construction of the tug aircraft. Obviously, the lower the flying speed of a fully loaded glider, the more types of aircraft which possess the necessary motive power are available to lift this into the air whilst providing the forward moving force which the glider requires in order to fly.

At the same time since one of the great military advantages of a glider is that it can come to rest on reaching ground in a very short distance, and it is often important for the success of the military operations that it should do so, it is highly desirable that glider aircraft should have a slow landing speed in order to avoid harming its load during the extremely rugged and sudden stop to its progress caused by the resistance of the surface of the earth to the skid with which most military transport gliders are fitted.

Speed Whilst Being Towed.

The forwarding acting force which causes the glider to fly obviously varies with the forward speed of the tug. This will therefore affect those stresses and strains which are borne by the longitudinal spars of the fuselage as well as the longerons of the wings. A consideration therefore of the towing speed is of the highest importance in deciding the weight, form, material, shape and position of these basic members in the construction of the glider.

Kind of Air-foil Used.

In order to obtain the maximum efficiency from a consideration of one or all of the above factors, it is necessary next to concentrate on the kind of air-foil used in order to obtain the required lift. The first consideration is the shape of air-foil used, because we have previously seen that the performance of the glider varies considerably with the shape and relative proportions of the air-foil. For example, if it is possible to build a weight-carrying glider with a swept back angle between the wings and the fuselage, the stability of the glider will be affected. But this must not be achieved at the expense of the strength of the wing spars. It will therefore be necessary to have a thicker air-foil than would be required for a lighter aircraft.

The Area, Form and Position of Wing.

Upon the area of the wing depends the maximum load per square foot of wing area, which is the wing loading, which in turn is the basic factor which decides how much free load the aircraft may carry. The form of the wing and its position affect the moment of forces acting on the centre of gravity, and it is therefore necessary that both form and position of the wing in relation to the centre of gravity should be carefully calculated.

Local Condition of the Atmosphere.

This is a far more important factor than is usually realised. For example, a glider which would take off with a full load at 60 miles per hour in the heavy atmosphere of Gt. Britain might require a higher speed and a longer time and distance to take off, say, in the desert of North Africa, or in the high plateaux of India, where the air, either because of the local heat and dryness of the atmosphere, or its reduced density at altitudes, offers less resistance to the passage of the air-foil and therefore does not give the required lift and drag to enable the aircraft to fly.

Some Special Characteristics of Towed Glider.

Other considerations are the type and weight of the towing rope between the tug and the glider. It is also necessary that the release gear for the towing rope should be effective at both ends of the rope in order to enable both pilots to carry out a speedy release. The strength of the towing rope must be sufficient for the total up weight of the glider. It will probably be found that this rope extends by as much as 1% in its length during towing operations beyond its normal length on the ground. It will be found that a glider takes off before the tug, and the tendency is for the glider to exert an upward lift of the tail of the tug aircraft. If this tendency is unchecked it may result in the towing aircraft turning its nose into the ground. Its pilot must therefore be careful to watch for this, and to hold the tail down until he has got an ample margin of speed over that required for his own normal flight.

Once take-off has occurred, aerodynamic forces different from those normally engaged in gliding, come into operation. For they are affected by such factors as the speed of the tow, the position of the glider in relation to the tug aircraft and the length and weight of the towing rope, as well as the position of the towing rope in relation to the centre of gravity of the glider. Towing is faster than normal gliding and the climb is steeper.

As we have mentioned above, the glider takes part of the tug plane's weight through the rope when it starts to fly.

During towing, it is necessary that any turns should be made over great radius. (See Fig. 80.) The towing rope should

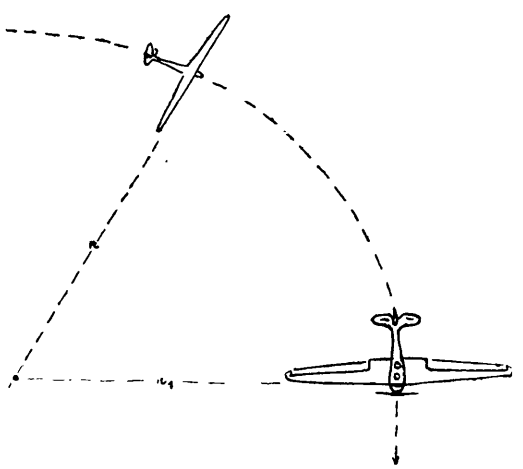


FIG. 80
r=r, RADIUS

always be taut, but, if weather conditions make this difficult and the rope hangs loose, the pilot of the glider must use the rudder and not the elevator to correct this. If the glider is flown at the same height as its tug aircraft, similar conditions obtain to those in which the towing plane flies. That is, the total pull on the rope equals the drag plus the components of weight. If the glider is suspended above the centre of gravity, it will be nose heavy, and tail heavy if the suspension is below the centre of gravity. It will be noticed that air reaction on the wings $=\sqrt{W^2+T^2}$ (Fig. 81). The normal position for a glider is above the plane of the tug aircraft where the aerodynamic conditions are again different because the angle of tow changes and therefore the angle of attack of the glider aircraft in relation to the wind caused by the direction of flight, which in turn involves a further combination of aerodynamic forces.

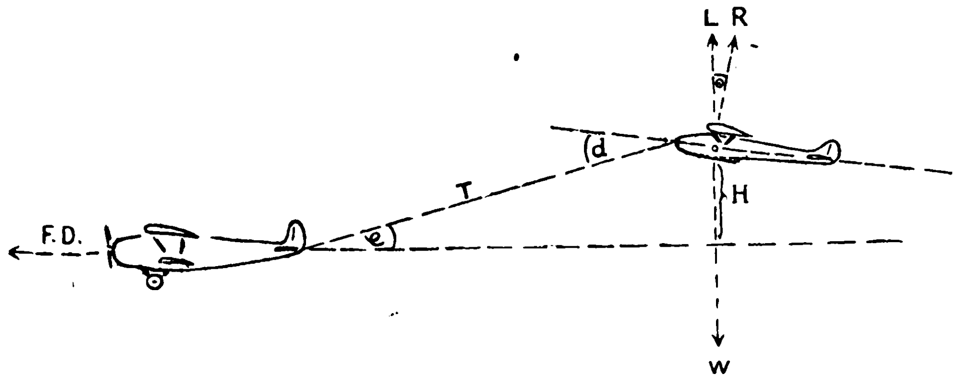


FIG. 81

FD	Flight direction	L	Lift
e	Towing angle	R	Air reaction
T	Towing line	W	Weight
		H	Height difference

In considering the load factor, of the rope and in relation to the power of the tug aircraft, allowance will have to be made for the type of undercarriage with which the glider is fitted. A wheeled undercarriage would, obviously, offer less resistance on a forward motion than that given by a skid.

There is finally one other extreme factor in relation to load which is to be considered. The ratio of the glider's weight to that of the combined weight of the tug and the glider is variable, and depends on the speed of the flight and on any change of direction into or away from that of the prevailing wind. It is also affected by the angle of climb and of glide. In a steep climb there is a certain increase in the moment of forces acting upon an upward lift, whose gravity counterpart is greater than that of the combined weight of both aircraft. Conversely in a steep descent, the apparent weight is less than the true weight. But any change in the direction of flight causes therefore a variation of the weight factor which must be taken into consideration by the constructor in relation to the load when designing the aircraft. It is obvious that the maximum speed and therefore the greatest moment of force which a glider will have to overcome will be when the pilot pulls out of a dive. It has been calculated that the glider's weight is then increased approximately 8 times.

Safety Factor.

If in design and construction the maximum load bearable by the component parts of a glider was only reckoned at 8 times that required in normal flight, or during the recovery from a dive, there would then be no safety factor because the forces of disintegration would equal those of cohesion. A designer who wishes to have a safety factor of 4 must design his aircraft to carry 32 times the load expected, whilst if he desires to have a safety factor of 8 he must reckon on carrying a load 64 times greater than the normal load.

V

MODERN GLIDER BUILDING

Materials.

FOR the building of the modern glider, one of whose great advantages is cheapness of its construction, it is necessary to use materials which are easily available, and which, therefore, do not have to be imported. In the main in countries where there is plenty of wood, it is the chief material from which they are made, but in other countries where light metals and alloys are easily available, these materials are sometimes used. Generally speaking, however, any material which is used for the manufacture of power-driven aircraft can also be used for the construction of gliders, if cost does not enter into the matter.

Requirements of Material Desired.

(1) Plentiful and easily available.

(2) First-class quality, strong, durable and not brittle, light, easily worked and non-inflammable.

(3) Cheap.

(4) Resistant to atmospheric conditions (humidity, dryness, high or low temperatures).

These are difficult conditions to fulfil. Solid material is often too heavy, absorbs moisture or may rot. Some metals rust easily and are not resistant to shocks, *i.e.,* they bend and break. No ideal substance has yet been discovered for use throughout a glider. Therefore different materials are used for different parts of a glider. The wings are usually made of wood, the fuselage is of wood or metal, the skids and undercarriage are metal also. Some of the metals employed are :—

(1) *Rustless Steel.*—For the parts bearing the greatest strain and load, such as joints between the fuselage and wing roots, screws, bolts, splints, stiffening cables; control cables are made of rustless steel where possible. Otherwise a normal hard steel is used which is painted with a weather-resisting dope.

(2) *Iron.*—Is used everywhere where steel is not absolutely needed. Although easily workable, it is too heavy, but fulfils the desired conditions for shock, strain and fatigue of metals. As it reacts rather easily to weather conditions it has to be covered with protective paint.

(3) *Copper and its Alloys.*—Although quite strong, tensile, and with other good qualities, it is not so resistant as steel or iron. If used in exposed places it rusts, but not to the same extent as iron. It is mostly used in electric wiring, and for securing nuts.

(4) *Aluminium and its Alloys.*—Very light but fragile. Easily workable. Some of the alloys, however, have very great tensile strength, especially those in which dural is a component of the alloy. Only highly industrialised countries like U.S.A., Great Britain, Germany and Russia, are in possession of large quantities of duraluminium, which is highly necessary to power aircraft.

(5) *Glass and Plastics.*—Commonly known as unbreakable glass, derivatives of cellulose are used for windows, wind-screens of pilot and crew, gun turrets, etc., expensive to manufacture and demanding a high degree of industrialisation of the country manufacturing. Successful attempts had been made in the U.S.A. to build whole gliders out of plastics, and also power aircraft, *e.g.* Clark 4C.

(6) *Wood.*—Must have the required density and whilst dry must still retain tensile properties. It has to be tested for breakage before use. Spruce and ash are the woods most generally used, but great use has been made in the last few years of what are known as " improved " woods. These are woods cut into thin laminated strips and stuck together with plastics under great pressure. Their strength has been found to be greater than that of an equivalent untreated wood. The test of good wood material is whether, when breaking, it breaks into long fibres, *i.e.*, whether it splinters or whether there is a clean fracture. The first is good, and the latter is too dangerous.

Generally speaking, the wood used is cut in such a way that the year rings show longitudinally.

The advantages of wood are that it is cheap, obtainable almost anywhere, and can be found in good qualities and in good quantities. Its disadvantages are that it is not as strong as metals, is affected by weather conditions, and loses strength when wet, whilst when dry it is apt to break. It may rot and is inflammable. Against these disadvantages it can, to some extent, be protected by the use of protective paint.

(7) *Glue.*—Glue and plastics are used to connect wooden parts of a glider. Only the best quality is used. It is applied cold, and therefore takes time to set and dry. Nevertheless, the glued parts stand a great strain.

(8) *Cloth for Covering.*—Used to cover wings, fuselage, rudders, etc. Must be high quality linen, light weight, and it is sometimes possible to impregnate it with weather-resisting compounds during manufacture. This may be done after the material has been fixed to the aircraft.

(9) *Paint and Dope.*—These must be of high quality to resist weather and also to give a smooth finish to the surface. They must be lasting, light, non-inflammable and blister proof. This also applies to colours used for camouflage and international distinction marks.

Construction.

As we have explained before, the wings are that portion of the aircraft which are exposed to the greatest strain from opposing aerodynamic forces. To resist these they must be built with extraordinary strength. At the same time, it has to be borne in mind that the weight of the wing should be as low as possible. It is therefore necessary on occasions to forgo advantages of an aerodynamic nature in order to satisfy the requirements of construction.

Military gliders, which might be compared with a road trailer but fitted with wings, have to be fast, strong, of great capacity and yet easy to handle. Since they are not required to carry out soaring flight, the conditions of their construction vary greatly from those of sail-planes.

Construction of the Wing.

In general, both the rectangular and tapered wing consists of one or more main spars with a certain number of ribs (Fig. 82). The wooden main-spar is made of one piece of wood, or it may be built of longerons forming a girder-spar. Further stiffening is provided by a plywood cover. The main-spar is sometimes constructed as a box which lies in the middle of the wing, or which may form the leading edge at the same time. Again, it is strengthened with plywood (Fig. 82, *a, b, c, d, e*).

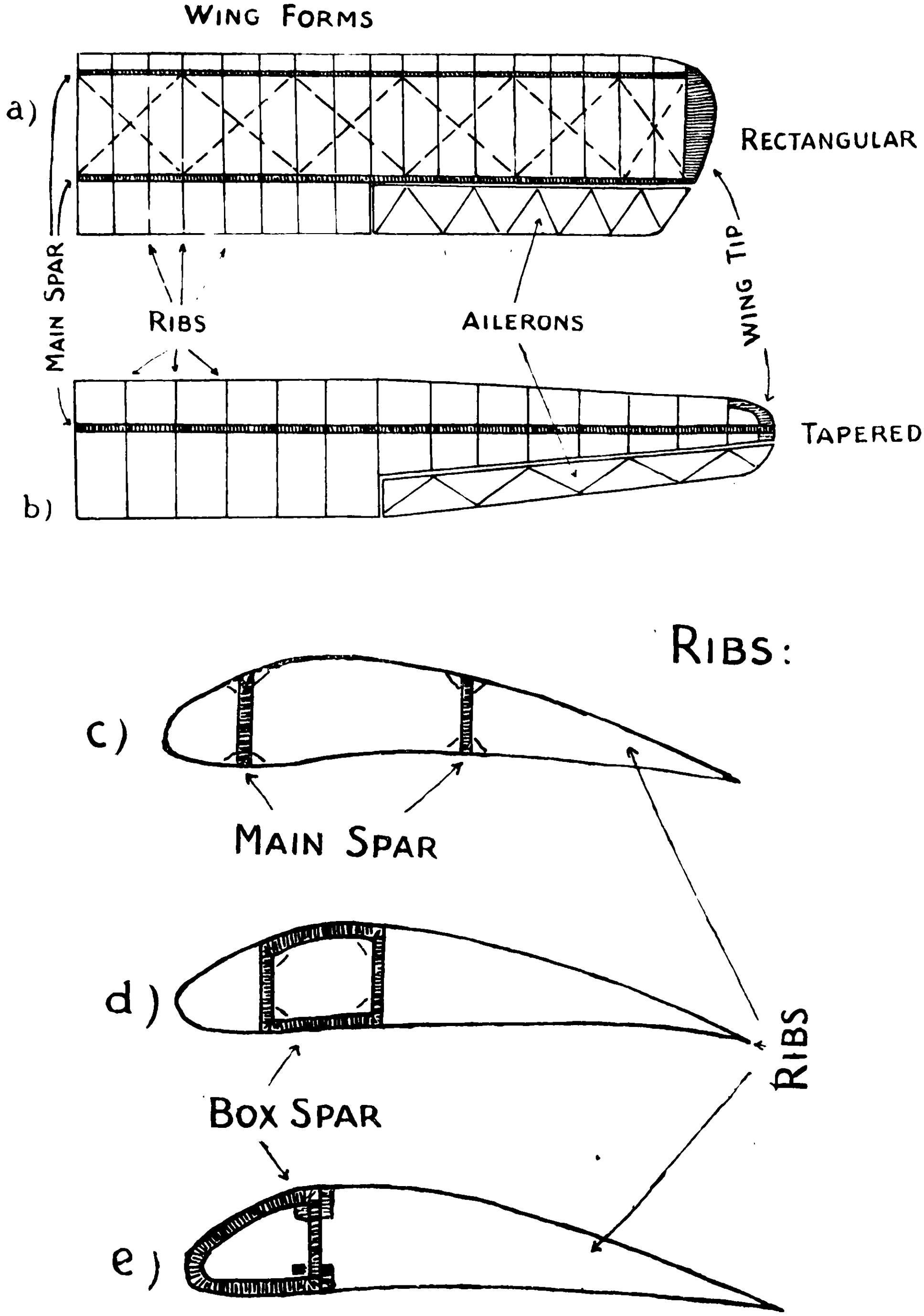


FIG. 82

Ribs, having a box-spar, are very strong and resist great bending and torsion forces. Box-spars usually have air holes drilled into them in order to provide a free circulation of air to remove moisture. The calculations of the size of the spars involve the factors of breaking strength of the wood and the coefficient of safety, reckoned as against the load in terms of horizontal as well as vertical thrusts.

Ribs.

These are made of thin wooden flanges and struts, constructed as is shown in Fig. 83. They are glued together with cold glue, and as a whole form the desired shape of air-foil. For certain types of gliders, ribs are built in the form of an airfoil of plywood (Fig. 84), stiffened on both sides by small flanges or struts. The

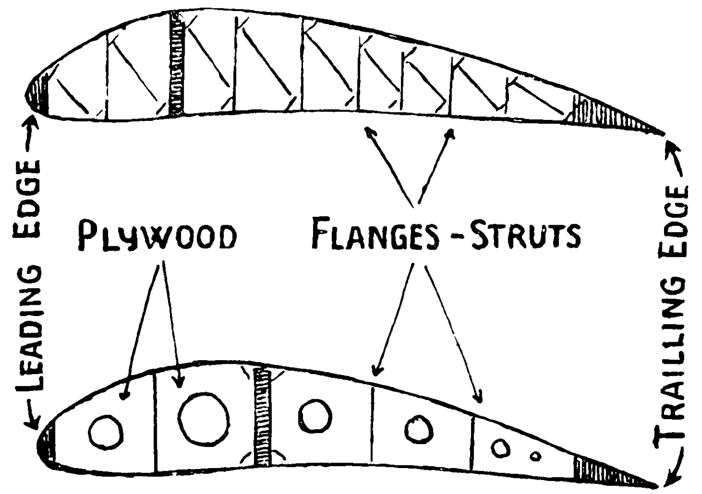


FIG. 83

FIG. 84

leading and trailing edges may be made of a strong wood or of thick plywood. Plywood, if used as covering, also helps to preserve the true air-foil shape. As with wings, calculations of load, strength and safety coefficient have to be made in designing the shape and size of the ribs.

Wing Tip.

These have to be relatively strong, not because they are exposed to abnormal aerodynamic forces, but because they are most likely to suffer damage during transport and on landing. They are usually therefore constructed of high quality wood such as ash, stiffened plywood, or even with compressed paper or plastics. Where ribs are made of metal, the section is as shown in Fig. 84.

Ailerons.

These are constructed similar to the wings themselves. They have a spar and ribs. In order to avoid vortices during flight it is necessary that they should fit as closely to the wing as possible. As they have to move up and down a certain amount of space is necessary but this is often obviated by fitting them into the body of the wing and also by covering the spaces between the ailerons and the wing with a suitable cover. The whole of the wing must be covered either with a light strong cloth, or partly with cloth and partly with plywood, which may be treated and painted with the appropriate coloured paint for camouflage and protection, as well as to secure a smooth surface.

Both wood, plastic and metal wings have their advantages and disadvantages, mostly matters of ease of manufacture and of construction, and their use therefore is a matter for the constructor.

Concerning both wings, it is obvious, of course, that they must be of equal weight and identical shape in reverse, otherwise they would not possess the same aerodynamic qualities and, in flight, would possibly be unstable and uncontrollable.

Position of the wing.

The placing of the wings on the fuselage is of the utmost importance to the balance of the aircraft and is the result of accurate calculations. As we have seen in discussing the principles of flight, the principle is that the centre of pressure of the wing must be as near as possible to the centre of gravity of the whole glider. Measuring from the leading edge it is usually found that the line of balance of the wing is along a longeron, and is about 35% of the distance from the leading edge to the trailing edge, that is along the chord. The angle between the centre line or longitudinal axis of the glider and the chord of the wings is the angle of incidence, and this is discovered by calculations which give the maximum L/D. This angle of incidence usually $+4°$ is that which gives the most rapid take-off and the slowest landing speed, which should be about 40 miles per hour. Comparisons are often made between similar types of aircraft and gliders in terms of what is called their wing loading. This is obtained by adding together the weight of the whole aircraft with its pilot and useful load, and dividing by the number of square feet of area of the wings. The result is given as so many pounds per square foot.

Fuselage.

The best form of fuselage would clearly be that designed like an air-foil, but it has various limitations in that it has to carry the load and must therefore be strong. This is not always possible for reasons of construction. Nevertheless, aircraft have been designed and are flying to-day in which the fuselage is part of the wing air-foil or may be separated from the engine nacelles and tail booms which carry the stabiliser, etc.

In modern gliders there are two forms of construction for fuselages :—

(1) The monocoque.

(2) The girder.

Monocoque Type (Fig. 85).

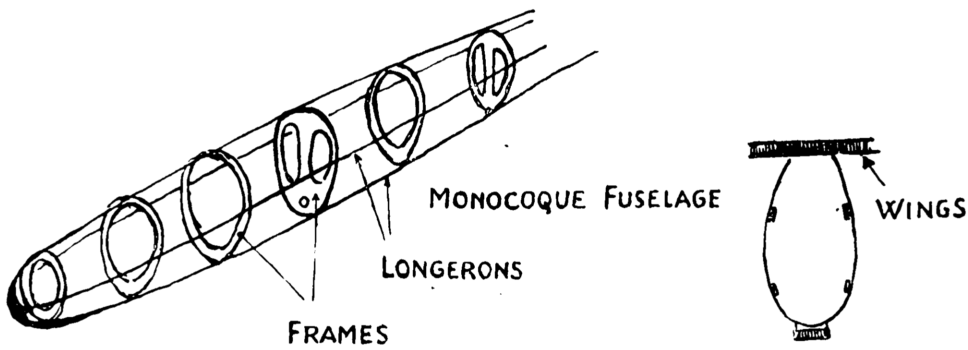


FIG. 85

The monocoque fuselage consists of fuselage frames placed at certain distances from each other along the longerons. Together they form the skeleton of the fuselage. This is covered with plywood, which also strengthens the fuselage to a very high degree. The frames consist of small parts glued together and stiffened on either side with plywood. They are consequently rather costly to make.

The Girder Fuselage (Fig. 86).

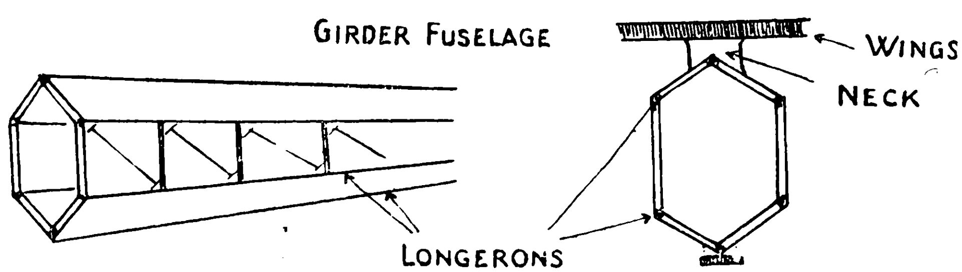


FIG. 86

This type is a square or hexagonal section. The foundations are longerons of the necessary form stiffened with cross-bars. This skeleton is covered with plywood or cloth, and is very cheap to make and easily repaired. However, it has obvious aerodynamic faults.

Military gliders, which are towed by powerful engine aircraft, have specially strengthened fuselages in addition to questions of load, it is necessary to provide them with a special gear for securing the towing rope and for releasing it when required.

In normal gliders, it will be found that the length of the fuselage varies between ⅓ and ¼ of the total wing spread. A short fuselage is stronger than a long one but requires a larger tail unit in order to exert the same amount of pressure and force on the centre of gravity. A long fuselage must bear more strain but has the compensation that it requires a smaller tail plane. Various types of gliders are shown in Fig. 87.

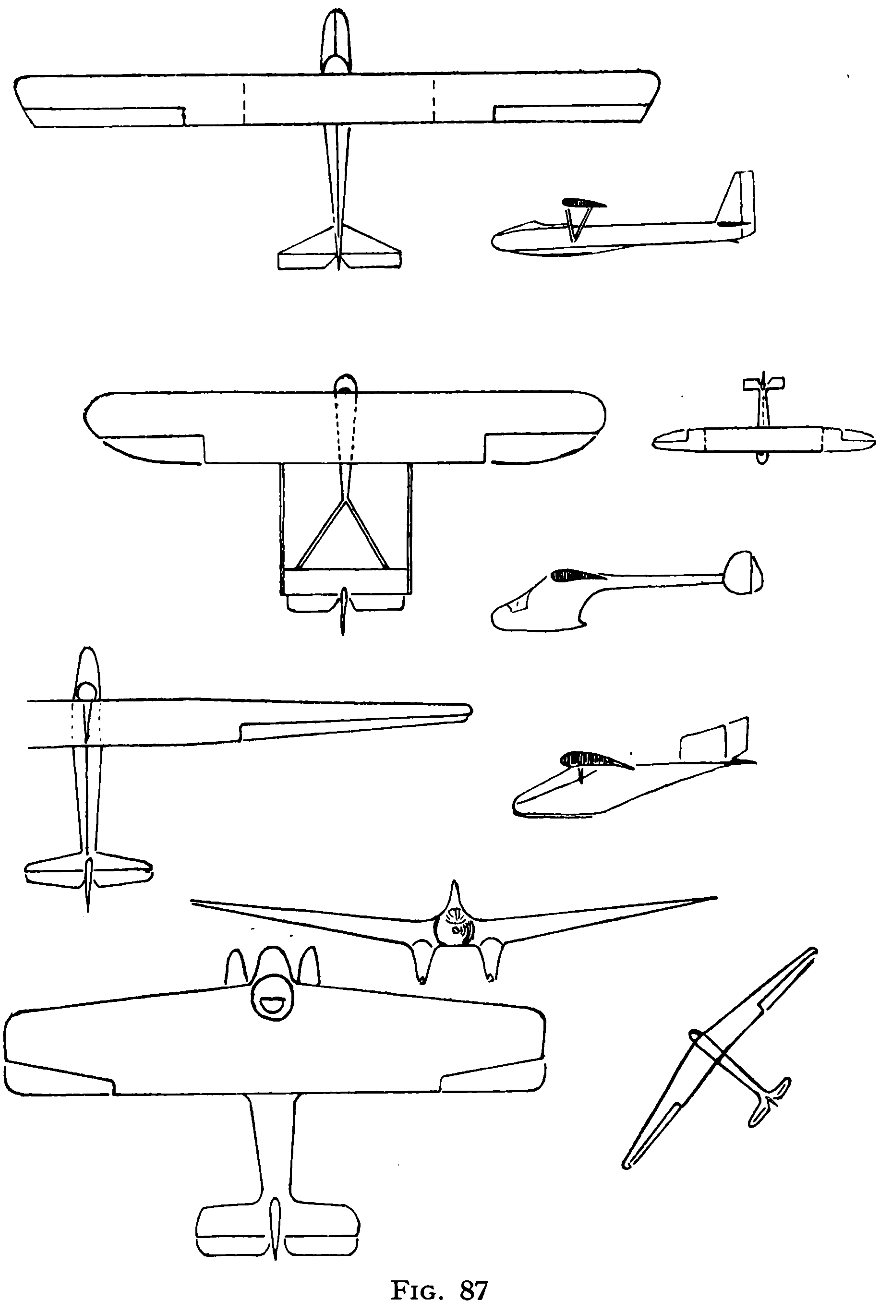


FIG. 87

VARIOUS TYPES OF GLIDERS

The Undercarriage.

Either wheels or skids may be employed for this purpose, or a combination of both. Since landing on a skid creates greater ground resistance it is necessary to provide a shock absorber of either rubber or springs between the fuselage and the skid (Fig. 88). Skids may be made of wood or metal. As may be seen, great

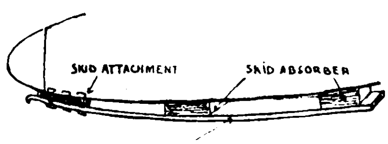


FIG. 88
FUSELAGE

friction suffered by skids to movement over the earth's surface shortens the distance of the landing space required but, at the same time, offers greater resistance to take-off. Therefore skids alone are only fitted to small gliders. For military purposes a combination of skid and wheel undercarriage is necessary. By this method, the glider takes off on wheels, which it may leave behind or jettison when airborne, but on coming to earth lands on the skid. Some gliders have a different design with tricycle undercarriage (see Fig. 89). By this means the glider lands in a horizontal position and it can be stopped immediately by the use of pneumatic brakes. This helps stability for take-off and landing, but is a heavy addition to the weight of the glider.

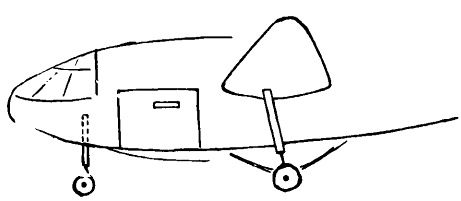


FIG. 89
DETACHABLE UNDERCARRIAGE

Hydro gliders, built to take off and land on water, are fitted with floats and fuselage similar to those of a flying boat.

Tail Unit (Fig. 90).

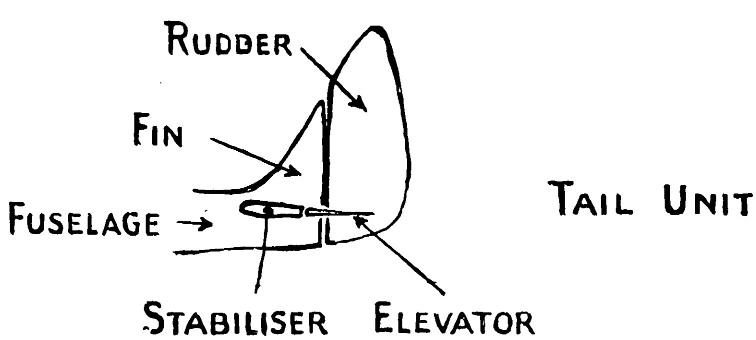


FIG. 90

This consists of a stabiliser which operates on both sides of the fuselage and of two elevators. The upper part of the tail unit is formed by the fin and the rudder. The size and emplacement of the tail unit is directly related to the size of the wings and the fuselage, and these, in turn, involve calculations of the centre of pressure and gravity of the glider, its load and the length of the fuselage. Both rudder and elevator are of aerodynamic air-foil shape and are constructed of ribs like the wings.

Control System.

The control system of a glider is similar to that of a power aircraft. The pedals are geared to the rudder by means of cables or duraluminium pipes, so that the rudder will be turned to the left, and the aircraft to the left, when the pilot presses his left foot (Fig. 91).

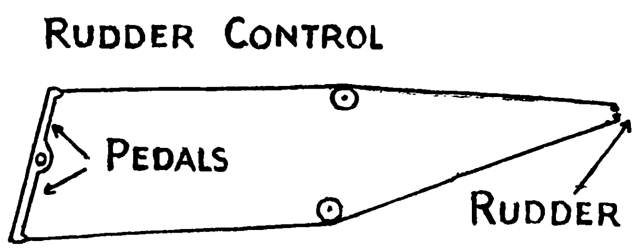


FIG. 91

Climbing and descending result from pulling the control column towards the pilot for climbing, and pressing it away from him for descending. Transmission of this movement to the elevator is effected by cables or tubes (Fig. 92).

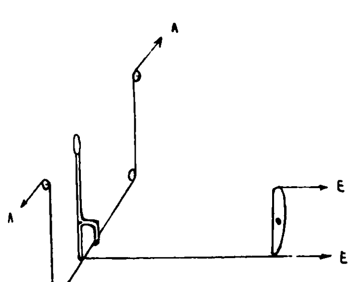


FIG. 92
CONTROL SYSTEM
A Ailerons
E Elevator

As has been explained before, the ailerons are also geared to the control column in such a way that the right aileron turns upwards when the control column is moved to the right. This makes the right wing descend, and at the same time the left aileron is moved downwards, which makes the left wing to climb. The effect is then that the lateral axis of the glider moves from the horizontal. This is usually used in conjunction with the rudder in turning or is often used by pilots wishing to obtain better momentary visibility on the side which is dipped.

Flying Instruments.

For the safe and correct handling of a glider a number of instruments are necessary. They are :—

(1) Air-speed indicator.

(2) Barograph.

(3) Variometer.

(4) Compass.

(5) Chronometer.

(6) Artificial horizon.

(7) Turn indicator.

(8) Towing indicator.

(9) Other special instruments according to type of glider.

The Air-speed Indicator.

In general, glider pilots do not have to take much account of their flying speed when taking off, as the natural tendency is for the aircraft to be airborne as soon as flying speed is reached. But when height and flying speed have been gained, it is most important that a pilot, especially in a closed cabin, should be aware of his speed through the air. A certain speed is required to keep up the best flying angle whatever the wind conditions. There are many types of air-speed indicators which are mostly designed on two principles. The first is that of air pressure in a pipe which is transmitted to a diaphragm. This pipe, commonly known as the " pitot tube," is usually placed on the wing or on the fuselage where it will avoid air vortices. The other principle is that of a rotating cup. It is therefore important that these instruments should be exact for gliders which engage in blind flying, whilst their importance for pilots of power aircraft is highest of all.

The Barograph.

This indicates the absolute height above sea-level and by looking down on the earth the pilot can judge his actual height above land. It operates on the aneroid principle which is a box of very thin metal sensitive to changes of pressure which react like a diaphragm. It is most important for blind flying.

The Variometer.

This instrument indicates whether the aircraft is climbing or descending and the rate of such movement. It is therefore of the greatest importance to those glider pilots who are taking advantage of air currents for height and distance. It is also based on the principle of the diaphragm.

The Compass.

This obvious instrument shows the pilot his direction of flight in relation to the magnetic North. It must be used to fly on a set course for long gliding flights or when flying in tow, since it is impossible to navigate without knowing the direction in which the aircraft is proceeding.

The Chronometer.

Of equal importance for navigation and in operation for synchronisation of action. In military gliders, as in all military aircraft, chronometers are synchronised by all crews at the same time by radio.

Artificial horizon.

This instrument enables a pilot, flying blind or at night, to know whether or not he is flying laterally, horizontal.

The Turn Indicator.

This indicates the correct amount of bank whilst making a turn.

Towing Indicator.

This shows the pilot the position of the glider relative to the towing plane, *i.e.,* whether it is above or below and to the right or left of the tug aircraft.

Other Instruments.

These usually consist in military gliders of apparatus for communication either between the pilot and the tug pilot, between the pilot and the ground, or for inter-communication between members of the crew. It has also been used for communication with other gliders. Communication between tug and glider is by telephone, as it is between members of the crew. Communication with the ground or with other aircraft is by radio. In military operations, however, since this would possibly inform the enemy about the operations in progress, it is rarely used except in training where it makes possible control by a central commander.

VI

GLIDERS IN GENERAL.

IT is now possible to describe in detail the various types of gliders in a way which the reader, who has read through the previous chapters which have set out the conditions of the laws of aerodynamics in relation to flight, would understand. It is apparent that a glider is an aircraft without an engine, but it is the same shape and similar construction to a power driven aeroplane. It has wings, a fuselage and controls, but since it lacks an engine it lacks that motive force which enables it not only to overcome unfavourable conditions of weather, but which also enable an aeroplane to fly, even when there is no wind. According to their purpose we divide gliders into three categories :—

(1) Sporting gliders.

(2) Research gliders.

(3) Military gliders.

SPORTING GLIDERS.

There are four types of sporting gliders, they are :—

(*a*) *The Primary Gliders* (Fig. 93).

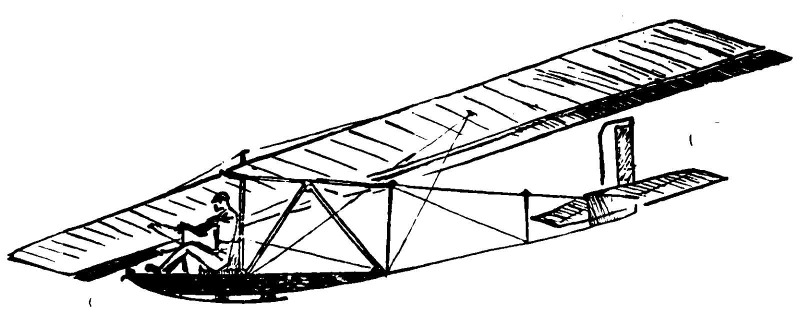


FIG. 93

This is usually a high wing monoplane with wooden fuselage and wings, constructed on longerons, stiffened with steel wire. It has a wing span of approximately 30 ft. and a wing surface of approximately 20 square yards, and weighs 170 to 220 lbs. without a pilot. Its degree of descent is approximately 1 to 2 metres per second, and it has a gliding ratio of 1 in 7. Its flying speed is about 25 to 30 miles an hour with a maximum speed of about 70 miles per hour. Its use is for initial training at low heights. It is launched into the air by the use of a rubber shock cord, or more usually by being towed by an automobile or winch. Since its aim is to give the beginner confidence and instruct him in the art of balance, it has no special aerodynamic qualities beyond that of stability.

(*b*) *The Utility Glider* (Fig. 94).

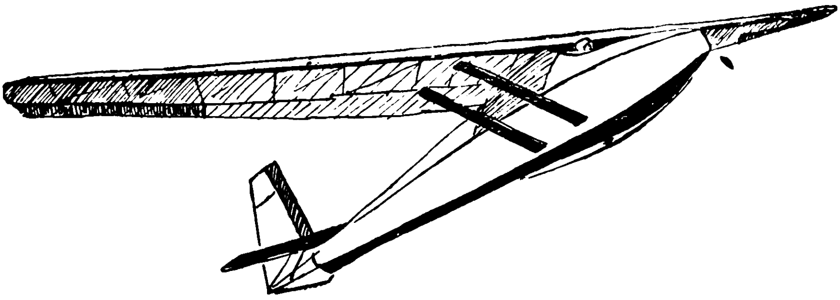


FIG. 94

This is usually a high wing monoplane with a wooden body and wings. It may be a single or double seater, and is usually specially strengthened to make it suitable for towing by another aircraft for training purposes. Its wing span is 30 to 45 ft. and its wing surface approximately 25 to 30 square yards. Its unladen weight is about 250 lbs. It has a slow degree of descent, less than 3 ft. a second, and a gliding ratio of 1 to 15. Its minimum speed is 25 to 30 miles per hour, and its maximum 90 to 100 miles per hour. It is usually slightly streamlined and is used for advanced training on a slope or for being towed behind an automobile.

(*c*) *The Intermediate Sail-Plane* (Fig. 95).

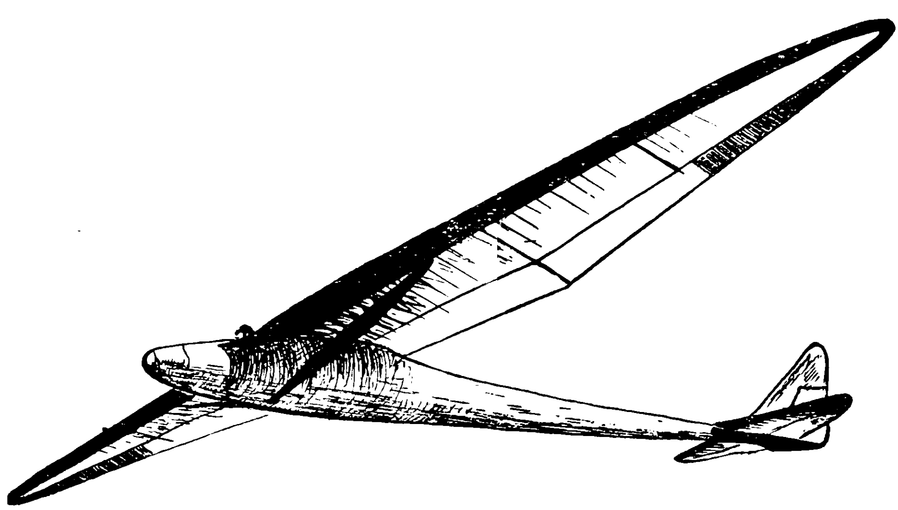


FIG. 95

This is also a high wing monoplane, well streamlined with wooden fuselage and wings. It is equipped with the necessary instruments built into a cockpit. Its wing span is about 45 ft.

and the wing area about 25 to 30 square yards. It weighs about 250 lbs. and descends at a rate of about 2 ft. a second. Its gliding ratio is about 1 in 20 and it has usually a minimum speed of 25 to 30 m.p.h., but its maximum speed is over 100 m.p.h. It is used for advanced training, or for thermic soaring, and, if constructed with a stiffened fuselage and wings, it is suitable for towing by an automobile or by aircraft at high altitudes.

(*d*) *High Performance Sail-Plane.*

This may be made of wood or of light metal. It is well streamlined with a wing span of over 60 ft. and tapered wings. It may weigh as much as 450 lbs. and has a gliding ratio of 1 in 30. Its rate of descent is rather over 1 ft. a second. Its flying speed is slightly over 30 m.p.h. and its maximum speed well over 100 m.p.h. It is equipped with all the instruments necessary for thermic gliding and blind or cloud flying. If intended for aircraft towing and racing, such as high altitude flying, cross-country flights, or flights in front of or below thunderstorm clouds, it has to be specially constructed.

Research Gliders.

These are largely used at aircraft factories and by constructors for the testing of various designs and improvements in aircraft construction, *e.g.*, the first rocket plane experiment was carried out by the use of a glider which reached a speed of over 200 m.p.h.

This type of glider has also been used by national metereological institutes for atmospheric research. Gliders, since they do not possess engines, do not suffer from vibration, and, consequently, have less effect on delicate instruments such as those used to register atmospheric conditions. By their use, the speed, width and altitude of up-currents have been measured. Their convenient rate of gliding, small rate of descent and their manoeuvrability, have enabled a great deal of study of the atmosphere to be undertaken by skilled observer-pilots, which could not have been done so conveniently by any other method.

Military Gliders.

There are many types of military gliders ranging from the two-seater towed glider of the Hotspur type, to the German Goliath capable of transporting over 140 men. The latter type of giant glider can be fitted with six or more engines, so that it can hardly be described as a glider except that it is constructed like a glider. But in none of these types is the art of soaring flight practised, and very little gliding. Their subordination to the military machine makes this impossible. They are not, therefore, discussed in this work. Further details about them and the manner of their use can be obtained from the Authors' companion book *The Flying Soldier* (Alliance Press, Ltd., London).

VII

TRAINING.

The Choice of Trainees.

EXPERIENCE with civilian soaring and training in flying light aircraft has shown that almost everyone, unless suffering from some special illness or unless very short sighted, can be taught to fly. In general it has been found that the best pupils are those between the ages of 17 and 30, but a great many people, both younger and older than these limits, have not only learnt to fly but are flying successfully to-day. The demands of military flying require high standard of physical and psychological fitness. The standards in Great Britain and the United States at the outbreak of the war were very high, but as wartime conditions have shown that first rate flying can be and has been done by personnel who did not reach the original high standard, and as the demand for air crews has grown enormously, it has generally become accepted that such high standards are neither necessary nor desirable. In Great Britain, for example, it is to-day possible to learn to fly under the Air Training Corps Scheme at the age of 15½, whilst pilots are accepted for training up to 32 years of age in the Air Force and up to 35 in the Army Air Corps. Other pilots, who have already learned to fly, who are very much older than this, have been and are on operations as well as engaged in ferrying large transport aircraft.

Other flying personnel—observers, navigators, radio operators and air-gunners, flight engineers, etc., may be as old as 55 years of age in the R.A.F. to-day.

It is now recognised by the R.A.F. that preliminary instruction in soaring and gliding flight is the ideal method of training operational pilots. Consequently, the training of the Air Training Corps, which accepts boys at the age of 15¼ for training in all subjects which would be useful to members of the R.A.F., either as ground or air crews, includes a full course in gliding, but not in soaring.

Training.

Amongst those who have studied gliding seriously, it has become recognised that there are three different types of training, which are:—

(1) The German, or so-called classical training.

(2) The American training.

(3) The military training.

(1) *The German Method.*

This is called the classical method because from the very beginning pilots relied entirely on natural air currents to provide the uplift necessary to gain height in order to glide. As we have explained before, gliding became very popular in Germany immediately after the war of 1914-1918 as the Peace Treaty forbade the Germans to train aeroplane pilots or to engage in motor flying. A few airforce pilots were engaged by civilian airlines and many became members of soaring clubs, where they were put in charge of training. There were many of them to be employed, and this was one reason why so many clubs for motorless flying began and became popular throughout Germany. As the fame of the German exploits spread, other countries took up soaring flight with the same enthusiasm. These schools were established near to slopes of land or hillsides, where the prevailing wind produced conditions suitable for gliding. From this developed thermic flying, soaring above or below clouds, flights in front of a thunderstorm cloud, and eventually to high altitude as well as long distance flights. The fact that neither engines nor petrol were used and that the gliders were cheap to construct made this form of flying extremely popular because it cost so little.

Method.

(i) *Training on Primary Gliders.*

A group of 6 to 12 pupils, led by an experienced instructor, began the initial theoretical study and practical experience, and informative workshop practice. The trainee was made to sit in a primary glider where he learned about the functions of the control column verbally and by practical experience in a light wind. To make this more effective, the glider was mounted on a stand with a universal joint, something like the Link trainer of to-day but not so advanced. All this made the pupil react automatically to the conditions of flight (Fig. 96).

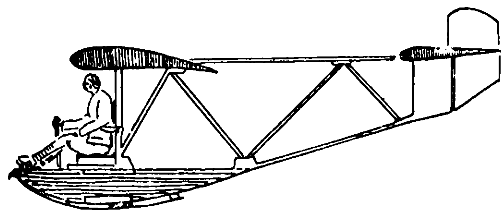


FIG. 96

This having been mastered, the pupil next undertook short runs in a glider which was dragged rapidly forward by the use of a shock-cord. One end of the shock-cord was fastened to the nose of the glider, which in turn was fastened to the ground by a short cable. The shock-cord was then pulled by four men on either side, but only for a long enough distance to make the glider traverse a few yards of ground without being airborne, when the instructor ordered the cord fastening the glider to the ground to be released. In this way the pupil became accustomed to the shock and acceleration, and to the reaction of the rudders. When the pupil was confident about this, the runs were extended by pulling out the shock-rope further and further, so that in the end the glider would take off and fly a few yards through the air, at a height of 5 to 15 ft. This was increased as the pupil increased in confidence until greater lengths of flight at greater height were achieved—as much as the limited pull of the shock-cord at its full extent would provide. All this part of the training was done without wind (Fig. 97).

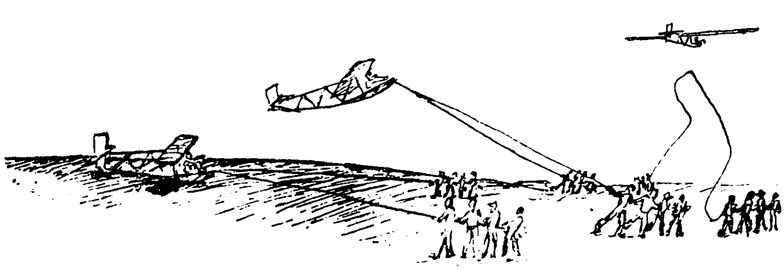
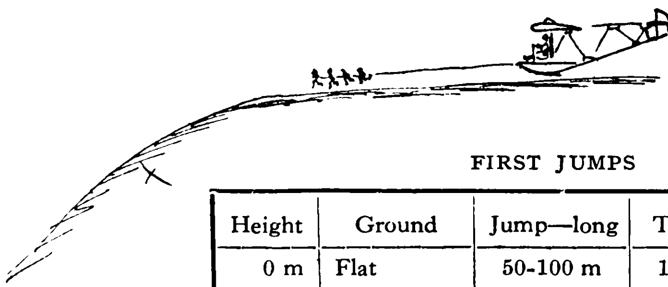


FIG. 97

The pupil was then introduced to slightly more difficult conditions of flight. At first in a light wind, and later in strong winds. The initial training began on a plain or low down on a hillside. Gliding distances grew greater until it was finally possible for the pupil to fly his glider on a straight line for 30 seconds and to land without a bump (Fig. 98). This entitled him to an



FIRST JUMPS

Height	Ground	Jump—long	Time	Shock cord prolonged at 100% cord load 300 lb.
0 m	Flat	50-100 m	10 sec.	
30	Small slope	300	50	
50	,,	600	60	

FIG. 98

" A " gliding certificate, but, of course, the flight must have been stable and level. (See Figs. 109, 110, 111.)

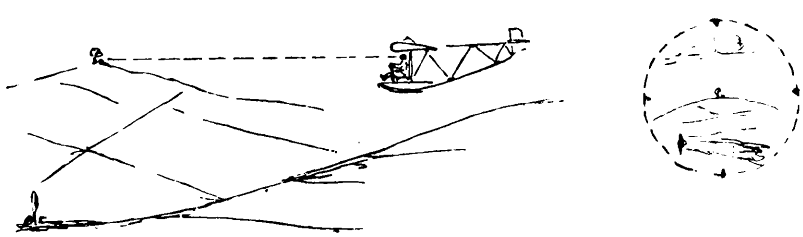


FIG. 99

Pilot sees horizon—correct gliding

FIG. 100

Pilot sees trees—not correct—too fast

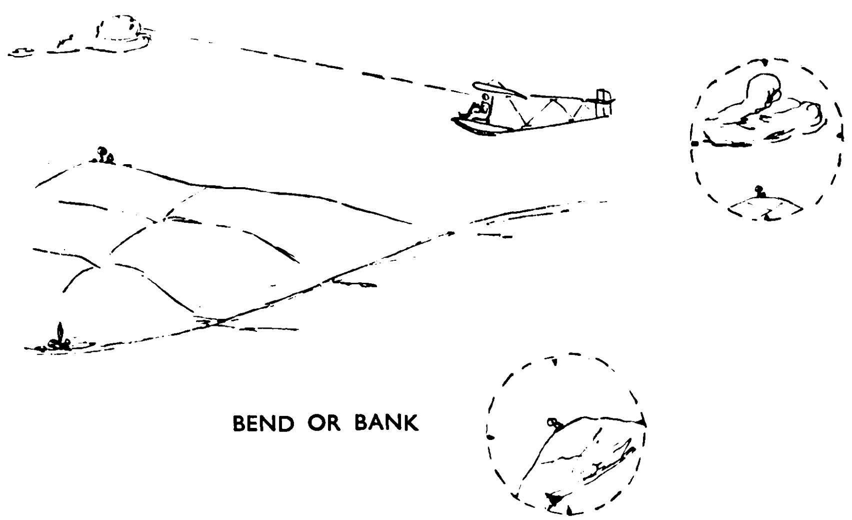


FIG. 101

Pilot sees clouds—not correct—loss of speed—possibility of a stall

(ii) *Advanced Training on Hillsides in Sail-Planes.*

The next phase of training was on hillsides in intermediate gliders where the pupil learned to govern his glider at greater heights, for longer distances and under more variable atmospheric conditions. His first " take-offs " were from a high hill without wind; in these flights he learned to turn right and left, and the correct method of landing. As he progressed he was instructed in light winds and latterly in strong winds.

The conditions for obtaining a " B " certificate were :—A correct start, a short straight flight, then two flights of 60 seconds, each with an " S " bend in each flight, and correct landings. It was in these flights that the pupil started to " hear " the speed of his glider and to observe its relation to atmospheric conditions and phenomena. With daily training this period usually lasted between three and four weeks. But this was still only gliding.

(iii) *Final Training.*

The pupil was then introduced to more efficient sail-planes which had greater soaring and gliding capacities. Under close supervision, he was taught to sail along the hillside in a slight wind (Fig. 102).

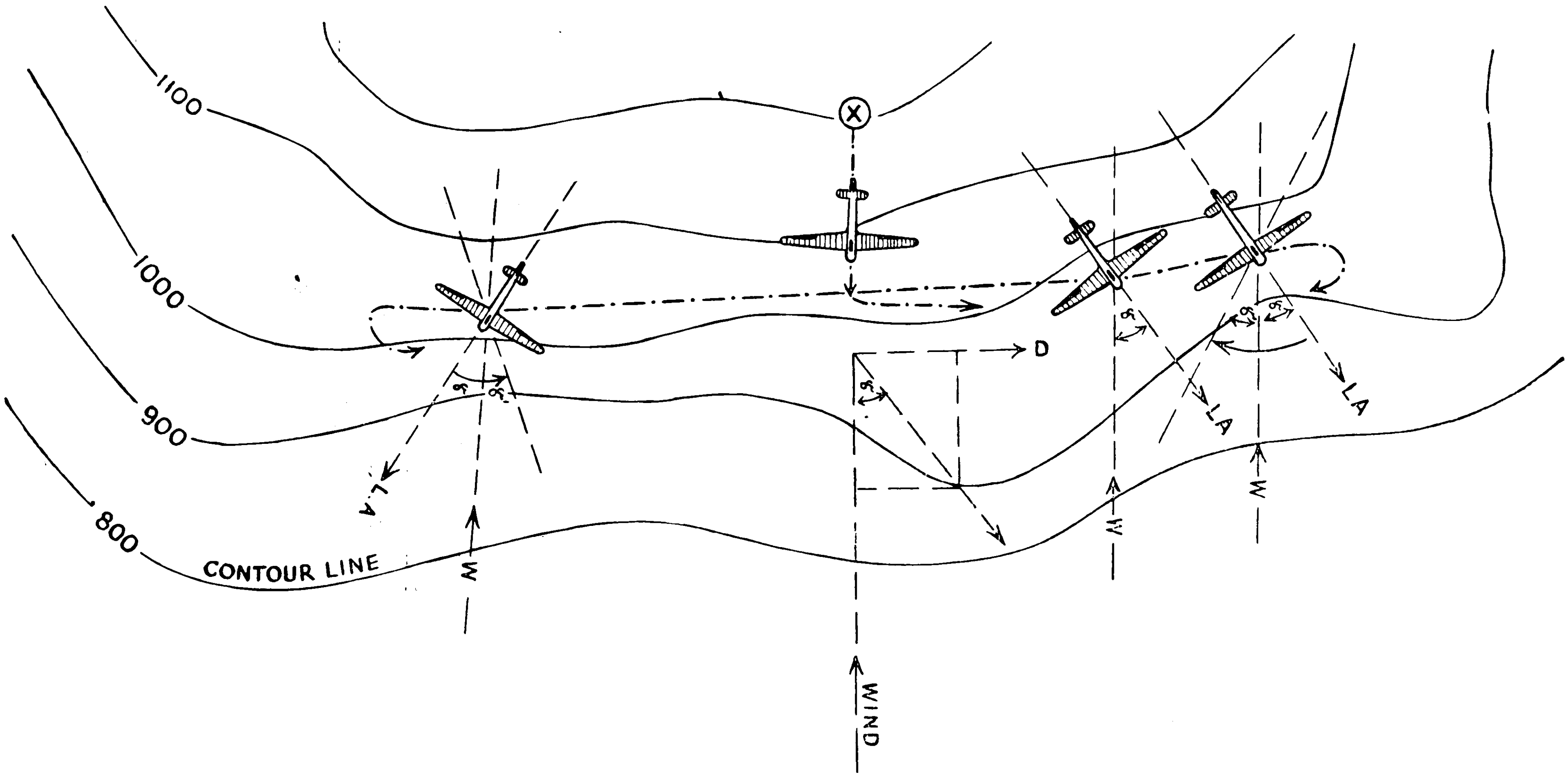


FIG. 102

GLIDING (SOARING) ALONG THE SLOPE. × = TAKE OFF POINT. D = DIRECTION OF FLIGHT ALONG THE SLOPE. LA = LONGITUDINAL AXIS DURING FLIGHT. γ AND γ_1 ANGLES EQUAL. IF VELOCITY OF WIND INCREASE, ANGLE γ WILL DECREASE. WIND VELOCITY ZERO—ANGLE ZERO—LONGITUDINAL AXIS IN THE DIRECTION ——→D

After starting by means of a shock-cord from a slope the pupil had to turn his glider along the slope, and to take advantage of the up current of wind with which to soar to the other end of the slope. He then turned against the wind and flew back to the opposite end of the slope again, where again he turned away from the slope. By this method the pilot learned to recognise the influence of the wind and the effect of flying a little nearer or a little further away from the slope, either above or below the level of his starting point (Fig. 103). In approximately three weeks

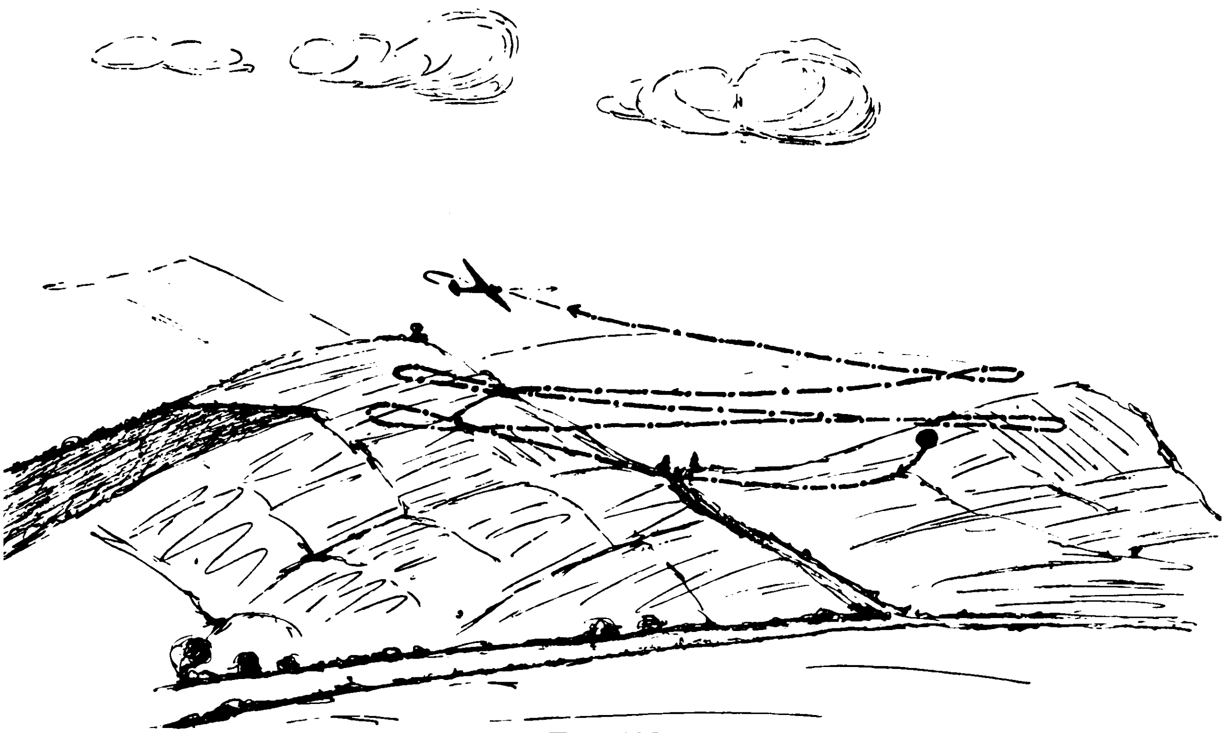


FIG. 103

a normal pilot would be able to fly for a period of 5 minutes after a correct take-off, and if he succeeded in handling his glider pro-

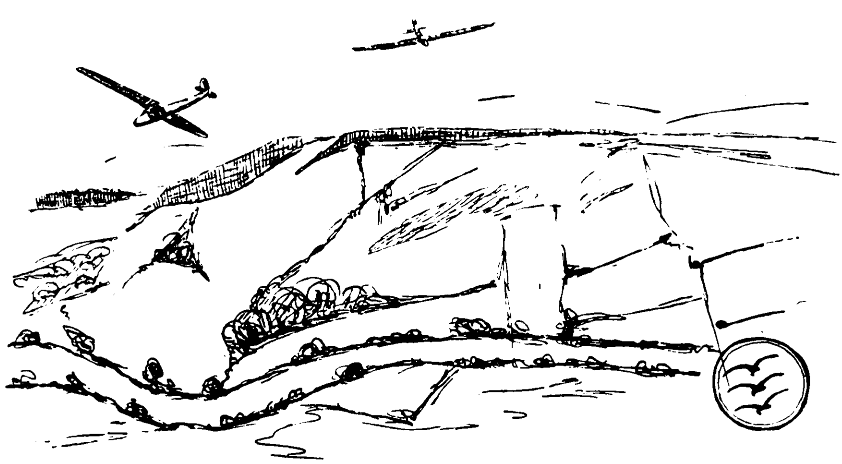
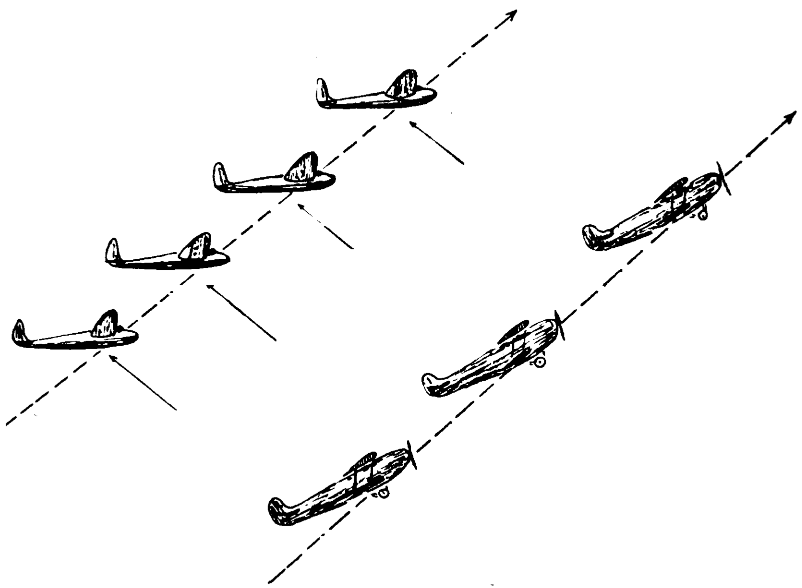


FIG. 104

perly and making a correct landing he was entitled to his " C " certificate (Fig. 104). By this time he has made somewhere between 150 and 200 flights from the beginning of his training.



Sailplane climb   Aircraft climb

FIG. 105

It will be noted that the climbing of a sail-plane and of a power aircraft are not the same. (See Fig. 105.)

It was observed that more pilots failed to complete the course for financial reasons than for ineptitude, but in spite of this, there was a very large number of qualified glider pilots in Germany at the outbreak of the present war.

Pilots of outstanding qualities who wished to proceed further could obtain a " Silver C " certificate or " D " certificate. The requirements for these were the ability to reach a height of 3,000 ft. above starting level, to fly for 5 hours at least, and to cover a distance of not less than 30 miles.

It may be said that the great advance in the art of soaring came from these people who achieved the " C " certificate. By intense concentration of purpose the results achieved far outran the expectations of the most sanguine enthusiasts, and served, of course, to increase their enthusiasm. " High Schools of Soaring " were formed which built special high performance sail-planes. In some countries technical high schools and experimental departments placed their services at the disposal of the training centres established in Germany. This co-operation, thoroughness and persistency chiefly led to the extraordinary understanding of sail flying which developed in Germany.

"Ace" glider pilots made their appearance whose aim was to undertake flights under more and more difficult and unknown atmospheric conditions. Thermic flying without clouds, flying above and below clouds, in clouds, and in front of a thunderstorm cloud bank and general research of the air and its phenomena were the main tasks of these pilots. Patient waiting for the required weather conditions were necessary for these experiments, but they ultimately resulted in outstanding performances both for high and long-distance flights. Research in construction and design went hand in hand with practical experience in the high air. Special performance sail-planes were built, such as the "Rhonadler," "Rhonsperber," "Grunau Baby," etc. Various international meetings were held at which R. Kronfeld became world famous in gliders of his own construction, such as the "Wien" and later his very interesting glider "Austria."

These experienced pilots sometimes used aeroplanes to tow their special sail-planes from one place to another or to attain sufficient height to start on their special soaring flights.

There were two well known sail-plane training centres in Germany apart from the Wasserkuppe; they were the "Rhon" and "Rossiten." The Rhon was on somewhat sloping ground and the Rossiten near the coast, which offered opportunities for thermic soaring as well as the almost constant on-shore wind from the sea. As might be expected, however, it was very rare that training centres could be established on terrain suitable for gliding which was also close enough to the large centres of population from which large numbers of pupils might be drawn.

In general, this method of training seems to be very good. Although the pupil is left alone in the aircraft right from the beginning and himself suffers immediately from his mistakes and errors, this method certainly both induces confidence in those who are capable of becoming efficient glider pilots as it quickly weeds out those who are neither temperamentally nor physically suited for sail-plane flying. There are a number of slight accidents by this method but damaged wooden gliders can easily be repaired both quickly and cheaply. For flying off a slope makes the pilot recognise how ground formations influence the air currents above, and the necessity of responding to changes in wind pressure and differing currents give valuable training in quickness of mind and of decision. At the same time, the beginner soon learns the art of landing on the slope or on difficult ground, and can even land on the slope safely with a tail wind behind him.

The disadvantages of this system are that suitable slopes are likely to be far away from the centre of population and such establishments would probably have to be built in far-away hills, which sometimes necessitated even the building of a road to get to the area. In Germany it was found that the distance between the establishments and the cities meant that it took time to get there and this limited the period of training to week-ends, so that the whole course of training took longer than would have been the case had it been possible for the pupils to reach the gliding grounds in a short space of time. It also added to the cost as it was necessary to keep a greater staff of instructors permanently on the premises who could undertake no other task. It became necessary in the end for subsidies to be granted to these schools one way or another. At the present moment, the Air Ministry in Great Britain is subsidising a great number of these glider schools throughout the country. At these schools gliding instruction is given by civilians who are gliding experts, under the control of R.A.F. officers.

(2) *The American Way.*

The American method of training in sail flying or soaring flight differed from that in Germany almost entirely for economic reasons. In America there were no restrictions on flying with motor aircraft, the standard of living was higher and petrol was cheap. After the last war there existed a large number of airfields and light aircraft. Flying flourished all over the United States. Americans therefore did not have the same urge to get into the air at all costs, and were not prepared to take the trouble of driving long distances to find convenient slopes in order to imitate the German method. So they invented a different way of getting a glider into the air, by starting on level ground and towing the glider behind a motor car or even an aeroplane. Not many people were required to help in this sort of soaring and it could be carried out anywhere near towns or inhabited localities.

(i) *Initial Training.*

This was carried out on a small strip of level ground, a lawn or an aerodrome. The pupil was first taught to react to the movements of the rudder and elevator in a standing glider against a slight wind. Then the glider was mounted on a low under-carriage hooked to an automobile by means of a short rope a few yards in length and towed over the field at a low speed, lower than the minimum flying speed of the glider. This was to make it possible to obtain experience in reactions of the rudder at a higher speed and to teach the pupil to govern the glider and keep it in equilibrium during the run. The instructor sat in the towing car and corrected the pupil either by signs, coloured flags or even by telephone.

When the pupil had succeeded in controlling his glider so that it remained stable and horizontal during these runs, the towing rope would be replaced by a longer one, and the speed of towing increased to somewhat above the minimum flying speed of the glider, which could now be towed at a low height of a few feet above the ground behind the towing motor car (Fig. 106).

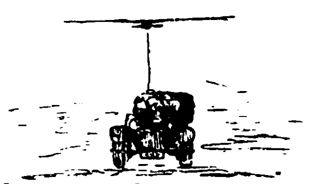


FIG. 106
Glider towed behind the motor car—few feet high

The instructor had to be very careful in regulating the towing speed because atmospheric conditions, such as wind, have a very different effect on a motor car and on a glider. In a 20 m.p.h. wind a car running at 40 m.p.h. would be creating a wind of 60 m.p.h. to pass over the aero-foil of the glider. This speed is increased by the radial upward movement of the glider whilst taking off because it is clear that whilst the motor car would travel say 100 yards in a fixed time, the glider, in addition to travelling that 100 yards, would also travel a distance equal to the length of the arc of the circle of which the towing rope is the radius. This becomes more obvious when the towing cable is lengthened, as it is in this sort of training, from 100 to 300 yards which would allow the glider to climb to a greater height (Fig. 107).

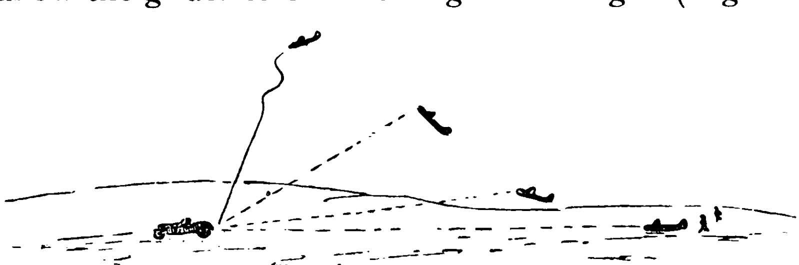


FIG. 107
Glider towed behind the motor car—100-200m. high

Flying with the wind, the speed of the glider through the air would be less than that of the car over the ground, but it was only in very light winds that this manoeuvre could be practised.

The towing car had to be sufficiently powerful to be able to reach the required flying speed in a certain time and distance without changing gear by means of a gear lever as it was imperative to keep a constant tension on the tow rope. The necessity of disengaging the engine and clutch in order to change gear made it imperative therefore that there should be no gear change before the glider was released. As American cars were in general more highly powered than those elsewhere, almost every open normal car was suitable for the purpose.

The best method of releasing either the car or the glider from the towing rope was quickly discovered, and was usually that of a ring at each end of the rope fitting over a half hook on the car or on the glider.

It was found, however, that very few airfields were as level as they appeared and cars were worn out rather quickly by driving at high speed over uneven ground. Consequently, other means of towing were looked for. A winch was constructed to take the place of the car (Fig. 108). One back wheel of the car was anchored to the ground, the other was jacked up and taken off and replaced by a drum on which were wound 500 to 1,000 yards of cable. On starting the engine and putting the wheel into gear, the cable would be rolled up and as its other end was fixed to the glider, the effect was to draw the glider along the ground and into the air. As soon as the minimum speed was reached, the glider became airborne and sailed a few yards above the ground. In this case there was no connection at all between the speed indicated on the speedometer of the car and the speed of the glider through the air.

FIG. 108
Towing cable wound on a bobbin

When the pupil could, by either method of towing, reach a height of 300 to 600 ft. he was then allowed to release the glider, make a turn and land. At first these turns were only slight and these flights were carried out in the middle of the aerodrome so that the glider had plenty of room in which to land. The same principle was followed where turns of 180 degrees to 360 degrees were taken. For a right turn the car would start from the left side of the aerodrome and vice versa (Fig. 109). In all cases, the instructor had to be careful to increase the speed of the tow in a regular and even manner, for otherwise the effect would be to increase the height of the glider suddenly, which might take the pupil by surprise, and disturb his equilibrium.

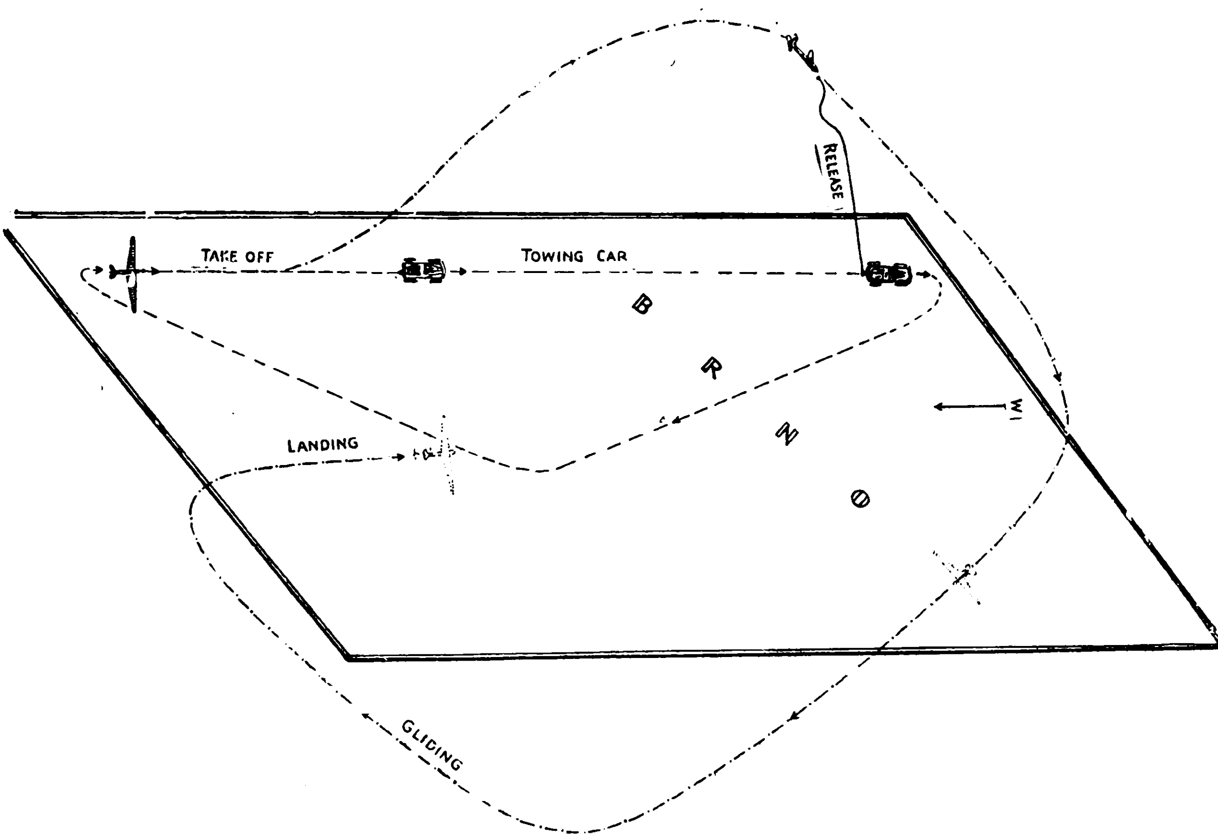


FIG. 109

By fitting a pair of iron scissors to one side of the automobile, through which the towing cable had to pass, care was taken that in the event of anything going wrong whilst the cable was still unreleased from the car, it could be cut through instantly and the glider freed.

Another method of starting was similar to that employed in Germany, of a shock-rope, but this was pulled by a car instead of by hand. The tail end of the glider was fastened to the ground or to some standing object (Fig. 110) the standing object might even be another motor car. A second car pulled out a shock-rope to the required length, distances being marked on the ground by flags. Then the instructor released the rear of the glider which was thrown forward. For the protection of the pilot against the breakage of the rubber cable the last 50 yards of the tow rope was steel cable which would not be thrown back against the front of the glider should the rubber cable break.

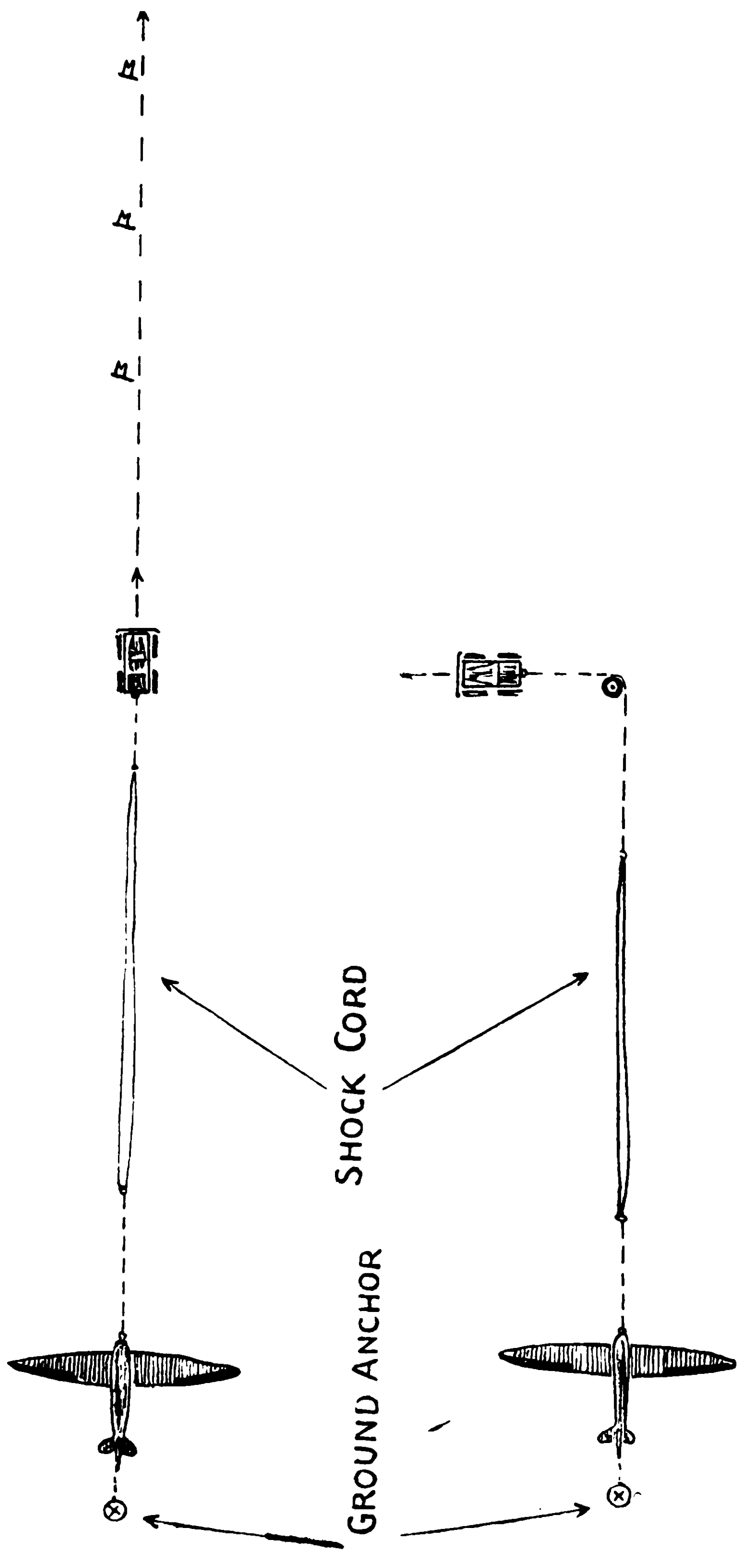


FIG. 110

A similar method of starting is shown in Fig. 111. The advantage of this method is that the glider and the car are not going in the same direction, and therefore the danger of collision is avoided. These shock methods, however, require highly skilled drivers and instructors.

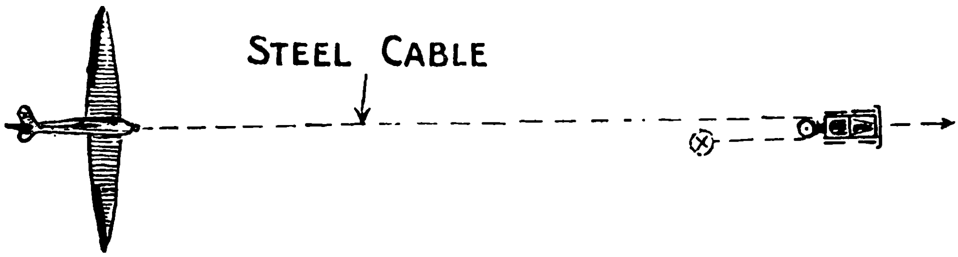


FIG. 111

(ii) *Advanced Training.*

The last phase of this training was towing by aeroplane, which is not very difficult for a good pilot. But to begin with for greater safety two-seater gliders, carrying pupil and instructor, were used. It was necessary to have telephone communication between the glider and the towing aircraft in this method which made co-ordination between the two pilots easier. It was necessary, of course, to design special sail-planes for towing behind aircraft. The length of cable found most suitable was anywhere between 300 and 1,000 ft. From a height of 1,200 to 1,500 ft. was quite enough for the pilot to release the glider and be able to carry out the required turn and prepare a correct landing.

A pilot who was endeavouring to fly under clouds or to do thermical flying, could be released where he thought most suitable conditions were to be found. He could fly to a cloud bank, or could go on being towed until he found a suitable thermic current upon which to soar.

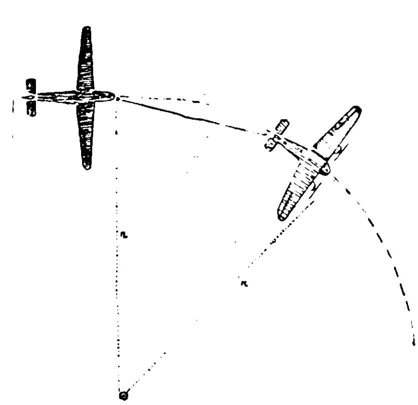


FIG. 112

It has to be noted that should the towing aircraft wish to make a turn, the rate of turn had to be very slight (Fig. 112), the minimum radius being at least that of the length of the towing cable.

Aero-towing was not difficult to carry out. The towing 'plane had to be sufficiently strong to get the glider off the ground. Its pilot had to have some experience of this kind of flying; it was not merely a question of becoming airborne himself as will be explained later. A special anchorage for the towing cable was usually fitted to the undercarriage, or as near the centre of gravity of the glider as possible. In recent years, anchorage from the tailplane has been successfully applied. The glider, or sail-plane, was pulled into the direction of the towing aircraft, and at a sign from the glider pilot the motor aeroplane slightly increased its speed. The glider took the air first, as the slip stream helped it, but the pilot controlled its height at 2 or 3 ft. until the aeroplane itself was airborne. Just before this happened, the glider pilot would ease his control column slightly forward which reduced the drag of the cable to almost nil. This helped the towing aircraft to take off normally. Any slacking of the cable was corrected by the glider pilot moving his aircraft to right or left, *i.e.* by applying right or left rudder pedal. During flight, he would keep up his position at the agreed height above the puller plane and flying exactly in the same direction. On no account should he drop below the puller plane, for this would have brought him into its slip stream which would have increased momentarily the strain on the cable, and, at the same time would have given the glider a greater speed than the puller plane, because of the thrust given by the slip stream. On reaching the required height, and after conferring with the puller pilot, the glider pilot would release himself, and carry on with his flight. This would leave the puller plane in the air with a length of heavy cable hanging from it. Therefore it was necessary for the manoeuvre of releasing the glider to take place at a height greater than the length of the cable so that on arriving over the aerodrome again, or in any other pre-determined area, the puller pilot could himself release the cable without causing damage to houses, buildings and other obstructions on the ground. To make it more obvious to other aircraft and to people on the ground, the towing cable was fitted with flags at various distances along its length.

The advantages of this method of training is that it is short and easy, it requires very few personnel and little in the way of establishment. Only the glider and release gear have to be specially constructed. It could take place over any level surface and almost any car could be used to provide the motive power.

The disadvantages of this method were that pilots trained in this manner did not have to contend against atmospheric changes, wind pressure, etc., and knew nothing about winds and their performances on slopes. Hence these pilots did not have the same training in instant decision and had little experience of landing on unprepared ground. Consequently, the art of soaring did not reach such a high degree of efficiency in America as elsewhere in the world, where slope flying was the chief method of instruction.

(iii) *Military Training is discussed in the companion book to this volume "The Flying Soldier."*

N.B.—Since this book was written the British R.A.F. have developed the training of Air Training Corps Cadets using discarded Balloon Barrage winches. The method followed closely resembles the German and American methods.

GLOSSARY

Aerodynamic force ... Power acting on static or mobile subject in the atmosphere.

Aeroplane—aircraft ... Flying machine, heavier than air, driven by a motor and an airscrew/propeller.

Aileron ... Mobile part in trailing edge of wing, causing alternative deviation from direction of wind, i.e., a rolling motion round the longitudinal axis of the glider.

Airfoil (Aerofoil) ... Aerodynamic form of a subject-wing, elevator rudder, which creates an aerodynamic force while moving.

Airfoil profile ... Outline of an airfoil.

Air ... Atmosphere, its composition and reaction on the glider.

Air speed ... Speed of wind relative to the aircraft.

Altitude ... Absolute height of glider relative to the ground.

Angle ... Relation of two lines or planes to each other.

Dihedral angle ... Angle of lateral axis of the wing with a horizontal plane. Difference of height of wing-tips above horizontal plane " V " angle of wings.

Flight angle ... Angle of flight path and horizontal plane.

Gliding angle ... Angle of flight-path during a glide, and horizontal.

Landing angle ... Angle of wing chord and ground, when glider is resting on the ground.

Lift angle zero ... Zero angle of attack=Lift Zero.

Angle of attack ... Angle between chord line and relative wind.

Critical angle of attack ... Maximum angle of attack, when airflow separates from top part of airfoil.

Angle of incidence ... Angle of wing setting (longitudinal axis-wing chord).

Angle of pitch ... Angle of longitudinal axis of glider with relative wind. Positive angle of pitch of glider points upwards, negative a.o.p. if glider points downwards relative to the wind-direction.

Angle of yaw ... Angle of direction of relative wind and longitudinal axis of glider, in horizontal direction. Positive angle of yaw, if glider is turned right. Negative a.o.y. if glider is turned left of its direction.

Atmosphere ... Mixture of gases enveloping the earth to a certain height.

Area ... Width by length, measured in length measures^2.

Aspect ratio ... Relations of wing-span and main chord of an airfoil, or the square of wing span to the total area of an airfoil.

Attitude of flight ... Inclination of a glider's axis to the relative wind.

Axis of glider ... Three perpendicular axis of glider, longitudinal, lateral and vertical.

Balance ... Equilibrium of forces during flight of glider.

Bank ... Angle of bank, angle of lateral axis of glider with horizontal plane.

Beaufort letters ... Numbers indicating speed of wind or water.

Cloud ... Originate in condensation level with condensation of air humidity, in certain atmospheric conditions.

Centre ... Middle point on which aerodynamic forces react.

Centre of pressure ... Point on wing where aerodynamic force reacts.

Centre of gravity ... Point where weight reacts.

Chord ... Straight line connecting leading edge with trailing edge of wing.

Dive ... Steep descent with big angle of glide (60°–90°) speed increase to the maximum.

Dive headlong	Vertical diving (90°).
Drag	Aerodynamic forces acting in prolonged direction of relative wind.
Induced drag	Drag created by lift of wings.
Parasite drag	Resistance of the entire glider without wings. Consists of skin ; friction and turbulence.
Profile drag	Resistance of profile.
Interference drag ...	Created by touch of parts of glider.
Edge trailing	Rear part, concluding part of an airfoil of the wing.
Edge leading	Front part of an airfoil of the wing.
Elevator	Movable airfoil by which the glider is deviated upwards or downwards from the direction of flight.
Factor load	Relation between real weight and multiplied weight which is created through movement.
Factor safety	Relation of load factors greater than breaking point.
Flap	Additional airfoil on upper or lower part of wing, increasing lift and drag.
Flight path	Direction of movement of centre of gravity in glider relative to wind or the ground.
Fuselage	Part of glider carrying wings, tail unit and under-carriage/ski.
Glide	Descent under normal angle of attack without thrust.
Gliding angle	viz., angle of glide.
Incidence angle	viz., angle of incidence.
Landing	Operation whereby the glider loses height and speed until it finally touches the ground with the under-carriage/ski—and comes to a rest.
Lift	Aerodynamic force acting on point of airfield vertically upwards to the direction of relative-wind.
Lift/drag ratio	Relation of lift and drag.
Longeron	Longitudinal part of fuselage of glider.
Manoeuvrability	Ability of glider to change longitudinal and lateral direction very quickly (without action of parasite aerodynamic force) in response to normal physical action of pilot.
Nose down	To depress the nose of a glider in flight.
Nose heavy	Attitude of glider flying normally but with nose down.
Performance	Several positive characteristics of the glider during flight.
Rudder	Movable airfoil causing change of direction/yawing of glider.
Side-slipping	Caused in a steep turn in which gravity is greater than forward speed.
Skidding	Caused in a flat turn where forward speed is greater than gravity.
Slot	Additional airfoil (static or mobile) mounted on leading edge of wing. Increasing adherence of streamlines of air under large angle of attack.
Slipstream	Aircurrent from towing plane created by rotating airscrew.
Span	Distance between right and left end of wing.
Stalling speed	That speed of glider, by which maximum lift is created.
Spin [flat spin]	Falling of glider after loss of speed under the limit necessary to support the glider at height.
Spoiler	Small airfoil on top of wing which, if brought into action, disrupts flow of streamlines round wing and so creates diminished lift and increased drag.

Stability of glider ...	Ability of regaining equilibrum, after such had been disturbed by counteracting forces during flight. Dynamic, directional, lateral, longitudinal, static, stability.
Stabiliser	Fixed horizontal tail surface.
Stall	Moment when angle of attack is greater than the maximum angle of attack which creates maximum lift.
Streamline	Path of airstream which does not create eddying through friction.
Streamline form	Curved object that offers minimum resistance.
Trimming tab	Additional airfoil on control surface, which can be adjusted before or during flight to hold elevator or rudder at a certain angle, so that the pilot must not hold the stick.
Tail of glider	Tail-end, carrying vertical and horizontal stabiliser, elevator, rudder, and in some cases, rear gun turret.
Tapered wing	Decreased chord length along the wingspan to the tip of the wing.
Thrust	Force pressing glider in parallel direction to direction of advance during towing.
Weight gross	Glider fully loaded.
Wind relative	Constant direction and speed of wind used as foundation for the calculation of aerodynamical force.
Visibility...	Distance at which subject can be recognised by eye.
Yawing	viz., angle of yaw.