AVIATION

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AVIATION

ITS PRINCIPLES
ITS PRESENT AND FUTURE

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PREFACE

In the following pages the author has endeavoured to give an accurate description of the construction and working of balloons and aeroplanes in simple language. He hopes that the matter which he has produced will be of interest and of service to the many men and women who are so intensely interested in Aviation matters. Whenever an aeroplane appears in the neighbourhood of any town, practically the whole town comes out to meet it, and is eager in its questions of the aviator and his mechanics. The author hopes that the matter contained in this book will enable those who see an aeroplane, or a balloon, for the first time to understand its working, to recognise its different parts and their uses, and to follow the different manœuvres in the air, on alighting, and on the ground.

He also hopes that it will answer as a primer for the student of Aviation. The author has purposely avoided mathematics and explanations other than such as can be embodied in simple language. He hopes, however, that the student will find this book a good introduction to heavier books on the subject.

He begs to offer his hearty thanks to Messrs. C. G. Spencer & Sons, Messrs. Bleriot & Co., Graham White and Co., A. V. Roe & Co., The Blackburn Aeroplane Co., the Green Engineering Syndicate, the Wolseley Tool and Motor Car Co., and the other firms who have responded to his inquiries, for the information upon practical details they have been kind enough to give him. He has endeavoured to embody in the book as much useful and practical information as possible. Readers of the book are requested to remember that Aviation is literally in its infancy, and that it is moving along very fast.

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CONTENTS

AVIATION

CHAPTER I

HISTORICAL

The conquest of the air, which may be said to be in a fair way of being accomplished, has been attempted in two ways: by two distinct classes of machines, known as the "Heavier than Air" machines—those we now call aeroplanes—and the "Lighter than Air" apparatus which we call balloons. Almost from time immemorial man has watched birds fly, has wondered how they accomplished the feat, particularly how they succeeded in soaring, in remaining at one time apparently stationary in the air without flapping their wings, at another time moving against the wind, also apparently without effort. As early as the year 1660, Allard, and in 1678 Besnier, both Frenchmen, made an attempt to fly with "Heavier than Air" machines, and are said to have been partially successful, to have made short flights. Very little appears to have been done after the attempts made by MM. Allard and Besnier for a very long time. In the year 1783, attempts were made by the brothers Montgolfier and by the brothers Robert with "Lighter than Air" apparatus, or balloons. The Montgolfier balloons were filled with hot air, the gas-bags, as we should now call them, being suspended over a fire of straw; hence the name Fire Balloons, by which they were known for a long time. Heating the air renders it lighter for a given volume than the corresponding volume of air around, and gives a certain lifting value. The brothers Robert employed hydrogen. Several ascents with Fire and Hydrogen Balloons were made in the year 1783, and the brothers Robert are stated to have been working under the direction of an eminent French physicist, M. Charles. It is perhaps interesting to note that the arrangements made by M. Charles for supporting the car from the gas-bag, and for allowing the gas to escape, continued in use down till very recent times.

Nothing further appears to have been done of any consequence till the year 1836, when a balloon ascended from the Vauxhall Gardens, near London, the popular London resort in those days, crossed the Channel, and landed in the duchy of Nassau. It was known as the Nassau balloon, and it carried 85,000 cubic feet of gas. In 1863 a Paris photographer constructed a balloon containing 200,000 cubic feet of gas, which carried thirteen persons.

Numerous ascents were made from time to time by adventurous spirits, the art of ballooning, as it was then called, being gradually worked out.

The first dirigible balloon was constructed by Giffard, the inventor of the steam injector, in 1850. It was cigar-shaped, 114 feet long, and 39 feet in diameter at the largest point. It was driven by a steam-engine. Various other inventors, principally French, attacked the problem from time to time; some apparatus being driven by the hands or the feet, some by electric power, and at last in the present century petrol engines being employed. It may be said that the development of the petrol engine has rendered the dirigible balloon and the aeroplane possible.

In the "Heavier than Air" machine problem many minds have been at work, principally from the year 1867 onwards. Professor Langley of America made some very important experiments to determine the pressures upon planes passing through the air; Sir Hiram Maxim also made important experiments; but the work which led right up to success appears to have been that due to the brothers Lilienthal, one of whom lost his life in 1899, and the brothers Wright of America. Both the brothers Lilienthal and the brothers Wright turned their attention to the school-boy's kite. They modified it considerably, giving it the form now known as the box-kite, and proceeded to carry out a number of experiments in gliding. From gliding by the aid of the force of gravity, as will be seen in later chapters, it is but a short step to driving the glider by motive power. The first practical flight, the writer believes, was made by the Wright brothers in America in 1905 on a biplane of their own construction, which had been developed from the gliders with which they had been working. In 1906 Henry Farman worked out a biplane and flew half a mile.

In September 1908, Orville Wright was flying in America and covering distances up to 60 miles and over, while his brother Wilbur Wright was flying in the neighbourhood of Paris, giving exhibitions that will be in the memory of most of us, and for which he was awarded the Deutsch Prize of £20,000. In December 1908, Wilbur Wright made a record flight of 2 hours 20 minutes.

In 1909 the monoplane came to the front. The work done by the brothers Wright had been with the biplane. The London *Daily Mail* offered a prize of £1000 to the first aviator crossing the Channel, and this was won by Bleriot, the head of the firm who now exploit machines of that name, in July of that year. Hubert Latham, who had been waiting to accomplish the flight in an Antoinette monoplane, made an unsuccessful effort shortly afterwards, falling into the water and having to be picked up.

Since then things have moved very rapidly in the Aviation world. In the early autumn of 1909 the first Aviation meeting was held on a large plain in the neighbourhood of Rheims in France, and this was followed shortly after by Aviation meetings at Blackpool and Doncaster in the United Kingdom. At Blackpool, Henry Farman scored what was then the record, viz. a continuous flight of 30 miles. This flight, however, we should hardly consider now as worth looking at. Farman flew only a few feet above the hoardings forming the enclosure, and it was very monotonous watching him going round and round. At Blackpool and Doncaster, however, practically the whole of the aeroplanes that were then on the market were exhibited. Various Aviation meetings have been held all over the world since. Aerodromes have been established at Hendon, just outside of London; at Brooklands, near Weybridge, not far from London; at Eastchurch, in the Isle of Sheppey; at Shoreham, near Brighton, and in a number of other places. In France there are a very large number of aerodromes. Flying schools are attached to all the aerodromes, conducted by the makers of the principal machines upon the market, and any one who wishes may qualify as an aviator for a sum varying from £50 upwards. Shortly after the Cross Channel flight, the London *Daily Mail* offered a prize of £10,000 for the first flight from London to Manchester, with only one stop, and the race came off on April 27, 1910, between Paulhan, a French mechanic, who was not only a skilled aviator, but who had taken part in the construction of the machine he flew, and Graham White, an Englishman, who was then heard of for the first time as an aviator. Paulhan won by a very small amount, and it will be instructive to note that, on returning to France, he was reported to have declared that he would not make another such a flight for twice £10,000, though he has since been heard of at intervals as a successful pilot.

Immediately afterwards the London *Daily Mail* offered a second £10,000 to be competed for in what was afterwards known as the Circuit of Britain. A course was laid out, the contest being carried out under the control of the Royal Aero Club of London, and the course being from Brooklands to Hendon, thence to Harrogate, Newcastle-on-Tyne, Edinburgh, Stirling, Glasgow, Carlisle, Manchester, Bristol, Exeter, Brighton and back to Brooklands.

The contest took place in July 1911. Though seventeen competitors entered for the race, it practically resolved itself into a contest between Lieut. Conneau (or Beaumont, as he called himself for Aviation purposes) of the French navy, and Vedrines, a French mechanic. Conneau won through Vedrines losing his way when approaching the Bristol aerodrome. The contest excited the most intense interest throughout the Kingdom. Similar contests took place in 1911 on the Continent; one called the Circuit of Europe traversing a portion of France and Belgium and England; a flight from Paris to Rome, and one from Paris to Madrid. At the present time a race from Paris to Pekin is projected by a French journal, *Le Matin;* a Circuit of America, 1810 miles in extent, is projected in the United States for this year, and there will probably be many others.

The advance which has been made, it will be seen, is confined to the last ten years, but, as in all of these cases, the rate of progress is steadily increasing. With the increased knowledge obtained by a greater familiarity with the machines, increased skill is available in aviators and in the manufacture of the apparatus. An American has proposed to cross the Atlantic in an aeroplane. The speed of aeroplanes had increased a few months back from 30 miles an hour to 80, and the latter speed has now been exceeded by later records. The time during which aviators are able to remain in the air has increased from a few minutes to several hours, and is still increasing.

During the same period there has been a steady progress with the balloon. The drifting balloon has given way to the dirigible, and an enormous amount of money has been spent upon its development, principally in France and Germany. Not much has been done in the matter in this country, the principal success having been obtained by Mr. Willows, a private individual, with a small balloon, and by Messrs. Spencer Bros.

CHAPTER II

THE BALLOON AND THE DIRIGIBLE

Why they Float in the Air

The balloon floats in the air for the same reason that a ship or a boat floats in the water. The volume of air displaced by the balloon is much heavier than the same volume of hydrogen gas that balloons are usually charged with. It will be remembered that our earth is surrounded everywhere by an atmosphere extending outwards for a good many miles. This atmosphere consists mainly of a mixture of two gases, nitrogen and oxygen, in the proportion of 79 parts of nitrogen to 21 of oxygen. The atmosphere also contains small quantities of some of the elements that have been discovered in recent years, and always carries a certain quantity of the vapour of water. It has the property of absorbing a quantity of the vapour of water, the quantity increasing with its temperature. The mixture of gases and watery vapour is generally known as air, and it is called by physicists a fluid, and possesses a very large number of the properties of water. It possesses weight, for instance, as our barometers tell us; and when a body like the gas-bag of a balloon is in the air, the weight of the surrounding air presses on the under-side, just as the weight of the surrounding water presses on the bottom of a boat, tending to lift it up.

The weight of the balloon, its car, its occupants, and whatever it may carry exert a certain force, due to gravity, tending to draw the balloon downwards. When the two forces present, that of gravity and that of the pressure of the surrounding air, are equal, the balloon remains at the same level. If the weight of the balloon is decreased, the pressure of the surrounding air tends to lift it; and if the quantity of gas present in

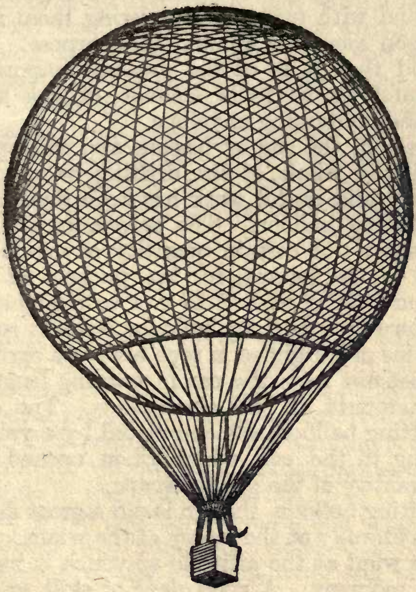

FIG. 1.—Typical drifting balloon, showing gas-bag and basket with the method of suspension.

the balloon is decreased, so that the difference between its weight and that of a similar volume of air is decreased, the balloon descends.

THE DRIFTING BALLOON

Fig. 1 shows a typical drifting balloon. As will be seen, it consists of a globe or sphere, in which the gas is enclosed. The gas receptacle is covered with a net, and from the net the basket or car is supported. It is important that the weight of the basket and whatever it contains shall be carried as far as possible by the whole of the gas receptacle. The globe or sphere in which the gas is contained is made of various substances. Silk has been largely employed, but other substances, if impregnated with materials rendering them non-porous to hydrogen gas, will answer the purpose. It will be understood that it is of the greatest importance that there should be as little leakage of gas as possible through the containing envelope.

The gas-bag, the car or basket, and its support comprise then the whole of the drifting balloon. A good deal of bold and useful work has been done in the past by the drifting balloon. The aeronauts are supported by the basket. A certain quantity of sawdust or sand is carried in the basket, for the purpose of lightening the balloon if it is wished to rise to a higher altitude. In later forms of drifting balloons, and in some of the earlier forms of dirigibles, a rope also was carried, which could be let out from the car in varying lengths, giving varying amounts of pull earthwards. The equipment of the drifting balloon was completed by a valve worked by a string in the car, which when opened allowed a certain quantity of the gas to escape.

The drifting balloon, though it did a great deal of good work, was literally at the mercy of the winds. It drifted before the wind at the altitude at which it happened to be at the moment. A good deal of skill was acquired by balloonists, previous to the development of the dirigible, by carefully observing the direction of motion of the clouds, sometimes above them and sometimes below them. It was usual to wait for a wind blowing in the direction the balloonist wished to go ; but if the wind changed after he had started, he usually tried to secure a favouring wind by feeling for it, so to speak. He would let out ballast, sawdust or sand, and rise into a higher altitude. If he secured a favouring wind there, he continued his course until the wind again failed him, when perhaps he came down. The rope was of service, as it was able to be used over and over again, and the amount of pull downwards could be regulated by skilled balloonists with a fair amount of accuracy. When he required to land, the balloonist gradually allowed a sufficient quantity of his gas to escape, and threw over more and more of his drag-rope; and when a favourable spot presented itself, he threw out a rope with a grappling anchor, which caught branches of trees, and, if fortune favoured, held the balloon fast. Many lives were lost by ardent balloonists taking too great risks. The English Channel was repeatedly crossed by balloonists. Only a few years ago a balloon race was carried out on the continent of Europe which ended up over a part of the North Sea, some of the balloons being rescued by passing steamers.

The Dirigible Balloon

The dirigible balloon is merely a drifting balloon with its gas-bag elongated to the form shown in fig. 2, more or less cigar-shaped; the car being also elongated; and the whole being provided with power to drive it through the air, and with arrangements for steering it as a ship is steered, and for varying its altitude, just as the depth of a submarine in the water is varied.

The forms of the gas receptacle for the dirigible vary from a cylinder with spherical ends to more nearly that of a fish in section—a blunt nose, and rather fine tail. The size of the dirigible also varies from one that will carry one passenger, and which has a gas receptacle of 4500 cubic feet of gas, up to one capable of carrying thirty or forty men, and whose gas receptacle has a capacity of 350,000 cubic feet. It is calculated that approximately 35,000 cubic feet of hydrogen will lift one ton dead weight, and the sizes of gas receptacles may be taken roughly from this. Coal gas has rather more than half the lifting power of hydrogen. The car of the dirigible is made very much stronger than that of the balloon. In some of the larger and later forms, the whole thing is of a special metal that has been worked out for the purpose, an alloy of aluminium, which has great strength combined with light weight, low specific

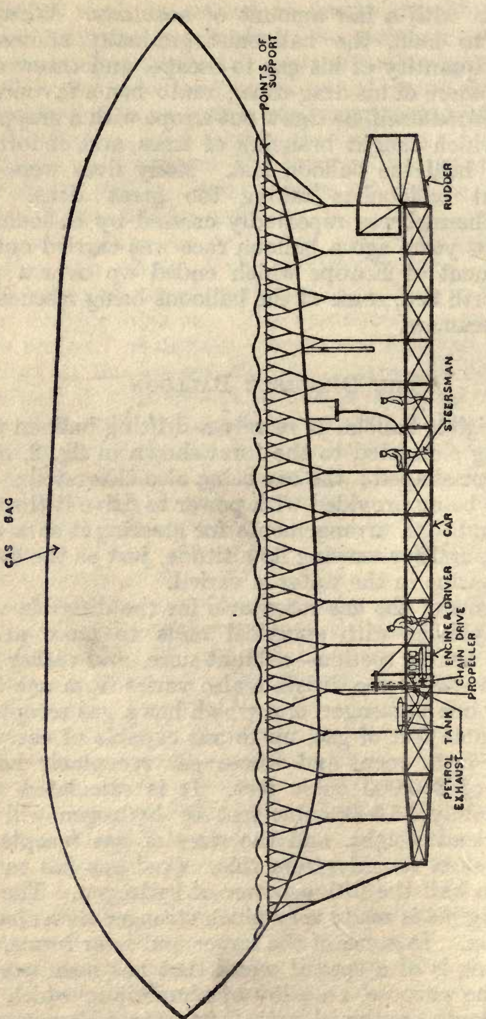

FIG. 2.—Longitudinal view of typical dirigible balloon, as made by Messrs. Spencer Bros., showing the gas-bag, the car, the petrol engine, and the rudder.

gravity. In the small forms of dirigible the car is suspended from the gas receptacle very much in the same manner as in the drifting balloon. It is supported directly from the gas envelope itself. In Mr. Willows' dirigible he has a single spar or boom, running the whole

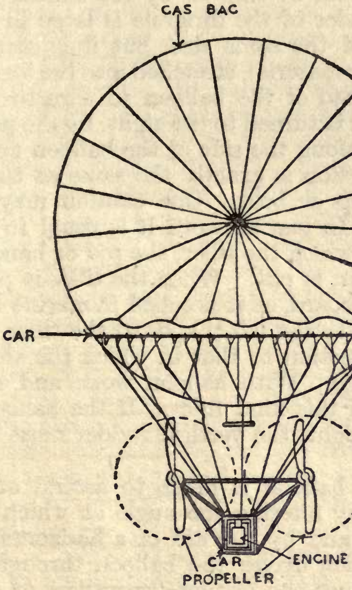

FIG. 2A.—End view of typical dirigible balloon, as made by Messrs. Spencer Bros., showing the gas-bag, the car, the petrol engine, and the two propellers.

length of the balloon, suspended from the gas receptacle; the engine, pilot's seat, propeller, &c., being supported by the spar. In the larger forms longitudinal metallic girders are supported from the gas receptacle, and these in turn support the car.

The power employed to drive the dirigible through the air is in all cases a petrol engine. The petrol engines employed for the purpose are described in a later chapter.

It will be sufficient here to mention that they range in power from about 35 h.p. up to 400 h.p. In the larger dirigibles there are two or more engines working two or more propellers.

The dirigible is steered, caused to turn to the right or left, just as a boat or ship is, by the rudder shown in fig. 2. The rudder of the dirigible is large in comparison to a ship of the same size, but it is composed of canvas or similar material, stretched into the form shown. It causes the head of the balloon to turn to the right when the rudder is turned to the right, by the pressure of the air passing along the side of the balloon against the rudder. The action is exactly the same as that of the rudder of a ship or boat. One caution may perhaps be given here. In marine work it is usual to speak of the direction in which the tiller, the rod or handle which works the rudder, is put. When the tiller is put to the right, or to starboard, as it is called in marine language, the rudder goes to the left; and so the tiller is put in the opposite direction to that in which the ship's head is intended to go. With balloon work and aeroplane work nothing of this kind rules. If the balloon's head is to go to the right, the vertical rudder must be pulled to the right.

The dirigible balloon is made to ascend or descend in two ways—by altering the angle at which the propeller revolves, and by the aid of a horizontal rudder. The engine, which drives the balloon through the air, does so by causing one or more propellers or screws to revolve rapidly in the air; generally two are employed. The propeller is very much like some of the fans that are employed in offices for causing a draught of air, though the blades are longer, larger, and stronger. It is also very much like the screw propeller of a ship, except that the latter usually has three blades. The propeller is dealt with more fully in a later chapter. When the dirigible is to go straight forward, the propellers are revolving in a vertical plane, perpendicularly to the direction in which the dirigible is moving. When it is required to move upwards or downwards, the propellers are inclined at an angle. If they are inclined in one direction, for instance, the nose of the dirigible is turned downwards, and vice versa.

The horizontal rudder is somewhat similar to that of a submarine. It is like the elevator that will be described in a later chapter in connection with the aeroplane. Stated shortly, it consists of one or more planes of treated canvas or other material, stretched upon a frame, and held in such a position at either end of the dirigible that the air will meet it when it is turned up or down. Turning the horizontal rudder down causes the nose of the dirigible to turn downwards; turning the horizontal rudder upwards causes the nose of the dirigible to turn upwards. It will be seen, therefore, that with the petrol engine, the propellers, the vertical rudder for steering to right and left, the horizontal rudder for turning up or down, the pilot in charge of a dirigible should have complete control of it.

There is one more point that should be mentioned. Gases expand and contract as they become hotter or colder, and this has a very important bearing upon balloon work. When the gas reservoir, for instance, is exposed to the full glare of the sun's rays, as it may be at a considerable altitude, the gas within the reservoir expands considerably, and unless a certain amount is allowed to escape, the gas envelope might burst. Relief valves are provided for the purpose. On the other hand, when, if after the gas reservoir has been exposed to the heat of the sun's rays, it comes under or in the shadow of a cloud, the temperature falls very quickly, and the gas contracts. To meet this difficulty a ballonette has been added to the dirigible, and to later forms of the drifting balloon, at about the middle of the gas-bag, which is arranged to compensate for the expansions and contractions of the gas. With large balloons several ballonettes are employed. The ballonette is filled with air. Under normal conditions the vessel occupies a certain space, and there is a certain air pressure within. When the hydrogen or coal-gas expands under the heat of the sun's rays, air can be allowed to escape from the ballonette, and the expansion of the other parts of the gas reservoir can be provided for by the space released by the collapsing of the ballonette. The air within the ballonette also will compress and allow the other to expand. When the balloon descends, or comes into a cold atmosphere, and the gas contracts, air is forced into the ballonette by the aid of a fan, at a sufficient pressure to take up the space released by the contraction of the main gas reservoir. The fan is driven from the engine, or one of them that drives the balloon through the air. There will be several fans where there are several compensating ballonettes, as in the larger dirigibles.

Construction of Dirigibles

The dirigible balloon can hardly be said to be a throughly practical apparatus yet. It is not so reliable, by a very long way, as its younger rival the aeroplane. The great difficulty with which it has to contend is the force of the wind acting upon its large bulk. In the large dirigibles that have been constructed by Count Zeppelin, Major Parseval, and others in Germany, by our own War Office, and our Navy in this country, balloon after balloon has been wrecked after a very short life immediately it encountered a wind above a certain figure, a wind that a skilled aviator would now easily face upon a well-found aeroplane. To meet this difficulty various lines of construction have been devised. They are known as the flexible, the semi-rigid, and the rigid. The names practically describe them. In the flexible construction a containing fabric is stretched over a metal framework, and the idea is that it shall give to the wind, &c. In the rigid form the reservoir is divided up into a number of ballonettes, each independent in itself, each constructed very strongly, and the whole being fixed in an outer strong containing framework. In the semi-rigid there is more or less of a balance between the flexible and the rigid. Ballonettes are used in some forms of semi-rigid, without the outer strong containing framework. A very great deal remains to be done before the dirigible is a practical apparatus.

The Cost of Working Dirigible Balloons

The cost of working dirigible balloons is made up of three items: the power required to drive it, the gas wasted, and the labour for driving and repairs. The cost of the power will depend upon the size of the engine and other factors; the quantity of gas wasted depends upon the fabric employed for the gas reservoir, and upon the conditions under which the balloon is worked. As mentioned above, gas has to be allowed to escape, when the gas reservoir is exposed to the sun's rays; and in addition there is a continuous leak of gas through the fabric.

The cost of labour and repairs is again a variable quantity, depending upon the journeys the balloon makes, and the conditions to which it is subject. The present writer was given the cost for a balloon that was exhibited at the Aviation Exhibition at Olympia last year, as about £20 a week.

CHAPTER III

THE GLIDER

THE glider was the parent of the aeroplane as we know it to-day. It was derived originally from the boy's kite. The school-boy's kite was supported in the air by the pressure of the wind passing under it. Most of us remember that a kite would only fly when there was some wind blowing, and the stronger the wind the better the kite flew, and the more difficult it was often to hold it. The old-fashioned kite, shaped something after the pattern of one of the shields of Norman times, gave place very early in the investigation that was undertaken by Lilienthal and others to the box-kite. The box-kite consisted usually of two flat planes, held together by distance pieces, and in such a manner that the air could pass between the planes. It was found that kites of this form had great lifting power; and some interesting experiments were carried out by French military officers, by Mr. Cody and others, with box-kites, in which it was shown that a sufficient number of them would lift a man off the ground quite easily if the wind was strong enough. Some awkward experiences were met with; a man at the end of the rope attached to a string of kites, for instance, being kept bobbing up and down in the air. When the wind freshened a little he was lifted up, and when the wind fell he was dropped.

It was a short step from the box-kite to the glider, and from the glider, as will be shown in a later chapter, to the biplane. In the glider, as it was eventually worked out, there were two planes fixed one above the other and separated from each other by distance pieces, the lower plane having at its centre some arrangement for holding the operator during his descent. The glider

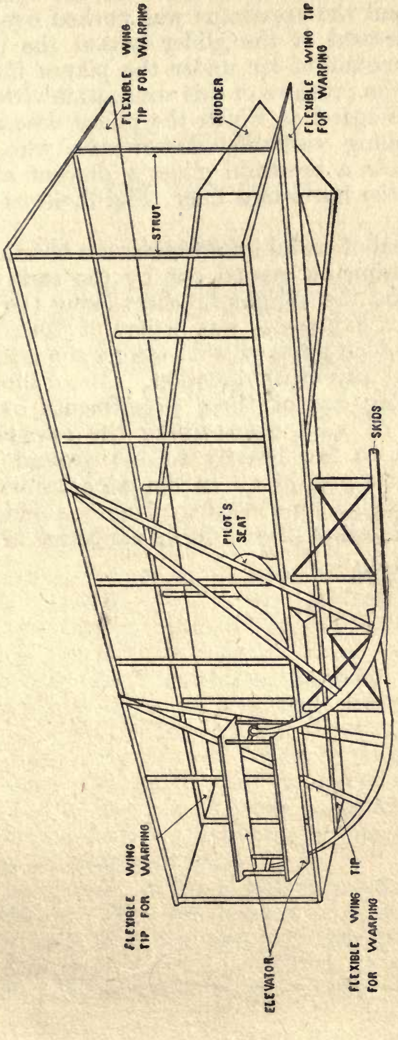

FIG. 3.—Typical glider, as used by the Wright Bros. and others. It will be noticed that it contains nearly all the parts of the biplane.

was taken to the top of a hill, or cliff, the operator took his place, and the apparatus was pushed over into the air. The descent of the glider caused the passage of a certain amount of air under the planes forming the glider, and the pressure of this wind, as it virtually was, lessened the speed at which the glider descended. In place of falling vertically downwards, when all was right, it made a beautiful glide, a descent at a slight angle with the horizontal line. Fig. 3 shows a typical glider.

A good deal of useful information was obtained by the gliding experiments carried out by the early aviators, Lilienthal and the Wright brothers being the pioneers. In particular, experience was gained of the effects produced by sudden gusts of wind taking the glider on the side, or from any other direction. Otto Lilienthal lost his life during one of these experiments owing to a heavy gust of wind over-turning the apparatus, and causing him to fall heavily to the ground with the apparatus on top of him. In the later forms of glider, as shown in fig. 3, an elevating plane was added. The use of the elevating plane will be explained in the next chapter.

CHAPTER IV

THE AEROPLANE

WHY THE AEROPLANE FLOATS IN THE AIR

THE aeroplane floats for the same reason as the boy's kite, the glider, and a bird when "soaring" or "sailing." It floats in the air by reason of the upward pressure of the current of air passing under it. If an aeroplane could be transported to a certain height above the ground, where a wind was blowing of sufficient strength, the passage of the wind under its planes would keep it floating in the air, just as it does the boy's kite or a soaring bird. Obviously it makes no difference whether the wind which passes under the planes supporting the apparatus is natural, blowing from natural causes, owing to changes of temperature, of barometric pressure, &c., or to the apparatus itself being driven through the air by mechanical means. And that is the method adopted in all aeroplanes, or "Heavier than Air" machines, as they are termed. In all aeroplanes there are a certain number of planes arranged to be driven through the air at a considerable speed. In the early days of Aviation, 25 and 30 miles an hour were sufficient; then we came to 40 miles, 50 miles, and at the present time some of the leading pioneers in the Aviation world have flown at a speed of 80 miles an hour, and over.

In all aeroplanes, to use a Hibernianism, the planes are not planes. They are formed of flexible material, just as the sails of a ship are, and they are cambered, like the surface of a road, or bellied, as sailors would express it. In scientific language the under side is concave and the upper side convex. Further, the supporting planes, when the machine is flying through the air, are inclined to the horizontal at a varying angle, usually about 8 degrees. This is known in aeronautical parlance as the angle of incidence, the angle at which the plane strikes the air through which it is passing. It will be seen that the slight inclination of the plane, added to its concavity, allows the air through which it is passing to enter the concave space formed by the camber of the plane, and in so doing it exerts a certain pressure upwards. This is the cause of the aeroplane floating. The amount of pressure exerted depends directly upon the total surface of the supporting planes, whatever form they may have, and in whatever manner they may be arranged; it also depends directly upon the square of the speed at which the machine is driving through the air. Thus, increasing the speed from 20 miles an hour to 40 miles an hour, with the same supporting surfaces, quadruples the lifting pressure. The weight which any aeroplane will carry depends directly upon the lifting pressure, this again depending upon the surface and the square of the velocity, and upon certain other points that need not be entered into here. It should be noted that the lifting power of the different forms of aeroplanes to be described, the biplane, the monoplane, and the triplane, varies with a given spread of surface. As mathematicians would express it, each form of aeroplane has its own constant; but with each form the above rule holds, viz. the lifting power increases directly with the surface of the supporting planes, and directly as the square of the speed at which the machine is being driven through the air.

It may be mentioned *en passant* that the fact of doubling the speed of the machine quadrupling its lifting power does not simplify the matter so much as a cursory glance at the subject would imply. Unfortunately, the power required to double the speed is eight times that for the original speed. The supporting power varies as the square of the velocity; the power required to produce the velocity varies as its cube.

Forms of Aeroplane

There are virtually only two forms of aeroplane now on the market, known respectively as the monoplane and the biplane. A third, known as the triplane, was also introduced, and a certain number were made and flew, but the writer understands its manufacture has been abandoned in favour of the other forms.

The Biplane

The writer proposes to describe the biplane first, because it is virtually the glider with a few additions. Fig. 4 shows a typical biplane. It will be seen that it consists of two planes arranged vertically one above the other, together with the elevating plane to be described below, a tail plane and the steering arrangements, and the engine propeller and accessories. In the biplane the lower of the two planes is virtually a platform, upon which the driving engine, the seat for the pilot, and all accessories are carried. The middle portion of the lower plane is very strongly constructed. In the Wright biplane it was made of stout timber. The planes consist of frames, made in the early machines of bamboo, sometimes of hickory or other suitable wood, rectangular in form, divided into convenient divisions, so that the treated canvas, or other material forming the supporting planes, can be stretched over them. Both planes are lifting planes, both feel the pressure of the wind passing under them. The upper plane is supported from the lower plane by what are called "struts"; virtually pillars or stanchions made in the form that will offer the least resistance to the wind, more or less like the body of a fast fish. From the middle of the lower plane, what is called the fusellage stretches out to the rear. It is an openwork structure consisting in the early machines of timbers; its office is to carry the tail plane and the rudder, and it is useful to hold guides for the wires controlling the rudder planes.

The elevator or elevating plane in the typical early form of biplane projects in front of the two main planes. It is supported from the central platform of the lower plane by outriggers, as shown, and its movements up or down are controlled by wires or tapes, worked by levers or other arrangements close to the pilot's hand. The elevator and the tail plane assist to support the machine as a whole.

In the central platform is fixed the engine which is to drive the machine through the air, the carburettor furnishing fuel to the engine, as will be explained, the

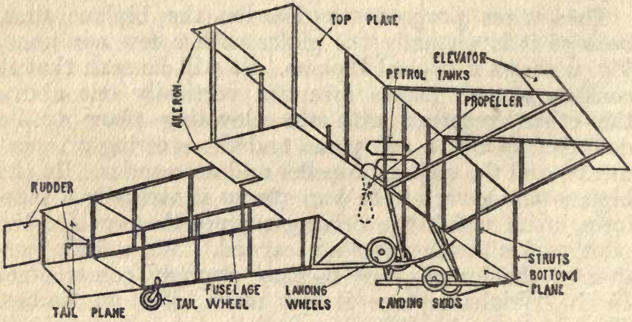

FIG. 4.—Typical biplane with elevator in front, and propeller behind the main planes; showing the main supporting planes, the elevator, and the tail plane and rudder.

radiator for cooling the water that circles round the engine, as will also be explained, and the gearing for driving the propellers.

The propeller in the earlier forms of biplane is usually fixed at the rear of the lower plane. It may be driven direct from the engine, its central boss being attached to the engine shaft, or it may be driven by chains. In the Wright and the Cody biplane, and in some others, there are two propellers, driven in opposite directions, by chains similar to those used in automobile driving, which deliver the power from the engine-shaft to the propeller shafts. In a later form of biplane, known as the Tractor biplane, the engine and propeller are placed in front, and the elevator, with the rudder, behind, part of the tail plane being used as the elevator. The hydro-aeroplane shown in fig. 8 is also a Tractor biplane.

In addition to the above, the biplane has usually some arrangement to assist in balancing, as will be explained in a later chapter. In the Wright biplane the outer ends of the upper planes carried hanging flaps, which could be moved at will, by wires ending in levers at the pilot's hand. In the Cody and some other biplanes these flaps are superseded by small planes, cambered similar to the main planes, fixed between the two main planes, and near the outer ends. These

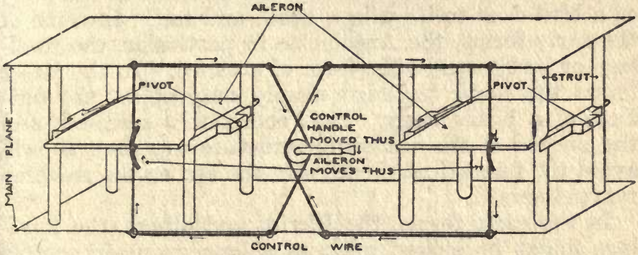

FIG. 5.—Diagrammatic representation of ailerons fixed to a biplane, as in Mr. Cody's machine.

smaller planes are capable of turning on a horizontal axis up or down, very much in the same manner as the elevator. When they are arranged in this way they are known as ailerons. Fig. 5 shows a biplane with ailerons arranged in this way.

THE MONOPLANE

The monoplane, typical forms of which, the Bleriot and Deperdussin, are shown in figs. 6 and 7, is a much prettier apparatus, and very much more like a bird in form. The Antoinette and some others, when in flight, are by no means unlike huge birds. The Bleriot, which has done the most important work and won the greatest number of races, is more like a biplane, with the supporting planes arranged on the same lever. As the name implies, in a monoplane, the supporting planes—there must necessarily be two—are approximately in the same horizontal plane. They nearly always slope a little out of the horizontal as they recede from the central fusellage.

But the general arrangement of the monoplane is very different from that of the biplane, as will be seen from the drawings of the two machines respectively. In the biplane, it will be remembered, the fusellage is merely an accessory to support the tail plane and vertical rudder; in the monoplane the fusellage bears nearly the same relation to the rest of the machine as the body of a bird does to its wings, head, and tail. In some of the early forms, the Antoinette in particular, the fusellage or body was in the form of a canoe. In the latest forms the main fusellage closely approaches the outlines of a bird's body. It is completely enclosed, and the curves of the enclosing structure are such as will avoid the formation of eddies in the air, as the machine moves forward.

In the early forms, the Bleriot and others, the fusellage might be looked upon as a long openwork cradle of rectangular section, but tapering from the front to the rear.

In the monoplane also the propeller is fixed in front of the machine, where the bird's head would be; and immediately behind it is the engine, whose shaft is directly attached to that of the propeller. Behind the engine is the chair for the pilot, with the levers and other arrangements for giving him the necessary control of the machine. At the other end, as mentioned above, is the combination tail forming both the rudder and the elevator. As in the biplane, the tail plane assists in supporting the machine, part of it only being movable and acting as the elevator.

The fusellage or framework forms, as in the biplane, a convenient place in which to carry the guys controlling the rudder and elevator.

In the monoplane also, balancing, which will be ex-

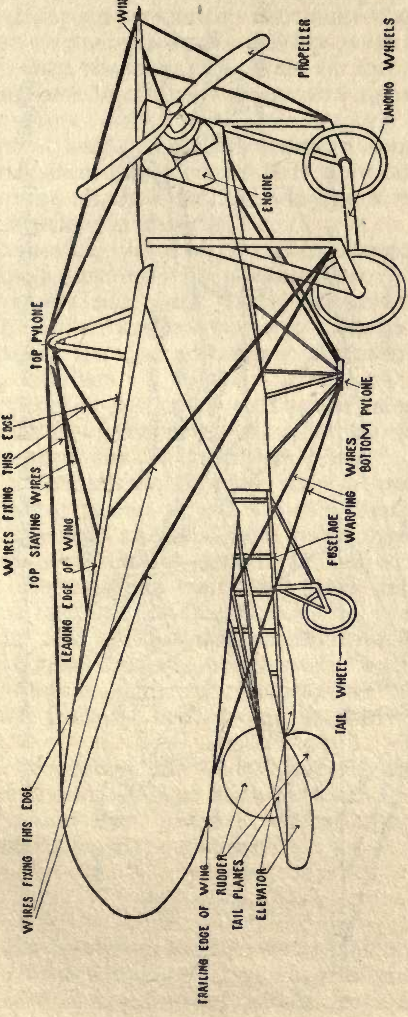

FIG. 6.—Bleriot monoplane, showing the wings, tail plane, elevator and rudder, and landing apparatus.

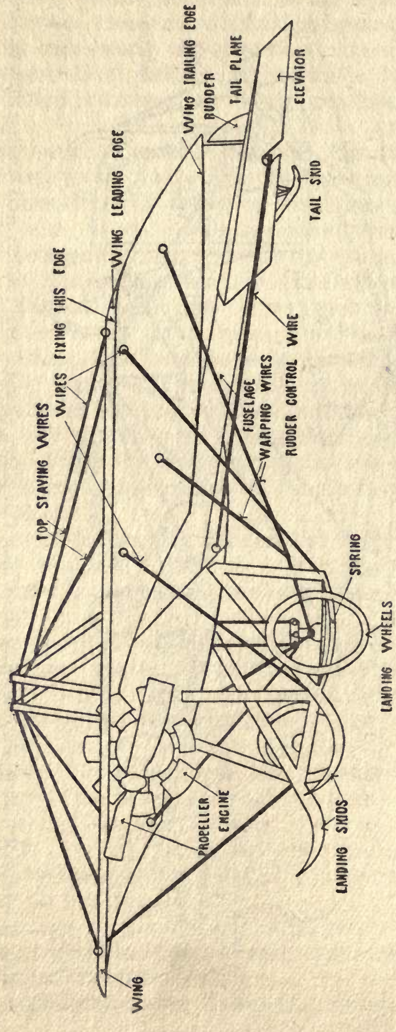

FIG. 7.—Deperdussin monoplane, showing wings, tail plane and rudder, and landing apparatus.

plained in a later chapter, is obtained by warping parts of the wings, up or down. In some monoplanes a portion of the wing towards the tip is arranged to be movable, very much on the lines of the flaps in the Wright biplane, and they are moved up or down by means of guys, wires, or ribbons, ending in levers at the aviator's hand. In other forms of monoplane the wings themselves are moved bodily up or down; that is to say, the angle which the wing as a whole makes with the fusellage is changed.

The wings of the monoplane and the supporting planes of the biplane are built up of a number of longitudinal and transverse ribs, over which the treated fabric is stretched. It is usually secured to both the upper and lower faces of the ribs. The form of the ribs gives the necessary camber.

In the earlier forms of monoplane a considerable quantity of the lubricating oil was thrown out from the engine, and the pilot got very liberally bespattered with it. In later machines the pilot is protected from this by metal plates placed between himself and the engine. There is an important point that should be mentioned—the relative danger to the aviator if the machine comes down suddenly head first. In the monoplane and the Tractor biplane the pilot is behind the engine, and is either thrown out clear or is thrown out on top of the engine. In the earlier form of biplane, with the engine behind the aviator, if the engine is dismounted from its bed, it may be thrown on top of the pilot.

In the monoplane the under sides of the wings are secured to the fusellage at various points by steel strips or wires; they are always cambered, the under side being concave, as in the biplane.

The Triplane

In the triplane there are two sets of three planes, each connected by a fusellage. The whole of the planes are smaller than is usual. Each set of three is suspended vertically one above the other. The triplane is virtually a biplane with an additional plane above the upper one. The lower plane forms the platform for the engine and for support of the fusellage, which extends to the rear to support the three triplanes forming the tail. The three planes at the rear are also fixed one above the other, for the fusellage entering between the lower and middle planes, and supporting the rudder which projects out beyond in that space. The pilot in the triplane sits in the fusellage, midway between the front triplanes and the rear triplanes, the engine being in front of him, and the propeller or tractor in front of the leading planes.

The Hydro-Aeroplane

The hydro-aeroplane, or hydroplane, as it is sometimes called, is merely any aeroplane fitted with floats that will enable it to rest upon the water. Fig. 8 is a typical hydro-aeroplane. It is also a tractor biplane. The idea is that the machine shall be used with men-of-war cruisers, and the writer suggests also with ocean passenger steamships. The floats are merely curved pieces of timber of such dimensions that their power of flotation is sufficient to support the weight of the aeroplane and its passengers when it is resting on the water. It is hoped that the aeroplane will be used for scouting. In that case the pilot on his machine would be lowered on to the water by the side of the ship. He would rise from the water, just as an aeroplane rises from the ground, would conclude his reconnaissance, and on returning to his ship would land on the water and be hoisted in. The recent performances of Commander Samson and Lieut. Gregory, at Portland, before the King will be fresh in the minds of readers. Commander Samson on a Short hydro-aeroplane easily rose from the water, scouted for the Royal Yacht, found her in a fog, and after executing other manœuvres, alighted on the water again. Lieut. Gregory located a submarine that was quite invisible from the deck of the ship it was going to attack. At the Portland manœuvres the hydro-aeroplanes were launched from an inclined plane fitted up above the forward turret of *H.M.S. Hibernia*. In actual practice, however, the writer believes the hydro-aeroplane will be hoisted out by tackle, as boats are, with the pilot on board. It will be dropped upon the water and will rise from it, alighting on the water alongside the ship on return.

General Structure of Aeroplanes

The principal points in the general construction of aeroplanes have been indicated in the preceding chapters. During the last eighteen months, however, a revolution

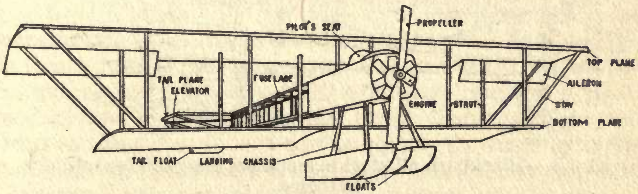

Fig. 8.—Hydro-aeroplane, fitted as a tractor biplane, showing supporting planes, fusellage, propeller, tail plane, elevator, and floats.

has been taking place in the material of which the framework is built up. Bamboo was almost universally employed in the early days, occasionally ash and hickory. Now steel and some of the alloys of aluminium are taking their place. It will be obvious that metal parts can be made smaller and lighter than wood. In addition to this, the body of the monoplane is more and more taking the form of a bird. The protecting cover fitted to the engine, to prevent the oil splashing over the pilot, has gradually been extended, till in some forms the whole of the fusellage is one enclosed vessel, something between a boat and the body of a bird, in which the aviator sits, and in which the engine and the other auxiliaries are held.

One monoplane of recent design, the Blackburn, is made entirely of steel, sheet and tubing being used for the different parts. The Blackburn all-steel machine is designed for military use and is shown in fig. 9. It is claimed that any part can easily be replaced.

How the Aeroplane Rises and Falls

The aeroplane is made to move upwards, to climb into the sky, so to speak, or to move downwards, by the aid of the elevator that was described in the earlier part of this chapter. The elevator consists of a cambered surface, fabric stretched over a wood or metal frame;

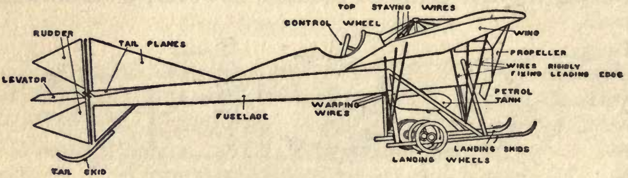

Fig. 9.—Blackburn all-steel monoplane, designed for military purposes.

carried in the case of the earlier forms of biplane usually in front, and in the monoplane and tractor biplane in the rear. When carried in front it is arranged with its inner ends as pivots, so that its outer ends can be raised or lowered. In the monoplane and tractor biplane the elevator is usually hinged at the centre, and guys or wires from levers near the pilot's hand in both cases enable him to place it at any angle he requires, with the horizontal. When the elevator is tilted upwards, the pressure of the air on the under-side when it is carried in front, and on the upper side when it is carried in rear, turns the front of the machine upwards, or, what amounts to the same thing, the rear of the machine downwards. In either case the course of the machine is directed upwards. When the elevator is turned downwards, the pressure of the air, on its upper side when it is carried in front, and on the lower side when it is carried behind, causes the front of the machine to turn downwards, or the tail to turn upwards. In either case the course of the machine is directed downwards.

How the Aeroplane is Steered Right and Left

The aeroplane is steered right or left by the aid of the vertical rudder, which in all forms of the machine is carried on the tail. The rudder is sometimes single, and there are sometimes two; and again the two are sometimes arranged side by side, and sometimes one above the other. The rudder consists of a frame of wood or metal, of very much the same form as a boat's rudder, over which fabric similar to that used on the main planes is stretched. The position of the rudder or rudders is controlled by guys running from levers or other arrangements at the pilot's hand. Turning the vertical rudders to the right causes the head of the aeroplane to turn to the right; and turning the vertical rudder to the left causes the head of the aeroplane to turn to the left. It is the pressure of the wind upon the vertical rudder which pushes the tail in the opposite direction to that in which the head goes.

There are various arrangements for the tail. In some forms of biplane, for instance, there is a kind of box, inside of which one or two vertical rudders are fixed, the idea being that the draught from the propellers, which in the earlier form of biplane are just behind the main planes, will be more effective if it is guided over the surfaces of the vertical rudders, by the box-like structure mentioned and shown in fig. 4.

How the Aeroplane is driven through the Air

The whole structure, whether it be a monoplane, a biplane, or a triplane, or in fact any other arrangement that the wit of an inventor may devise, is driven through the air by one or more propellers, or tractors, as they are called when placed in front of the machine. The propeller is precisely similar to that of a dirigible balloon, except that it would necessarily be smaller than those required for very large dirigibles. It consists usually of two blades of a screw, and is revolved at a very rapid rate, one thousand revolutions per minute and over, its revolution causing the whole machine to move forwards.

Propellers may have two or four blades. The usual construction is two blades. All monoplanes so far have one propeller, but some biplanes have two.

The propellers are driven by petrol engines, which have been worked out specially for the purpose, and are described in the next chapter. In the monoplane the shaft or axle of the engine has so far always been connected to the boss or centre of the propeller. In the case of the Gnome engine the equivalent of the shaft, a tube attached to the revolving cylinders described in the next chapter, is attached to the boss of the propeller. In the earlier forms of biplane, the propellers, when there were two, were driven by chains. In either case as the shaft or the tube revolves, in obedience to the power exerted by the engine, the propeller or propellers do so also, and drive the machine through the air.

CHAPTER V

THE AEROPLANE ENGINE

The aeroplane engine is really the motor-car engine made of very small weight to adapt it to aeroplane work. It is of the greatest importance that the weight of the engine to drive an aeroplane shall be as small as possible. In calculating the amount of power required to drive the aeroplane through the air the weight to be supported is an important factor, and the engine usually forms a large part of the weight. It was pointed out in a previous chapter that the lifting power, the pressure under the supporting planes, depends directly upon the extent of the planes themselves, and upon the square of the speed at which the machine is driven through the air. The supporting power or pressure required will be directly as the weight; everything which adds to the weight adds to the power required. There is the weight of the fusellage, of the framework upon which the supporting planes are spread, of the fabrics of which the supporting planes are formed, of the engine and its accessories, of the pilot and passengers if any are carried, of the propeller, and of the guys, pulleys and other appliances for controlling the apparatus. All have to be supported, and all add to the power required from the engine. In addition to that required for the supporting pressure, power has to be provided to overcome the resistance of the air to the passage of the aeroplane through it.

The air resistance is made up of two quantities—head resistance, or that encountered by the front of the aeroplane when forced through the air, and what is termed skin friction. Friction is set up between the air when any body is driven through the air, and all parts of the body. In the case of the aeroplane the supporting planes, the struts, the framework of the machine, the surfaces of the engine, of the elevator planes and rudders, the fusellage, the body of the pilot and passengers, &c., all add to the skin friction, and all produce resistance.

The power required to overcome skin friction depends on the surfaces over which the air passes, and upon the square of the velocity of the air. There is not space in this book to enter into the calculations required for finding the power necessary in each case. It will be seen from the above, however, how it arises that the actual power required varies as the cube of the speed, while the supporting pressure varies as the square of the speed.

The Engine

The aeroplane engine is really a development of the gas engine that has been before the world for some forty or fifty years, and is coming more and more into use.

With the steam engine it is necessary to have a separate appliance called a boiler, in which heat is applied to a body of water, causing the water to be converted into steam, and the expansive properties of the steam are used to force a piston from one end of a steam cylinder to the other.

In the gas engine it is the expansive properties of gas suddenly heated to a very high temperature that are made use of to force a piston from one end of the cylinder to the other. In the gas engine a mixture of gas and air is first drawn into the cylinder; it is then compressed, so that the gas and air may be thoroughly mixed; it is then fired, and the heat liberated by the combustion of the gas in the air with which it is mixed raises the temperature of the gases that are formed by combustion so much, that in their endeavour to expand, under the influence of the increase of temperature, they force the piston violently to the other end of the cylinder. All gases expand $\frac{1}{273}$ of their volume for every increase of temperature of 1° of the Centigrade scale, or $\frac{1}{461}$ for every increase of temperature of 1° of the Fahrenheit scale. The Centigrade scale is the one usually employed on the Continent of Europe, and always employed in the schools and laboratories; the Fahrenheit scale is the one commonly employed in every-day life. The temperature of the hot gases resulting from the combustion of the mixture of gas and air in a gas engine is often as high as 2000° C.; and it will therefore be seen what immense power is delivered to the gases by the explosion.

The petrol engine is a development of the gas engine. Petrol is a spirit formed by the distillation of petroleum. It has to be cleansed before it can be used, and a part of the cleansing process consists of distillation. The oil is heated, and its components come away at different temperatures. Petrol is the first product. It is the most volatile; it comes away with the smallest quantity of heat, and when condensed by passing through a still in the usual way, a worm surrounded by a stream of cold water, it forms the spirit with which we are familiar, and which is not unlike alcohol, except for the smell, &c. It will be understood that with a volatile spirit, such as petrol, its transformation into vapour is a very easy matter, and the vapour of petrol is used in the petrol engine in the same manner as gas in the gas engine. Vaporisation is performed by an apparatus called a "carburettor." The carburettor is of various forms; in principle, all are worked on the same lines. There is a reservoir of petrol which is kept at one level by a float, or some other convenient means, so that the pressure upon the petrol to force it to the active part of the carburettor is constant. The carburettor itself consists of a fine nozzle, a very fine tube, practically a needle bore, through which the petrol is forced in a very fine stream, partly by the pressure of the petrol in the reservoir, and partly by the suction of the air with which it is to mix, when it passes into the engine. In some forms of carburettor also, and particularly those exposed to low temperatures, heat is applied to assist the formation of vapour. There is always a certain quantity of heat available from the exhaust of the engine, as is explained below; and this can be used where required to warm the petrol as it passes through the carburettor.

The petrol engine is a gas engine with a carburettor added. It draws petrol vapour from the carburettor, instead of gas from the town's supply service.

The bulk of petrol engines, and of modern gas and oil engines, work upon what is known as the "Four Cycle" system. The meaning of the Four Cycle system is, that there are four complete strokes of the engine for every power stroke or every explosion. In every gas, oil, or petrol engine there is a cylinder accurately bored, and a piston fitting accurately in the cylinder, and moving to and fro in it, under the force of the explosion and the action of the fly-wheel as explained below.

Of the four strokes, the first is known as the Suction stroke; the second as the Compression stroke; the third as the Explosion or Power stroke; and the fourth as the Exhaust stroke. During the first stroke the piston is moving away from the rear of the cylinder, where the valves through which the gas or petrol vapour and air enters are filled. Its motion forwards in the cylinder causes a suction, or lessening of pressure in the cylinder behind it, the entry valves for the gas or petrol and air opening in response to the lowered pressure [1] and the air and petrol vapour in the case of the petrol engine flowing in. When the piston has reached the limit of its suction stroke, or usually a little before, the entry valves for the petrol vapour and air are closed. It should be mentioned that one entry valve answers for the two in the modern petrol engine, the mixing of the gases being done in what is called the Induction pipe, immediately behind the entry valve.

When the piston moves backwards towards the rear of the cylinder it compresses the mixture of petrol vapour and air. This compression is necessary, because if good combustion is to be obtained, each molecule of petrol vapour must have close to it the necessary atoms

[1] In the latest forms of petrol engine, the valves are opened mechanically, suction not being depended on.

of oxygen with which to combine. It is found that without compression the power obtained with a given quantity of gas or petrol vapour, in a given-sized engine, is less than when compression is employed. On the other hand, compression must not be too great, or the charge may be fired prematurely. On the commencement of the third stroke, the second out stroke, the mixture of petrol vapour and air is ignited by an electric spark. The arrangement of the electrical apparatus is explained below. The ignition of the charge, though it apparently causes instantaneous combustion, does not do so really. The charge takes a certain time to burn, and in some cases a certain portion is thrown out through the exhaust unburnt. That is the source of some of the unpleasant smell that follows in the wake of motor-cars. The combustion of the charge liberates heat, raises the gases to the temperature named, and forces the piston forward. Just before the end of the explosion stroke the exhaust valve opens, and the returning piston on the fourth stroke of the cycle forces the exhaust gases out. These gases are hot, and they form a convenient source of heat for anything to which they can be applied, such as the warming of the carburettor. It is estimated approximately, that of the heat liberated by the combustion of a gas or petrol and air charge, 30 per cent. is driven out wastefully in the exhaust gases.

The power is conveyed from the piston, or rather the pistons of the cylinders of the petrol engine, to the propeller by means of what is called a "crank-shaft," and what are termed "connecting-rods." The crank-shaft is the shaft or axle of the engine, and it carries a number of "cranks," one for each cylinder. The connecting-rods transmit the power from the pistons to the cranks, thence to the crank-shaft, and the boss of the propeller, as already explained, is attached to the axle or crank-shaft of the engine, except where a chain drive is interposed. The crank is a mechanical device arranged to convert the to-and-fro motion of the piston into rotary motion. While the pistons are continually moving to and fro in their cylinders, the crank-shaft is continually revolving, and carrying whatever may be attached round with it.

There is an important difference between the working of a gas, oil, or petrol engine and that of a steam engine, in the matter of transmitting the power to the apparatus to be driven. In the steam engine each stroke is a power stroke; steam is admitted behind the piston every time it moves from one end of the cylinder to the other. In the Four Cycle gas or petroleum engine only one of the four strokes is a power stroke, and the difficulty arises of distributing the power equally over the four strokes to the apparatus to be driven, and of furnishing the power required to work the piston itself, and the accessories, the valves, the connecting-rod, the crank-shaft, &c., during the three non-power strokes. In the gas and oil engine employed for industrial work, the difficulty is overcome by the use of a fly-wheel. A fly-wheel is merely a wheel of a certain size and weight attached to the axle, and it has the property of absorbing surplus power at a time when it is not wanted, and giving it up again when it is wanted. By properly proportioning the size and weight of the fly-wheels of a gas or oil engine, fairly uniform motion is obtained. In the motor-car petrol engine also a fly-wheel is usually employed. In the aeroplane engine, which has been developed from the motor-car engine, the propeller acts as a fly-wheel, and in rotary engines, like the Gnome, the engine itself also acts as a fly-wheel. It is of the utmost importance that the motion of revolution of the propeller should be uniform. In the aeroplane engine, therefore, in addition to the fly-wheel action of the propeller, there are usually a number of cylinders—3, 5, 6, 7, or 8. In the Gnome engine there are seven cylinders. It will easily be understood that if there are four cylinders, each taking its explosion on a different stroke, one stroke of each four will always be a power stroke. If there are eight cylinders, each taking its explosion stroke at a different time from the others, there may be two during each stroke. Or, to put it in another way, with four cylinders there will be two power strokes in each revolution; with eight cylinders there may be four power strokes in each revolution; and there

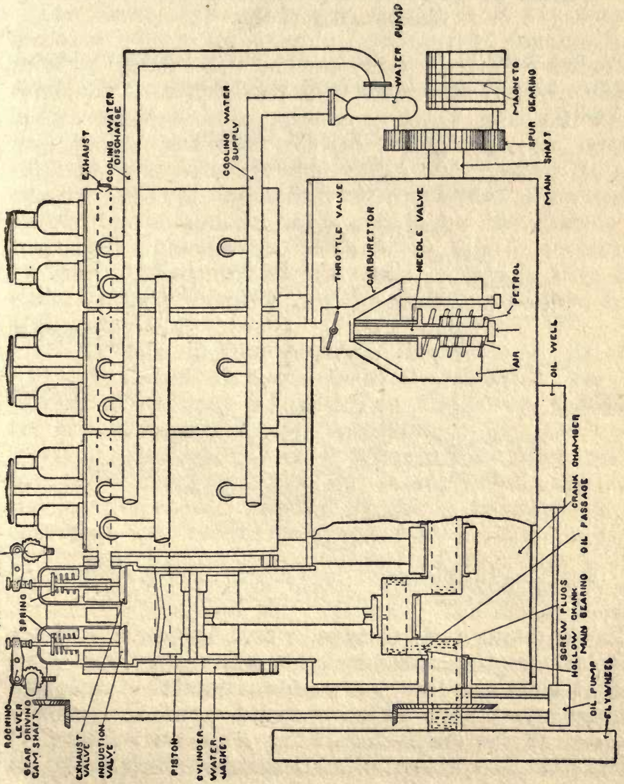

FIG. 10.—Green vertical engine, showing the arrangement of the different parts.

may be other arrangements enabling continuous motion to be given to the crank-shaft. With eight cylinders, or any number greater than four, it is more common to divide the total number of power strokes in aeroplane engines equally between each two revolutions forming the Four Cycles. This is explained more fully in connection with the Gnome engine.

Forms of Petrol Engines Employed for Aeroplane Work

At the present time there are three forms of petrol engines employed for driving aeroplanes. They may be termed :—

The Radial type of engine.
The V-type of engine.
The plain Vertical type.

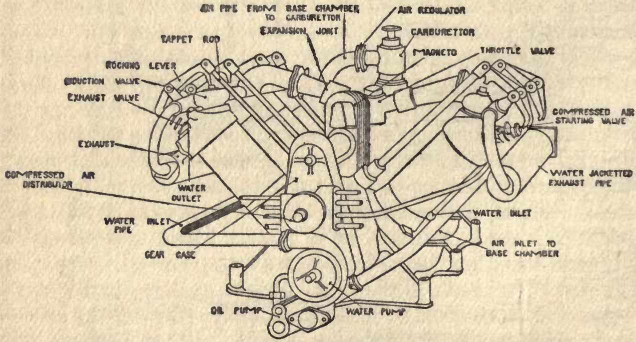

Fig. 11.—The Wolseley V-type engine, showing relative position of different parts and general arrangement.

In the plain vertical type, which is represented by the Green engine, which took the Alexander £1000 prize a short while ago, there are a certain number of cylinders arranged vertically, all connected to one crank-shaft, the end of the crank-shaft being attached to the propeller or to the sprocket wheel of the chain drive. Fig. 10 shows the Green engine.

In the V-type engine, of which the Wolseley, shown in fig. 11, is an example, there are usually eight cylinders, though four or six cylinders may be employed. The cylinders are arranged in pairs, each pair forming the letter V. The crank-shaft runs in a tube provided for it, a crank chamber as it is called, forming the junction between the respective cylinders, its end projecting outside and being connected to the propeller or to the sprocket wheel of the chain drive.

The Radial type of engine, again, is of two forms, those in which the cylinders themselves revolve and those in which they are stationary and the crank-shaft revolves. In either case there is only one crank, working in the centre of the apparatus, to which all the connecting-rods are attached. There may be five, six, seven, or eight cylinders, the explosions taking place in the engines with an odd number of cylinders alternately. In the seven-cylinder engine, of which the Gnome is an example, numbering the cylinders 1 to 7, according to their position round the circle of which they are radii, the explosions would take place in cylinders 1, 3, 5, 7, 2, 4, 6, 1.

In the Gnome engine, which is shown in fig. 12, which is the great favourite at the present time for driving monoplanes in particular, the seven cylinders are arranged around a tubular shaft, to which the propeller is attached. There is a solid shaft upon which the whole thing revolves, and is supported, inside of the tubular shaft. There is a special arrangement of valves at the centre, by which petrol vapour and air enter each cylinder in succession, in the order in which its suction has to take place. The exhaust valves are at the outer ends of the cylinders. The firing of each cylinder is arranged so that each has one explosion in every two revolutions, or one complete cycle. The complete cycle, or four strokes, gives two revolutions of the crank-shaft or its equivalent; and the movements of the cylinders are so timed that each cylinder receives its petrol and air, compresses it, and is ready for firing, so that there is an angular movement of 100° between successive explosions. The ignition apparatus follows the cylinders and delivers a spark at the right time.

In France a modification of the Radial engine is made, of which the Anzani is an example. It has three or five cylinders, arranged radially around part of a circle, adjacent cylinders forming a V, and having one crank attached to all the connecting-rods, the crank-shaft working in a chamber provided for it, as in the Wolseley.

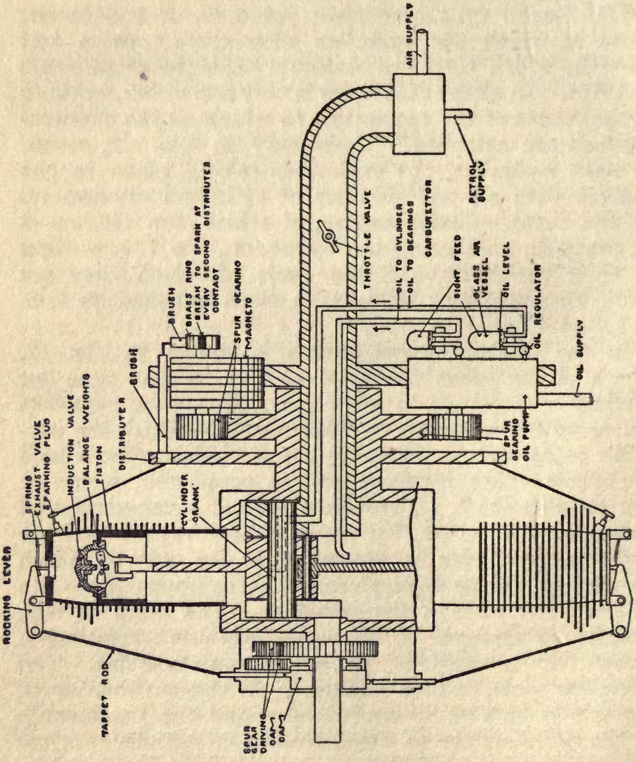

FIG. 12.—A diagrammatic detailed view of the Gnome engine, showing the working arrangements.

THE COOLING OF THE ENGINE

A very important matter arises in connection with all internal combustion engines, as those using gas or gaseous vapour are called, viz. the keeping of the cylinder walls below a certain temperature. When an explosion takes place in the cylinder, as mentioned above, the temperature of the products of combustion rises to about 2000° C. It falls very quickly in the process of performing work by driving the piston to the end of its stroke; but when the remaining gases are forced out through the exhaust-valve, they are still at a fairly high temperature, roughly in the neighbourhood of 600° C., and hence the temperature of the cylinder walls would be raised to a high figure, unless means were taken to prevent them. The raising of the temperature of the cylinder walls would have two important consequences: the material of which the cylinders are composed would have a comparatively short life, and the incoming charge on the next cycle might be fired before it had time to be compressed. Most of us have heard the noise of back firing in motor-cars, motor-cycles, &c. Back firing, as it is called, is really premature firing; it leads to a useless expenditure of petrol, and to a very much smaller quantity of power being obtained for a given quantity of fuel. The ignition temperature of petrol vapour is very much below the temperature to which the cylinder walls would be raised, if means were not taken to cool them.

With the gas or oil engine employed for industrial work, and with the motor-car engine, the universal method employed is by the circulation of water. With a motor-cycle, what is known as "air cooling" is employed. With water cooling, a jacket is formed outside of the cylinder, and water is kept circulating through the jacket. In the motor-car engine, and in the aeroplane engine, there is not room for the large reservoir of water that can be employed with stationary engines; and a device has to be arranged to use the water over and over again, by passing it through a cooling device, known as a radiator. In both the motor-car engine and the aeroplane engine, the passage of the engine itself and the car or the machine through the air, is made use of to cool the water that is passing through the radiator. A radiator consists of a number of tubes through which the water from the jacket circulates, the outer surfaces of the tubes being exposed to the current of air created by the passage of the car or the aeroplane through the air. In the motor-car a small reservoir of water is often carried; in the aeroplane there is no room for it. On the other hand, the very much greater speed at which the aeroplane travels, and the low temperature of the air through which it often moves, particularly at high altitudes, enables cooling of the water to be carried out very much more efficiently than in the case of the motor-car. In the biplane, notably in the Wright and Cody patterns, the radiator consists of a certain number of tubes, fixed vertically between the two planes, near the engine. There is a small space between the tubes, so that the air can flow all round them, and the cooling is very efficient.

In the Antoinette monoplane, a very ingenious arrangement of the tubes of the radiator was carried out. The fusellage of the Antoinette is shaped almost like a canoe, and the radiator tubes were fixed on the two sides of what would be the bows of the canoe, so that they were exposed to the full force of the wind created by the passage of the machine through the air. The arrangement is not so effective as the radiator in the Wright biplane, because the air cannot get to all parts of the tubes.

The cooling effect of air upon any tube, or any body over which it passes, depends directly upon the extent of the surface in contact with the air, and upon the velocity at which the air is moving. There are various forms of radiator, all developed from those used in the motor-car, and all designed to expose as much metal surface as possible to the air, and to break the water up into as fine a stream as possible. It is the thin layer of water next the metal of the radiator that is cooled. The radiator tubes are sometimes fitted with fins, to increase the surface exposed to the air.

Air-Cooled Engines

In air-cooled engines, the cooling effect of the actual contact of the air upon the outer surfaces of the cylinders as it passes over them is relied upon to keep the temperature of the inner walls of the cylinders down. Each layer of air, as it passes over the metal surfaces, carries off some heat. In order to assist the cooling effect the cylinders are all fitted with rins or fins on the outside, as shown in the Gnome engine in fig. 12. In the Gnome engine, the revolution of the cylinders creates a draught of air over their surfaces and through the spaces between the ribs, in addition to that created by the passage of the machine through the air.

The Relative Advantages and Disadvantages of Water and Air Cooling

Air cooling has the great advantage of simplicity. It has also the great advantage that the spaces occupied by the radiator and its accessories, and the pipes connecting it to the cylinder jacket, are saved. The cylinder jacket itself also is saved, and the weight of the engine and accessories is less.

There is the usual difference of opinion as to the relative efficiency of water cooling and air cooling. Water cooling is claimed to be more efficient, because a much larger surface can be exposed to the cooling action of the air, in a properly designed radiator, than is practicable where the cooling action of the air is applied to the engine cylinders direct. The cooling action depends directly upon the surface exposed to the air, and upon the velocity of the air current, and upon the difference between the temperature of the air and the body to be cooled. On the other hand, the difference of temperature between the engine cylinders and the air will be greater than between the surfaces of the radiator and the air. It will be sufficient here to say that both methods are successfully applied.

The Gnome engine is arranged to furnish power from 50 h.p. up to 140 h.p. It is made in two sizes, each with seven cylinders; the one with the smaller cylinders furnishing 50 h.p., and that with larger cylinders 70 h.p. For 100 h.p. and 140 h.p. two 50 h.p. engines or two

70 h.p. engines are secured together, their cylinders being arranged alternately, so that the cylinders of the one engine are opposite the space between two cylinders in the other engine. The two sets of cylinders revolve, and carry around a tubular shaft to which the propeller is attached, the other arrangements being similar to the single engine.

The Wolseley and other V-type engines are made to furnish power from 35 h.p. up to 120 h.p. In the early days of flying, 25 h.p. was considered to be enough; the Wright brothers were thought to have been rather extravagant in power when they furnished 35 h.p., and the Gnome furnishing 50 h.p. when it appeared, was considered to solve the power problem.

The increasing demand for speed, however, has obliged engine builders to produce engines of greater and greater power.

The weight of the aeroplane engines on the market are less per horse-power than of any other known motor.

The Ignition of the Charge of Petrol and Oil

This is accomplished in all aeroplane engines by an electric spark passing between platinum points in the space occupied by the compressed charge. The electric current for the spark is furnished, in practically all aeroplane engines, by a magneto-electric machine, worked by the engine, similar to those used for motor-car work, but made very powerful for their weight. The motion of a part of the magneto generates an electric current; and a distributor, worked also by the engine, directs the current to each cylinder in turn at the right moment.

CHAPTER VI

THE PROPELLER

In order to understand how the propeller drives an aeroplane or a dirigible through the air (the action is the same in each case) it will be as well to realise that the air we breathe, that surrounds us, is a fluid. We cannot see it, but physicists look upon it very much in the same light as water and other liquids. To the physicist all liquids and gases are fluids, and have very many properties in common. They all have weight, they all have the power of supporting bodies floating in them, they all resist the passage of bodies through them, they all set up friction over the surfaces of any bodies passing through them, and they can all be made the medium for the operation of screws or propellers.

Consider the action of an ordinary screw when it is driven into a block of wood. It will be remembered that the ordinary wood-screw is furnished with a needle point at one end, which a tap of the hammer causes to enter the wood. Then the screw-driver, turning the head of the screw, causes the outer cutting edge of the thread to cut its way into the wood, and as it cuts its way in, so the screw as a whole advances. If we had a block of wood of great length, and a screw of great length, with proper tools for the purpose, we could cause the screw to cut its way right through the block. In place of the screw as we know it, and which is usually tapered in form, we might have a rod with a pointed end, and a few threads near the end in place of the usual large number. We could drive this rod through a long block of wood, the screw cutting its way through the whole length, by applying sufficient turning force at the other end, the non-pointed end.

If we substitute water or air for the block of wood, the above is exactly what we have in a screw designed to drive a ship through the water, and an aeroplane or dirigible through the air. Just as the screw on the rod described above would cut its way through the wood, so the screw-blades forming the propeller cut their way through the air or water, and force the ship, the dirigible, or the aeroplane, forwards.

But there is of course a great difference between a block of wood and either a mass of water or air. The block of wood resists the passage of the screw through it, resists the cutting action of the edge of the screw very much more than either water or air do; but once the screw is through, once it has passed over any distance from the end at which it entered the block, the friction set up by the wood against the edges of the screw will not allow it to go back unless it is turned back by proper tools in the usual way. With wood there is practically no "slip," as it is called, until the thread in the wood is worn; with water and air there is a considerable amount of slip. Screwing through water or air by a propeller is like screwing through wood or metal in which the thread is worn. The screw-blades forming the propeller screw their way through the air or the water, just as the piece of the screw would go through a block of wood; but as the air and water are easily pushed out of the way, the full distance forward that would be obtained by each revolution of the screw in the case of wood is not obtained in the case of water or air, and particularly in the case of air. The distance advanced by an aeroplane, driven by a propeller, is that which it would be driven if the medium were solid, less the "slip."

The Pitch of the Screw

We are all familiar with the fact that screws vary. If we pick up a box of assorted screws, we shall find that the recesses in one are deeper than in another;

that they are wider in some screws than in others, and so on. The distance between any two threads, any two cutting edges as they may be termed, of a screw, is called its "pitch." The "pitch" of a screw is the distance through which the screw will move, and will carry whatever it is attached to, in one complete turn on its axis, if there is no slip. Taking the case for instance of screws arranged to enter wood, and suppose that there are eight threads to the inch; this means that the pitch of the screw is $\frac{1}{8}$-inch, and that with each complete turn of the screw-head the screw itself will have advanced into the wood $\frac{1}{8}$-inch. The propellers designed for aeroplane work are calculated in the same way, and their pitch is calculated in the same way; but if the pitch of a screw is say 6 feet, this means that with every revolution of the propeller, the aeroplane or the dirigible should move forward 6 feet through the air, if there were no slip. If the slip is as much as 50 per cent., the actual advance of the aeroplane or the dirigible for every revolution of the propeller will only be 3 feet.

Forms of Propeller

At the present time only two forms of propeller are in use, and one of them only to a very small extent; they are known as the two-bladed and four-bladed propeller, typical examples of which are shown in figs. 13 and 14. In both forms, each blade is a portion of a screw, or rather of two or more screws. The actual form of the blades found to give the best results includes portions of successive screws. As the different parts of the blades are moving at different speeds, the ends of the blades at the highest speed and the inner portions at gradually decreasing speeds, the air moved by the successive portions follows these varying speeds, and the screw of varying pitch is designed to meet this. Propellers at the present time are nearly all made of wood, and it is the common practice to build them up of a number of pieces, carefully secured together, and then cut to the right section, mainly by hand tools, so that the blades have the right pitch, and the grain of the wood is arranged to meet the strains set up as the propeller revolves, in the best way. They are

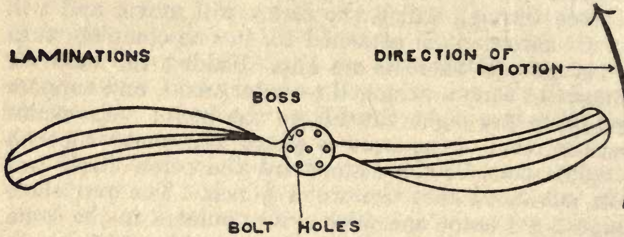

FIG. 13.—Typical two-bladed propeller, showing the central boss, by which it is attached to the central axle, and the two blades built up of wooden strips.

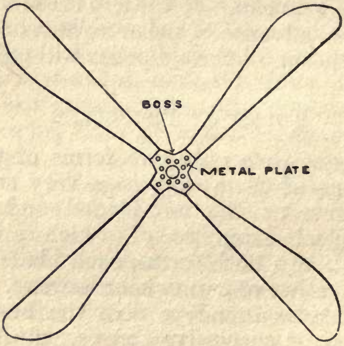

FIG. 14.—Typical four-bladed propeller. It is similar to the two-bladed propeller in every way, except that it has four blades instead of two.

varnished and protected from the weather as far as possible, and the strongest part is necessarily at the boss.

A few propellers are made of steel and of aluminium. It is claimed that wooden propellers stand best, and that built-up wooden propellers stand better than those cut out of one piece. Various woods are employed, one firm, who make a speciality of this work, use specially selected French walnut.

How the Propeller is Driven

The driving of the propeller has already been described. Either the boss to which the blades are secured is made hollow, to receive the shaft of the engine or a small shaft carrying a sprocket wheel or pulley, or the boss is held to the driving shaft by bolts. The boss and bolt holes should be bushed with metal, so as to withstand any friction that may arise from the axle or bolts, and also that it may be held securely. It will be understood that the axle and the propeller are to revolve as one. There must be no vibration, no motion to and fro of the propeller on its shaft. Such motion, if it does occur, will have two results; it will enlarge the holes in the boss until the propeller drops off, and it will lessen the efficiency of the propeller very considerably. The best results with any propeller are obtained by continuous motion of revolution; any rocking to and fro in any direction lessens the proportion of the energy delivered to the propeller that reappears in the form of work done in moving the aeroplane forward.

The Efficiency of the Propeller

There is not space in this book to deal fully with the question of the efficiency of the propeller. Sufficient experience has not yet been obtained to show which form of propeller will be the most efficient in the true sense of the term. By efficiency is meant that portion of the power delivered to the propeller which appears as thrust or pushing force, driving the aeroplane or dirigible forward. As the propeller revolves, it forces the air back behind it, and exerts a corresponding thrust forwards upon the aeroplane. It is this forward thrust that causes the aeroplane to advance. Certain points may be mentioned as bearing upon the subject.

The larger the diameter of the propeller, and the smaller the number of its revolutions per minute, the greater is its efficiency, and vice versa. With the engine that is employed to drive the propeller of an aeroplane, which runs at 1000 revolutions per minute and upwards, it will easily be understood that low speeds, such as 100 revolutions per minute, are out of the question, except by the aid of reducing gear. In addition, there is not space for the large propellers that would mean higher efficiency, and consequently the propellers that are being employed are usually two-bladed, and about 7 feet in diameter from the tip of one blade to the tip of the opposite blade. The speed at which any screw moves forward, and carries any object to which it may be attached, is measured by the product of the pitch, less the "slip," and the number of revolutions it makes per minute. Thus if a propeller has a pitch of 6 feet, a slip of 2 feet, and runs at a speed of 1000 revolutions per minute, the aeroplane should go forward at the rate of 4000 feet per minute, or a little over 45 miles an hour. The above does not represent all the factors that have to be taken into account in designing a propeller for a particular aeroplane, but it will probably be sufficient for the purposes of this book.

CHAPTER VII

LANDING APPARATUS OR CHASSIS

THE landing apparatus of an aeroplane, or chassis as it is called, is as important as any part of it. The machine, when it is not flying, has to rest upon the ground in such a position that it can run along and can rise easily, under the pressure of the wind created by its own passage through the air. The same appliances which are provided for supporting the machine when on the ground, are necessarily employed to receive the machine when it reaches the ground; and it is here that the great importance of its construction comes in. A great number of the accidents that have occurred, by which aviators have lost their lives and machines have been damaged, have been due to bad landing. With flying machines, it is very much the same with regard to the air as with ships with regard to the sea. What the sailor likes is plenty of sea room; his troubles commence very often when he is close to the land. With an aviator, mounted upon a well-found aeroplane and with good command of the machine, arising from a knowledge of the apparatus and experience in handling it, safety lies in being aloft. It is when he has to alight that his troubles very often commence. If everything is favourable, he may be able to glide down from a height by a vol plané, as it is termed, and alight on nice ground, with just sufficient way on, as sailors would express it, to bring the whole machine gently to rest. It may happen however that owing to an accident to his engine, to the ignition failing or the engine stopping from some other cause, he has to plane down quickly, and alight in the most favourable spot he can find. Where aeroplanes are employed for scouting in war, for instance, the aviator would have to alight, if he did so at all, on any ground that was available; and this is so strongly felt by the French Government, that in the trials that were recently carried out in France, the weaklings among the competitors were eliminated by the requirement to alight on practically any kind of ground. Anyone who has walked across country, across ploughed fields, over some of the enclosures that have been made for aerodromes in the United Kingdom, will be familiar with the uneven condition of the ground. Ploughed fields are necessarily uneven; and in addition, there are often ruts or channels cut for drainage, cracks produced by the sun, and so on. The level of the ground is often uneven in other ways too. Within a very short space, there may be a comparatively level piece of ground, then a slight hillock, then a slope in the opposite direction, then another level piece, and so on. The slight hillocks do not bother the pedestrian very much, but they make a very considerable difference to the ease of alighting with an aeroplane. All this means that provision has to be made to compensate as far as possible for the irregularities of the ground, not only at the point where the machine finally comes to rest, but for some distance before that point is reached. It is very rarely, indeed, with the present skill of aviators, that a pilot is able to come right down and bring his machine to rest upon the spot where his landing wheels first touch. He nearly always runs along the ground for a certain distance.

Forms of Landing Apparatus

The landing apparatus has taken practically one form for all kinds of machines, but with the usual many variations due to the views of the different inventors, and the different conditions they have met with. The bicycle wheel with the large pneumatic tyre is universally employed. The pneumatic tyre in itself provides a considerable portion of the resiliency, the give and take so to speak, that is so necessary for the landing apparatus. The pneumatic tyre has added to the comfort of motor-car travelling by reason of this very resiliency. It encloses a stone within itself, and discards it

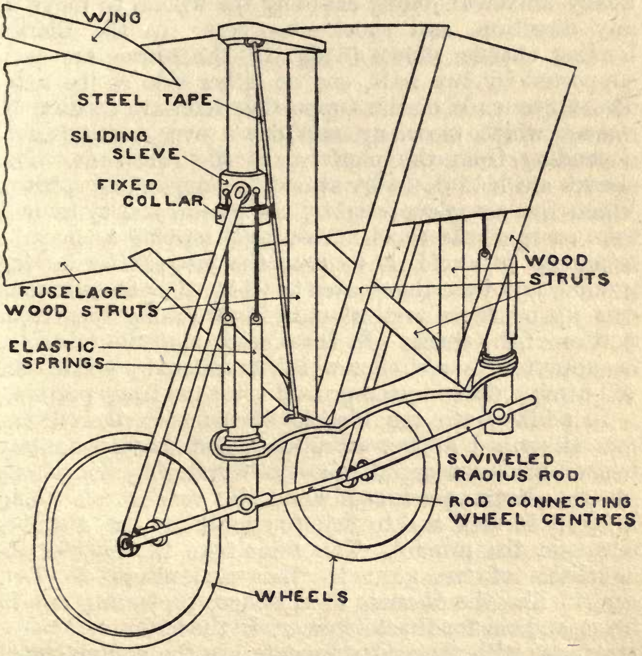

FIG. 15.—Typical landing chassis, taken from the Bleriot monoplane.

again after the car has passed, with very little jar to the occupants of the car compared to what the stone would have given if the tyre had been solid.

With both the monoplane and the biplane it is usual to have two, and sometimes four, bicycle wheels with comparatively large pneumatic tyres. Where there are four wheels, two are fixed on each side of the aeroplane. They are suspended from the platform supporting the engine, the pilot, &c. Fig. 15 shows a typical landing gear; it is taken from the Bleriot monoplane. The arrangements for supporting the tyred wheels are various, but all combine in themselves what are practically universal joints, enabling the wheels to move in any direction, and shock absorbers. In the Bleriot landing chassis, shown in fig. 15, the wheels are each supported by two rods, one on either side of the axle. The upper ends of the supporting rods are secured to sleeves which move up and down over vertical rods depending from the platform of the aeroplane. The sleeves are held down by two strong expanding springs. When the aeroplane alights, the pneumatic tyres first take some of the shock, the wheels moving as may be necessary to avoid or to pass the inequalities in the ground, and then the sleeves to which they are attached ride up on their vertical rods, they taking the major portion of the shock. In some aeroplanes the tail-piece is supported by a similar wheel, in others by a skid, the tail coming down to the ground after the front portion.

In addition to the bicycle wheels with their tyres, &c., described above, some aeroplanes have what are termed skids, arranged to assist in relieving the wheels of the strain produced when the machine is being brought to rest, and to help in supporting the machine when on the ground. The skids take the heavier inequalities of the ground. They are pieces of wood shaped like the runners of a sledge, projecting out in front, and one for the tail in rear. In the hydro-aeroplane, the floats with their attachments are the equivalent of the landing chassis.

CHAPTER VIII

OPERATING AN AEROPLANE

It will be understood from what has been said in the foregoing chapters, that the aeroplane is only supported in the air when it is being driven through it at a certain speed. It will also be understood that when on the ground it is supported by the landing chassis, the wheels, and other fittings described in the last chapter; and that these wheels are arranged so that the aeroplane can run along the ground until the speed at which it is moving creates sufficient pressure under the main supporting planes to lift it off the ground. Once it is lifted off the ground, providing the elevator is trimmed at the upper angle, the machine steadily rises. In practice, the engine is started, and some provision is made for preventing the machine, as a whole, moving ahead until the aviator is ready. A common method is, the mechanics, who have been tuning up the engine, and who are usually kept ready to see that all parts of the machine are right, are made to hold on to the rear parts of the fusellage in such a manner that they can let go quickly when the pilot gives the signal. When what was practically the first trial at launching an aeroplane from a man-of-war took place in the Medway, as many bluejackets as could get round the rear of the machine held on to it after the engines were started, the pilot got into his seat, gave the word "let go," and the machine slid down an inclined platform, and commenced to rise immediately she was over the bows.

In the early experiments of Mr. Wilbur Wright, near Paris, the starting arrangement consisted of a short length of tramway rails, upon which the wheels of the landing chassis ran during the start, the first impulse being given by a weight falling from a post in the neighbourhood, and pulling a rope, to one end of which it was attached, the other end being attached to the aeroplane. The rope was slipped from the aeroplane immediately she rose from the ground.

Several devices have been introduced for a similar purpose, to avoid the necessity of a number of men holding on to the machine, with the possibility of accident. A common arrangement is, a rope of sufficient strength to hold the machine against the pull of the engine is taken round any convenient post, a tree, or anything of the kind, and brought back to the aeroplane. What is practically a slip toggle is arranged to to be worked by the aviator. When he is ready he removes a plug or bolt, the slip is released, and the machine runs ahead. When starting from the ground the elevator is kept in a horizontal position with both monoplane and biplane until the machine has left the ground; when the machine acquires a certain speed on the ground the tail tends to lift, and the resistance to the travel of the machine along the ground is then very small. The elevator is then slightly tilted upwards. Great care must be taken in manipulating the elevator, because any ascent can only be at the expense of speed, unless more power can be given. For the aeroplane as a whole to rise through any vertical distance, in any given time, demands the expenditure of a certain amount of power, quite irrespective of that expended in driving it through the air. If the demand for lifting the aeroplane is large, the speed at which the machine is flying may decrease, and with it the support afforded by the passage of the air underneath the supporting planes. It is for this reason that ascents are always made in spiral curves of comparatively low inclination. With plenty of surplus power, as in the later forms of machines, great heights can be attained in a comparatively short time, but with the average machine, especially where it is carrying a passenger, if height is to be secured, it must be done gradually. The converse, of course, holds good when descending; the descent of the aeroplane creates the wind under the supporting planes, which gives the necessary upward pressure.

Every pilot has to become acquainted with what may be termed the "tricks" of each machine by actual experience of them, just as every rider has to become acquainted with the tricks of each horse that he rides.

The moment of leaving the ground is practically imperceptible. The only thing the inexperienced man or woman upon an aeroplane would know when the machine left the ground would be that the resistance to its passage has considerably lessened. The feeling is the same as when passing in a motor-car from a very rough road to a very good one.

Planing Down—The Vol Plané

The next question is, being up in the air, how is the aviator to get down. He may wish to come down in the ordinary way because he is at the end of his journey, because he has done sufficient flying for the time, or he may be obliged to come down because of the failure of his engine. Unfortunately, the aeroplane engine is a very tricky piece of machinery. It has two very weak components—the electrical ignition apparatus and the carburettor. If a very minute piece of dirt is allowed to remain in the petrol, and finds its way into the needle valve of the carburettor, it may stop the supply of petrol to the engine, and consequently the engine will stop. The electrical portion of the apparatus is full of possibilities of failure. Wires may break, dirt may accumulate upon the platinum wires of the sparking plug, and so on. In either case, if any one of these causes of failure happens, if it applies to the whole of the cylinders, the engine must stop. If it applies to only a portion of the cylinders, even then the aviator may be obliged to come down, because the remaining cylinders will not keep the speed at the figure necessary to maintain the requisite upward pressure. If three of eight cylinders, for instance, cease to work, they not only add nothing to the power that is being delivered to the propeller, and through it to the supporting pressure of the main planes, but their pistons have to be dragged through their cycles at the expense of the power delivered by the others. It will be remembered that when Latham was crossing the English Channel on his Antoinette three of his cylinders suddenly failed, and his machine came down in the water. With plenty of height there is no danger to the aviator, providing that he keeps his head and has control of the machine. He can plane down. Planing down is merely gliding. The operation is exactly the same as that of the early gliders when pushed off a cliff, except that in the aeroplane the aviator has an elevator and a rudder to help him to guide the machine to a convenient spot for alighting. When he wishes to come down, the elevator is tilted slightly downwards, the nose of the machine, as already explained, turns downwards, and the machine commences to descend on what is practically an invisible inclined plane, like the slope of a toboggan. The passage of the air under the supporting planes, as the machine descends, furnishes the necessary upward pressure, just as when the machine is being driven through the air by the engine. Every machine has its own gliding angle at which it will come safely to ground. It is usually a small angle with the horizontal. The possible safe angle increases with the speed and the power of the engine. If too great an inclination is given, the machine acquires momentum too rapidly, and is liable to turn head downwards. When an aeroplane descends at the natural gliding angle, it is called a vol plané. The descent is completed by slightly tilting the elevator upwards when a short distance from the ground, the machine then gliding on till it touches the ground gently, the wheels taking its weight, and the whole running along till any momentum that is left is expended, when the machine comes to rest

Alighting

There is not much more to be said on the matter of alighting beyond the explanation given in the last chapter. It is difficult for the aviator to see the exact nature of the ground below him. Practice will bring a certain amount of experience in this, as in every other part of the work. The aviator must look out for the smoothest piece of ground that he can find, the one with the smallest number of ruts, and, where ruts abound, the shallowest. With the high altitudes that are now common, planing down is the usual method. Skill in alighting is only to be acquired by practice. It will easily be understood that if a machine comes down with any appreciable velocity, the landing wheels strike the ground with considerable force, shaking up the machine generally. It may happen also that the inequalities in the ground, if the machine alights with too great velocity, will cause the tail, particularly of a monoplane, to lift and possibly to snap off.

Going Round Curves

Taking an aeroplane round a curve is one of the most difficult things the aviator has to learn. As will be seen by the particulars given in a later chapter on the requirements for certificate of the Royal Aero Club, a certain number of figures of eight have to be formed by the would-be holder of a certificate within a limited space. In order to guide the machine either to right or left, the vertical rudder is moved in the same direction as the head of the machine is wished to go. For good steering the rudder should not be put, as sailors express it, "hard over." It should be turned slightly to right or left, so that the machine may have time to accommodate itself to the new conditions. When the head of the machine turns, say to right or left, to commence the formation of the curve, a new sort of conditions comes into being; the inner wing of a monoplane, or the inner ends of the supporting planes of a biplane, will be moving at a slower rate through the air than the outer wing or the outer ends, and the velocity of the air passing the outer wing or outer ends will be greater than that passing the inner ends. Hence the pressure under the outer ends will be greater than that under the inner ends, and the outer ends will tend to lift. This is known as banking. There will be a number of forces at work during a turning movement. Centrifugal force, for instance, will be acting upon the outer wing. The danger is that excessive banking may result, and that the machine may tip up dangerously, and if a gust of wind happens to come at the same moment it may be overturned. There is also the danger, if the angle with the horizontal at which the machine is flying is great, of its moving bodily sideways and downwards. In going round a curve the aviator will have to employ the vertical rudder and the warping arrangements of the wings, or ailerons, as will be explained in the next chapter, to counteract the difference of pressure under the two wings, on the one hand, and the centrifugal force tending to send him out of the curve he wishes to fly in, on the other; and also to enable him to resist the sudden action of any gusts of wind to which his machine may be subject. Sudden gusts of wind are one of the aviator's great troubles; they tend to upset the balance of his machine, to make it difficult for him to steer and to maintain an even keel.

Air-Pockets

Readers will have noticed, in the accounts of aviation contests from time to time, that an aviator got into an air-pocket, and had considerable difficulty in continuing his flight. In some cases, too, where fatal accidents have occurred, such as that of Mr. Gilmour, it has been strongly suspected that the machine got into an air-pocket at the moment when the accident occurred.

Exactly what air-pockets are is not thoroughly known. Investigations are going on upon the subject, and these experience which aviators are making will be of great value in clearing up some of the mystery attaching to them. As far as is known, they are spaces in the atmosphere in which the air is either not in motion or in which its motion suddenly lessens, and in which certain conditions exist, such that the ordinary support afforded by the passage of the supporting planes through the air is considerably lessened. The result is that the machine, as a whole, loses a portion of its lifting power, and tends to make a dive to the earth. If the aviator is in full control of his machine, is on the look-out for everything of the kind, and the air-pocket is not of large size, and if the machine is at a considerable height above the ground, he will probably be able to pass over it. Air-pockets are found in the air above valleys between steep hills. In the circuit of Britain race considerable trouble was experienced by some of the competitors, in the Pentland Hills when leaving Edinburgh, and in the Cumberland Hills on the other side. As an illustration, supposing a machine to be flying against a twenty-mile wind, the machine flying at the rate of forty miles an hour. The lifting pressure is in the proportion of the square of sixty miles an hour. If, now, when passing over a valley or some other space where adjoining hills screen the air, the adverse wind of twenty miles an hour ceases, the lifting pressure decreases in the proportion of 36 to 16.

How an Aeroplane is Controlled

It has been explained that steering to right and left is accomplished by moving the vertical rudder to right and left; that directing the aeroplane to rise or fall is accomplished by tilting the elevator plane up or down. In addition, for the purpose of balancing, what are called ailerons are fixed on some biplanes; in other biplanes either the rear ends of the planes are moved up or down; or, again, in other biplanes, flaps attached to the upper supporting plane are moved up or down. In monoplanes portions of the wings are moved up or down. The object of the whole of these arrangements, the movement of the ailerons, the warping of the ends of the supporting planes or the wings, is to help to preserve the balance, to counteract any tendency of one side of the machine to lift more than the other. Inclining the ailerons upwards causes an increased upward pressure upon them and increases the lifting power on that side of the machine. Similarly, warping either the wing of a monoplane, or one end of the main planes of a biplane, or the flap mentioned above upwards tends to increase the lift on that side upwards. Depressing the ailerons, the wing, the flap, or the end of the supporting plane lessens the upward pressure on that side; so that if one aileron or the equivalent is tilted upwards and the other downwards, the machine tends to lift one side and to depress the other.

All of these have to be controlled from the pilot's seat. The pilot is seated in a chair at as near the centre of gravity of the whole machine as can be arranged. He has the engine either in front of him, at his side, or behind him; he has a tank of petrol either right behind him, right under him, or close in his neighbourhood. The radiator for cooling the cooling water is also fixed in his immediate neighbourhood, so that he has no space to move about. In many cases he is strapped into his chair, as it has been found that fatal accidents are sometimes avoided by the aviator not being thrown out when the machine strikes the ground. In other cases he is strapped in with an easily detachable strap, so that he can be held in case safety lies in that direction, or can spring clear if a chance offers. The Avio Company have a special strap made on these lines.

Drivers of motor-cars will have been drilled into the necessity, which also rules with the aeroplane, of having all controls easily handled without moving from the seat. Both hands and both feet may be employed, but the controlling arrangements must be such that they are easily within the reach of hands and feet respectively.

A favourite form of control that has many advantages consists of a steering pillar, as shown in fig. 16, which is the Bleriot form of control, closely resembling the steering pillar of a motor-car. It is usually arranged to have four distinct motions, without removing the hands from the wheel.

Throwing the pillar directly forward tilts the elevator

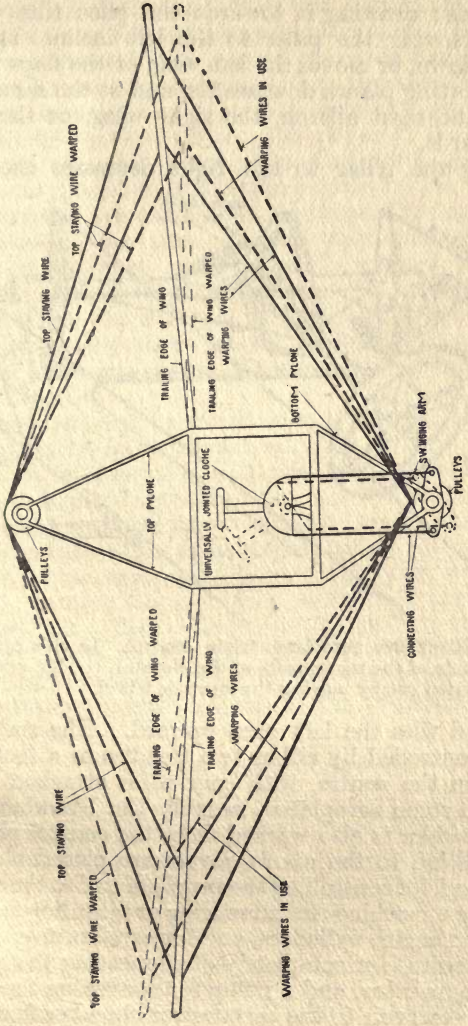

FIG. 16.—Diagram showing the method employed for warping the wings of the Bleriot machine. The universally jointed *cloche* is a form of the universal lever described in the text.

downwards; drawing it towards the pilot tilts it upwards. Moving the pillar to the left inclines the left ailerons down, or moves the left wing or the flaps of the left supporting planes downwards, and at the same time inclines the right aileron, the right wing, or the right flap upwards.

Moving the pillar to the right depresses the right

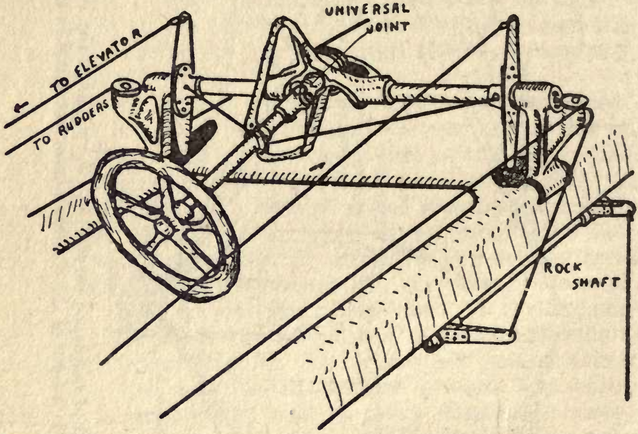

FIG. 17.—Blackburn aeroplane, triple control. In this apparatus the whole of the movements of the elevator, rudder, and wings are carried out by moving the steering wheel.

wings and tilts the left ones upward. The rudder is usually controlled by either two treadles or a foot lever pivoted in the centre, with guy wires attached to the ends. In some aeroplanes, notably the Blackburn (fig. 17), the rudder is also worked from the control pillar.

In addition to the above, levers are placed near the pilot's hand, for controlling the supply of fuel to the engine, and in some machines for advancing or retarding the ignition in the engine cylinders, and for accelerating. There is also a switch for completely disconnecting the electric ignition apparatus, and a pump for conveying the petrol from the reservoir to the carburettor chamber float.

It will be understood that the arrangements vary with the engine, the aeroplane and the pilot. The above will give a general idea. In all cases the motion of the different levers, the steering pillar, the steering wheel, &c., are communicated to the different parts under control, the vertical rudder, the elevator, the ailerons, the wings, &c., by either plain steel wires, plain steel strip, or a special form of stranded steel wires. Careful arrangements are made that, whatever the form of the transmitting apparatus, it shall work quite easily, so that the different controls shall respond certainly. One of the makers of aeroplanes, Mr. Roe, gives the caution that the controls should not be worked too quickly, as they move slowly. Literally a man's life may depend upon one or other of the controls responding to his will.

It may perhaps be noted *en passant* that the skilful aviator learns to act practically by instinct, by subconscious cerebration, as it has been termed. Those who are engaged in engineering know that there is an engineering instinct, a sort of sixth sense, which warns a man exactly what to do under certain changing conditions. This sixth sense is particularly in evidence in flying. It may be said that without it probably no one could fly. The aviator must be ready to do exactly the right thing, to turn the right lever in the right way at the right instant; and this can only be accomplished by constant practice, leading to the acquisition of this sixth sense.

Steering across Country

When one is in the air, the country-side one has left has quite a different appearance to that which it had when standing on the ground, or even from a slight elevation. The higher the machine ascends in the air, the greater is the area over which the survey of the aviator extends, and the more difficult it is for him to distinguish any particular object. Standing on the ground, we are accustomed to look at the sides of houses, of churches, and other large buildings, and to find our way about by the appearance which they present from their sides. They present quite a different appearance when looked straight down upon from above. Trees, roads, rivers, in fact, everything looks quite different. Further, in certain cases, as aviators have found, it is necessary to fly at a height, or under conditions, when no guidance whatever can be obtained from the appearance of the land below. Clouds often intervene between the machine and the ground. The machine may be obliged to fly in a cloud for a certain time, and everything that will furnish guidance is shut out. In flying across bodies of water, such as the English Channel for instance, the Irish Channel, the Atlantic Ocean, as will probably be done before many years are over our heads, the aviator is in exactly the same position as the sailor. The sailor has to find his way by compass, and by observation of the sun, moon, and stars. The aviator has not yet covered sufficient distances to be obliged to take observations of the heavenly bodies. That will probably come later on. Meanwhile he has arrived at the condition in which he requires a compass. The ordinary ship's compass is rather difficult for a landsman to understand. It consists of a card having all the points of the compass, North, East, South and West, with the intermediate points, N.E., S.E., S.W., and N.W., and the points intermediate between them marked on it, and a strip of magnetised steel attached to its under-side. The card, with the strip of steel, is very carefully balanced upon a jewel, so that it may move freely to right or left. It is fixed on the inside of a basin-shaped receptacle, suspended on gimbals so that it shall maintain a horizontal position under all conditions. At one point in the circumference of the basin is a strip of brass known to sailors as the "lubber's point." The "lubber's point" represents the direction of the ship's head, and when a ship is sailing on a certain course, that course as given by the compass card is always opposite the "lubber's point." The "lubber's point" in an aero compass will show the direction of the head of the machine. Two facts, however, should be mentioned. The compass needle does not point to the earth's North Pole; it points to the magnetic North Pole, or in southern latitudes to the magnetic South Pole, so that its indications will vary in different parts of the globe. A correction is made for this when laying the course of a ship. The error is called magnetic variation. In addition to this, any iron in the neighbourhood of a compass needle exercises an attraction for it; and as with the needle swinging round upon its centre, as the ship or the aeroplane alters its course, the positions of the masses of iron with reference to the needle change, their effect upon it also changes. Before any ship goes to sea, its compasses are "swung," as it is called for "deviation," the error due to the iron. The ship's head is swung to every point of the compass, and the effect of the iron upon the needle is noted; and this is allowed for when laying the ship's course.

M. Bleriot uses a specially constructed compass, slung in front of the aviator. It responds to motion in all directions. Apparently aviators flying the Bleriot machine are able to navigate by the aid of this compass.

Another and completely novel form of compass has been worked out by Mr. Eric Clift. In place of the usual compass card, with the points of the compass on it, the card is divided into degrees, so that airmen who do not know the compass points will understand it. The compass is mounted on gimbals, allowing motion laterally and longitudinally, and the deviation error is counteracted by two small steel magnets in the neighbourhood of the compass needle, the position of which can be adjusted. The aeroplane is "swung" just as a ship is, and by adjusting the steel magnets it is claimed that the "deviation" error is made very small. When an aviator is to fly across country, his course is marked out on a map, so many degrees from north, counting round by way of east and south. Thus east is 90°, south 180° west 270°, and so on. The correction for variation is made, and a pointer on the compass is set to the number of degrees forming the course. The "lubber's point" inside the case containing the compass shows when the aeroplane is on its course. On each side of the "lubber's point" are segments, one coloured green and the other red. If the head of the machine is turning off its course to the right, it will show on the green segment; and if it is turning off to the left, it will show on the red segment. For night flying three small lamps can be provided—a white light in the centre, and green and red lamps for the respective segments. Mr. Clift has also prepared what may be termed bird's-eye maps, upon which the different towns, villages, roads, rivers, &c., are coloured in a particular way. Railways are shown as thick black lines, with the number of lines of rails in figures; water is shown blue; trees and vegetation green, &c. Heights of various hills are marked in figures. The maps are made for different cross-country flights, as from Brooklands to Salisbury Plain, from Hendon to Brooklands, &c., the course to be steered occupying a middle line running through the length of the map. The map is made on tracing-cloth, and is rolled up and placed in front of the pilot, who unrolls it as he proceeds, so that he always has in front of him the ground over which he is flying.

Dressing for Flying

The matter of dress when flying is most important, as will easily be understood. Those who have done much motoring will remember how very keen the wind created by a motor running at a high speed is in finding its way through almost any kind of clothing. This is still more accentuated when flying. The speed of flight is very much greater than the speed of motoring, and, in addition, the temperature at the altitudes to which the machines ascend is often very much lower than that near the ground. It goes without saying that woollens should be used; but something is wanted outside of the woollens to protect the body from the keen blast of air, and also to protect it from the oil that is sprayed out from the engine. Various substances have been employed. Leather has been a favourite with motorists, and is worn by some aviators. One material which has found favour is an oiled silk, very light, very flexible, which resists the wind very well, while it also protects the clothes from oil-splashing. Ladies who take to flying will doubtless evolve their own dresses. Probably something on the lines that have been adopted for yachting in rough weather will come near what is required. In all cases the ankles should be protected, the ends of the sleeves should fit very tight, as the wind has a nasty knack of finding its way up the arms and legs, but the dress must be ventilated. The neck, also the head and the ears, should be well protected. Special forms of helmets have been designed to protect the head in case an aviator is thrown out of his machine. Goggles to protect the eyes are required; in those preferred the pilot can see out of the sides without turning the head. The hands should have very warm, very flexible gloves. If the hands become cold, the control pillar wheel is apt to be gripped too tightly.

Housing Aeroplanes

Up to the present the hangars, as they are called, for housing aeroplanes have all been temporary structures. As time goes on and the aeroplane assumes its final form, or one that will not change for some time, more permanent structures will be adopted. Hangars at present are built principally of wood or corrugated iron. The entrance must be sufficiently wide and high to allow the machine to run in and out on its wheels, without any danger of the tips of the wings or the ends of the planes touching. There should be a good clearance on each side in case the machine is canted on its way in or out.

It will be obvious that the hangar for a biplane must be higher, and usually deeper from front to back, than that required for a monoplane.

The hangar must be of sufficiently strong construction to stand the heaviest storms that may blow over the neighbourhood. The aerodrome is chosen usually because it is clear of surroundings, because the aviators can have a clear fly round and round; and this means that it is more or less exposed. Arrangements should be made for warming the hangar, and care must be taken that the warming arrangements are not such as will fire the petrol. Petrol evaporates at a very low temperature, and the vapour issuing from any body of petrol will ignite when in contact with a flame or any body at about a red heat, the vapour burning backwards to the body of petrol from which it issued, and setting fire to it with disastrous results. Probably the best method of heating hangars would be by hot-water pipes and hot-water radiators, the boiler for heating the water being fixed quite clear of the hangar itself, and protection being provided between it and any woodwork in the neighbourhood.

CHAPTER IX

THE PROBLEM OF STABILITY

The problem of stability, of maintaining the aeroplane on an even keel, to use a sailor's expression, is practically *the* most important the practical aviator has to master. It will be remembered that the whole machine is floating in the air, that it is supported by the pressure of the wind underneath its supporting planes, and underneath the elevator, the auxiliary planes, the ailerons, &c. It will easily be understood that any variation in the pressure at any part of the supporting surfaces will force that portion of the machine up, and other parts will be correspondingly depressed.

For comfort in flying, it is important that the machine shall float in the air very much as a boat comfortably laden floats in calm water. Everyone knows the discomfort which arises in a boat that is subject to a choppy sea, or that is under sail, with a varying pressure of wind. The same kind of trouble rules with the aeroplane and in very much the same way, though with the differences due to the larger supporting surfaces of the aeroplane, and the lower density of the fluid in which it is supported. Aeroplanes rock just as boats do, from side to side; they pitch head and stern again just as boats or ships do. Also the rocking and the pitching are due to practically the same causes as in the case of boats or ships.

The Centre of Pressure and the Centre of Gravity

In studying the problem of stability, two points in the body of the machine have to be taken account of, viz. the Centre of Gravity, and what is called the Centre of Pressure. The Centre of Gravity hardly needs description. It is that point at which the whole of the weights of the machine may be taken to be concentrated.

It is the point from which, if a line with a weight on the end of it were suspended, the weight and line would hang vertically in space. As explained in a former chapter, the pilot's chair is placed right over the Centre of Gravity, or as nearly as is practicable; and in some of the later forms of aeroplanes the tank containing the reservoir of petrol is placed under the pilot's seat, also over the Centre of Gravity, so that the change in the weight of petrol carried in the reservoir tank will not make any difference in the position of the Centre of Gravity.

The Centre of Pressure is that point at which the sum of all the pressures supporting the aeroplane are supposed to act. As explained in previous chapters, there are a number of component pressures going to make up the complete pressure supporting the machine. The component pressures act at different parts of the supporting planes; but the resultant pressure, as it is expressed in mechanics, may be taken to act at one particular point in the machine. It is of the greatest importance that as nearly as possible the Centre of Pressure and the Centre of Gravity should be in one.

This will perhaps be better understood when it is mentioned that the resultant force acting at the Centre of Pressure tends to turn the machine as a whole round the Centre of Gravity as a fulcrum. Readers will be familiar with the properties of the lever; how a weight acting at a distance from a point called the fulcrum has a greater and greater effect, a greater and greater power to lift the other arm of the lever the greater the distance of the weight from the fulcrum. Similarly, the greater the distance of the Centre of Pressure from the Centre of Gravity, the greater is the leverage exerted by the resultant pressure to turn the machine round the Centre of Gravity. As long as the aeroplane is flying at a certain definite speed, with wind of a certain definite force, and blowing in a certain direction, the position of the Centre of Pressure will not be changed; and provided the position of the Centre of Gravity is not changed, the stability of the machine should remain constant. But any change in the direction in which the machine is moving, any change in the direction or force of the wind will tend to change the position of the Centre of Pressure, to produce a "mechanical couple," as it is called, tending to turn the machine as a whole round the Centre of Gravity. Any change also in the position of the supporting planes alters the position of the Centre of Pressure. Tilting the elevator, for instance, or lowering it; tilting the ailerons or lowering them; turning the rudder to right or left, all tend to alter the position of the resultant of all the pressures acting, and to upset the stability of the machine as a whole.

With aeroplane engines, also of the Gnome type, which have what is called a gyroscopic action, there is another force introduced, tending to disturb the Centre of Pressure.

The Gyroscope

The gyroscope is only now emerging from the position it has occupied for a very long period, as a laboratory or even a school-boy's toy. The gyroscope in its simple form consists of a heavy wheel revolving in a certain plane upon an axle, which is, of course, at right angles to that plane. The peculiar property of the gyroscope is, if any change is made in the direction of the axle, or of the plane in which the gyroscope wheel is revolving, the gyroscope resists the change by executing a movement in a plane at right angles to that in which the change occurs.

To apply this to the gyroscopic action of the Gnome engine; the seven cylinders arranged radially, and revolving at the high speed at which they run, virtually form a gyroscope wheel; and if the axle upon which it revolves say turns to the right or left, the gyroscope wheel immediately tilts either up or down, carrying the head of the aeroplane with it. Also the gyroscopic action of the Gnome engine will tend to cause the machine as a whole to turn to right or left out of its proper path, if from any other cause it has pitched up or down. It should be noted that the direction in which the aeroplane moves under the influence of the gyroscopic action of the Gnome engine, depends upon the direction of revolution of the engine cylinders, as well as upon the other motions. If, for instance, the engine cylinders are revolving in a clockwise direction, as seen from behind, the machine will tilt up or down, with motion right or left; and if the Gnome engine is revolving in a counter clockwise direction, the tilt will be down or up, in a reverse direction to that in which it moved when the engine was running clockwise.

Longitudinal and Lateral Stability

By longitudinal stability is meant freedom from pitching, from the machine dipping its nose at one moment and lifting its nose the next. By lateral stability is meant keeping the general line of the machine in one plane, either horizontal or slightly inclined to the horizontal; and freedom from rocking, from one wing, or the ends of one set of supporting planes dipping at one instant, and rising at the next.

Longitudinal stability will be altered by a change in the tilt of the elevator, by a change in what is called the "angle of incidence," the angle which the main supporting planes make with the horizontal line, and by changes in the force or direction of the wind passing under the elevator and main planes. One use of the tail plane is to assist in providing longitudinal stability. As mentioned above also, longitudinal stability is interfered with by the aeroplane turning to the right or left, when an engine having gyroscopic action is employed to drive it.

The pilot has to keep his senses thoroughly alive to any change in the longitudinal stability of his machine, and only practice can enable him to do so. One of the instruments that is carried on some aeroplanes is an inclinometer, enabling the aviator to see any variation in the inclination of his machine to the vertical as a whole.

For efficient flying the best "angle of incidence" has been found in practice to be about 8°, about the eleventh part of a right angle. The "angle of incidence," when fully described, is the angle made by what is called the "chord" of the supporting plane with the horizontal. The "chord" of the supporting plane is a line drawn from the front spar to the back spar. It will be remembered that the supporting plane itself is cambered, that it bellies upwards just like the sails of a ship belly outwards, and also that the front edge of the supporting plane is slightly inclined to the horizontal. The angle between the horizontal and the cambered surface cannot be measured, as it is different at every point of the surface; but the angle between a horizontal line and a line drawn from the front to the rear spar can easily be measured, and that is called the "angle of incidence." It will easily be seen that if the supporting plane is inclined upwards, as in mounting in the air, the "angle of incidence" is increased, and *vice versa*. It may be mentioned that as the "angle of incidence" increases, so does the pressure of the air passing under the cambered surface, up to a certain angle, which is never reached. On the other hand, as mentioned in the previous chapter, power is required to be expended in lifting the machine when the supporting planes are inclined upwards, in addition to that required to drive it through the air, and it may happen that the power taken to drive it upwards so reduces that available to drive it through the air that the supporting pressure is lessened.

It will easily be understood also, that as the "angle of incidence" increases, as the supporting planes are tilted upwards, the position of the Centre of Pressure moves towards the rear of the machine, and as the supporting planes return towards the horizontal, the Centre of Pressure moves forwards again, and when the supporting planes are tilted downwards, as when the machine is descending, the pressure may be on the upper side of the supporting planes.

The aviator has to look out for all these things. It may help him when planing down, for the pressure to be acting on the upper side of his planes instead of the lower side.

Lateral Stability

Lateral stability is maintained mainly by warping the wings of monoplanes, by moving flaps attached to the supporting planes of biplanes, as described, or by moving the ailerons. Lateral stability is more difficult to maintain, according to the experience of most aviators, than longitudinal stability. If the machine tends to pitch longitudinally, a little trimming of the elevator plane will usually put the matter right. On the other hand, if there is a side wind, and if, as is very common, its force and direction are constantly changing, the pressures under the two wings, or the two sides of the main planes in a biplane, will be constantly changing, and the machine will be constantly tending to rock. This is particularly true when rounding curves. As explained in a previous chapter, it is absolutely necessary that the machine shall be banked up a little, just as it is necessary for the outer rail of a railway on a curve to be raised above the inner rail. The train could not pass round the curve without; and, similarly, the aeroplane could not make a turn unless it was banked up to a certain extent. But immediately one wing is raised above the other, it is more exposed to gusts from that side than when the machine is flying in a horizontal or nearly horizontal position; and hence the aviator has to be constantly on the look-out while he is rounding curves against gusts of wind taking his outer wing. When a machine is flying also, apparently in a perfectly horizontal plane, there will be little differences of density in the air, of pressure under one wing or the other, tending to lift that wing and to press the opposite. If, as so often happens, a gust blows from the side at which the wing is slightly raised, the trouble is very much increased, and several accidents have been due to this cause.

To maintain lateral stability the vertical rudder is used to a certain extent; turning the rudder in one direction will tend to correct the tendency to bank up. But the principal agents in maintaining lateral stability are the wing tips, the ailerons, or their equivalent. The aviator again has to be constantly on the look-out to see quickly if either wing is being lifted, and to immediately increase the pressure on the opposite side, and decrease the pressure on that side. He has to be careful, of course, as in all matters of this kind, not to over do it. If he puts too much pressure on the offside by tilting the ailerons or the wing more than is necessary, that side will be elevated too much in its turn, and he will have to repeat the operation on the other side. As in steering a boat or a ship, success in maintaining lateral stability is obtained by small motions of the wings or ailerons, the motion being carried out in good time, and not violently.

Automatic Stabilisers

There is very little to be said about automatic stabilisers; they are literally in their infancy. As the name implies, the object of the apparatus is to relieve the pilot. As will be judged from what has been said in this and previous chapters, the pilot must have all his senses fully alive, and must be able, by instinct practically, to do the right thing at the right time. The object of the automatic stabiliser is to do as much as possible of the right thing at the right time for him, in the matter of keeping the machine on even keel. So far, not much has been done in the matter. A machine has been invented by Lieutenant Dunn in which the main planes, in the case of a monoplane, are inclined to each other at a particular angle and have a particular curve.

It is claimed that this "dihedral" angle, as it is termed, with the particular curve given to the wings, enables the machine to right itself automatically in case of disturbance by gusts or other causes.

It has been proposed to employ the gyroscope to compensate for any movement of the Centre of Pressure. It has also been proposed to employ a pendulum to operate in the same manner. In connection with the Blackburn aeroplane, an automatic stabiliser has been worked out in which a cylinder containing compressed air, and with a freely-moving piston inside, is made to operate ailerons in the same manner as the pilot himself would operate them. A small rolling weight connected to the end of a long lever controls the cylinder of compressed air, and through it the ailerons.

As time goes on, doubtless very much more will be done in that direction.

CHAPTER X

GENERAL INFORMATION

Aviation Meetings

As mentioned in the first chapter, the first meeting of the kind was held at Rheims in France in the autumn of 1909, and the example set has been followed by a number of towns in the United Kingdom. Blackpool and Doncaster held aviation meetings in October of the same year, and a number of others were held at Lanark, Bournemouth, and elsewhere in the following and succeeding years.

At the early aviation meetings a piece of ground was enclosed, of sufficient area to provide practically an oval aerial race-course. Four "pylons," as they were called, were fixed at points to mark out the course, two near each end of the length of the "aerodrome," as the enclosure was called. Around the enclosure were other enclosures, to which the public were admitted on payment of various sums. On one side of the enclosure were temporary buildings called "hangars," for the housing of the machines. A grand stand, a judge's box, arrangements for signalling the force of the wind and similar matters completed the arrangements. The displays at the early aviation meeting were by no means satisfactory. Enormous numbers of spectators paid various amounts to stand for hours within boarded enclosures, without refreshment, with practically no accommodation beyond standing-room, on the chance of seeing some one mount in the air on one of the machines. In those days, however, aviators had to be very careful indeed as to when they flew. Careful observations were made of the air currents, and a wind of 15 miles an hour or so was the limit in which any aviator would venture, The consequence was that often the public had to wait for hours together, seeing nothing and doing nothing. At Doncaster during the aviation meeting in 1909 the present writer spent a whole afternoon without seeing any one fly, and no one had ventured out during the forenoon.

With the advance in the manufacture of aeroplanes, with increased strength in their construction, with increased power in their engines, with increased skill in the aviators themselves, the range of possible aviation has been steadily increased. Men are no longer afraid to fly in winds of 30 miles an hour, providing they are on good machines.

The aviation meetings, as they were held in the years 1909 and 1910, are naturally being discontinued. The public are no longer content to pay money and spend time and see nothing. Since then permanent aerodromes have been established at Hendon, a little way out of London; at Brooklands, near Weybridge, also a little way out of London; at Shoreham, near Brighton, and elsewhere. Salisbury Plain is also used as an aerodrome, without the necessity of enclosing it. The aerodromes are enclosures, similar to those where flying took place at Rheims, Blackpool, and elsewhere, and flying still takes place over them. They are more, however, in the nature of flying schools than of race meetings, though there is again a tendency to give exhibitions at the principal aerodromes, Brooklands and Hendon. The principal makers of aeroplanes have built sheds adjoining the aerodromes, in which in some cases the building of aeroplanes is carried on, and men and women who wish to learn to fly are trained. What are called school machines have been designed, arranged to carry two, the pilot and a passenger.

Learning to fly costs anywhere from £50 upwards, and may take from a week up to six months. Some men and some women learn very quickly; they appear to have something of the natural instinct mentioned in a previous chapter, which leads to their learning the tricks of the machine very quickly, and easily acquiring the automatic habit that is necessary for flying. Others again are very slow at learning, and only acquire the art after repeated trial and instruction. Time is often required to acquire the art of flying, because of the necessity of choosing when a pupil can be taken up, or when he can go up by himself. Obviously pupils have to be inducted into the art gradually. Their first step in learning to fly consists in running the machine on its wheels, by the aid of the engine, on the ground. The school machine is made with substantial tyres, and the landing chassis is strong enough to stand the turning movements that are necessary when working entirely on the ground. By rolling the machine to and fro, and turning round the aerodrome on the ground in this way, the pupil learns to know what the different levers are for, or the different motions necessary where the one steering-wheel lever is employed. Gradually a certain amount of the automatic sense comes to him. When he is fairly familiar with the motions of the levers to run to and fro, &c., he is taken for gentle flights, by the side of an instructor, at a few feet above the ground. He is taught to accustom himself to the difference in the behaviour of the machine when running on the ground and when moving through the air alone ; and again the effect upon the machine of coming suddenly to ground. As he becomes more and more familiar with being in the air, the instructor takes him a little higher and a little higher, and gradually inducts him into working the levers, to handle the machine himself. First he sits by the instructor's side, and watches every movement which the instructor makes. Then he holds the levers at the same time as the instructor, sitting in such a position that he can do so. Gradually the instructor resigns the levers to the pupil's hands, his own hands being ready to take hold of them in case the pupil makes a slip. Some firms have machines with duplicate control. Gradually as the pupil acquires more and more confidence, the control of the machine is given up to him more and more, and finally he is allowed to make short flights at a low height above the ground by himself. Then he flies higher and higher, he commences to make turns, and so on, gradually acquiring the necessary experience, and the all-important instinct that has been so often referred to. The pupil must live near the aerodrome for the time, and be ready to take advantage of every favourable opportunity to fly.

Aviation Races

The aviation meetings have naturally merged into aviation races. With machines flying at from 40 miles an hour upwards, the space furnished by the largest aerodrome is not sufficient for a race that would be of much interest. A race also in which a machine is going round and round an enclosure a large number of times is very tame. Hence on the Continent of Europe, and in the United Kingdom, aviation races have been arranged that were of intense interest, as mentioned in the first chapter. In the Circuit of Britain race, at each of the towns mentioned what was called a control was established. Experts appointed by the Royal Aero Club were established in an aerodrome, specially arranged for the purpose, at each control town. Each aviator had his machine examined at each control, and the times of alighting, &c., were taken. Compulsory halts for a certain time were enforced at Newcastle-on-Tyne, at Edinburgh, at Manchester, at Bristol, and at Brighton.

This year a number of other races are promised in different parts of the United Kingdom and still more on the Continent of Europe. France, which has been so much to the fore in the matter, is intensely enthusiastic over the subject. Money is being poured out like water in France to establish a school of flying men, the Government heading the movement. To anyone who is taking a holiday on the Continent it would be difficult, probably, during next summer or autumn to stay anywhere that he will not have an opportunity of seeing some aviation going on.

In addition to the races mentioned, a number of prizes are offered for competition by different gentlemen and by different bodies for various feats.

The Royal Aero Club

The Royal Aero Club occupies the same position with regard to aviation as the Jockey Club does with regard to racing. It consists of a body of gentlemen who are interested in aviation, and who have elected from among their number a council, committees, and stewards, The principal function of the Royal Aero Club is the granting of certificates of qualification to aviators and the control of aerial races. It will be remembered that the Jockey Club has what amounts to practically absolute control over certain horse race-courses in the United Kingdom. Jockeys are only allowed to ride when and as long as they hold the certificate of the Jockey Club. Similarly, one of the conditions that has so far been observed in all races that have taken place in the United Kingdom has been that no aviator shall compete unless he holds the certificate of the Royal Aero Club or of one of the foreign clubs affiliated with it. There are similar Aero Clubs in America, with headquarters in New York; in Austria with headquarters in Vienna; in Belgium with headquarters in Brussels; in France with headquarters in Paris; in Germany with headquarters in Berlin; in Italy with headquarters in Rome; in Spain with headquarters in Madrid; in Sweden with headquarters in Stockholm; and in Switzerland with headquarters in Berne. There are also Aero clubs affiliated with the Royal Aero Club in nearly all the large towns of the United Kingdom.

There is a body called the International Aeronautical Federation upon which all of the clubs mentioned are represented, and which legislates for the aviation of the whole of the countries named.

The subscription to the Aero Club is two guineas per annum, together with an entrance fee of two guineas.

The Royal Aero Club has balloons of its own, which it hires out for private ascents.

The Royal Aero Club has elected a committee of honorary observers of aeroplane flights, consisting of a number of gentlemen, some of them officers of the Army and Navy, and other private gentlemen who are interested in aviation. When an aviation race is in progress the Royal Aero Club provides observers at each point of control, and the decision of the Aero Club is taken to be final.

Aviator's Certificate

The following are the conditions for an aviator's certificate :—

A candidate must accomplish two distance flights, in a closed circuit, marked out by posts 547 yards (500 metres) apart, of 3 miles 185 yards (5 kilometres) each, and one altitude flight reaching 164 feet (50 metres) above the ground.

In the course of the distance flights the candidate must perform five figures of 8 in the air. He must alight at a point within 164 yards (50 metres) of a point previously marked by himself, the motor being stopped at or before reaching the ground. The Royal Aero Club officials are particular to note the manner in which the alighting is accomplished. The address of the Royal Aero Club is 166 Piccadilly, London, W., and there is the usual club accommodation there for male members.

Uses of the Aeroplane

When the first flight was made upon an aeroplane, and for a considerable time afterwards, the machine was looked upon merely as a toy. Everybody was interested in it, because it was so wonderful that the conquest of the air had at last been accomplished after centuries of effort; but the general feeling was that it was merely a toy, merely something for exhibition, something that would go though certain evolutions, for the sight of which the public would pay.

Now that feeling is gradually being superseded by one that the aeroplane will take an important place in the practical life of all civilised nations. The first important work to which the aeroplane has been put is that of scouting. When armies are manœuvring in the field, it is the great object of each general to find out what his opponent is doing, exactly where his forces are, where each particular arm is weak, and where, above all things, he is open to attack. On the other hand, each general makes the greatest efforts to prevent his opponents from finding out all about himself. The art of hiding men, and even of artillery and of horses, has been brought to such success that the non-military observer might be in the midst of an army of 30,000 or 40,000 men and be perfectly ignorant of their presence. Every inequality in the ground, every natural object, such as a tree, a mound, a house, &c., is made use of for the purpose of concealing the presence of men, horses, and accessories. One great object of cavalry, the principal work which they have to do, is to scour the country in front of them and sometimes in their rear to obtain all possible knowledge about the enemy. It will be evident that with an aeroplane flying at anywhere up to eighty miles an hour, and that has been exceeded at the time of writing, and viewing the surface of the ground from above—provided the pilots, or passengers accompanying them, are trained to observe the ground and the bodies of men on the ground from above—practically any disposition of the enemy could be discovered. The French army have already arranged for a special Flying Corps, and for the attachment of a certain number of aviators to each division and to each brigade. In the French army manœuvres which took place last autumn, the aviator scouts were able to locate what the friendly enemy, the other side in the manœuvres, thought were very well-hidden bodies of men. In the war of the future the aeroplane will perform a great part. It will not only have to scout, but each aeroplane will have to defend itself from other scouts, and sometimes to attack aeroplane scouts belonging to the enemy. It is as important to the general commanding to prevent information being carried to the enemy as to acquire information of the enemy himself.

For the Navy also scouting by aeroplane will be invaluable. The exhibition of hydro-aeroplanes before his Majesty at Portland, a few days before this was written, has shown how very valuable the aeroplane will be. It will be remembered that his Majesty's yacht was lost in a fog. It was expected at Portland some hours before it arrived. The aeroplanes were sent out to find him, and succeeded in doing so, though the yacht was at the time in a dense fog.

One of the greatest dangers to be feared by the modern battleship, costing anywhere up to two million pounds, is an attack by a submarine. A submarine is a vessel ranging from the size of a comparatively small sailing yacht up to that of a small cruiser. It is able to move about on the surface of the water up to a convenient distance from the ship it is intending to attack. It then dives; disappears below the surface of the water; approaches to within a fairly short distance from the object of attack, and discharges one or two torpedoes at her, escaping under water in the same way as it approached. The submarine is absolutely invisible from the deck of a ship, and even from such masts as are now carried. On the other hand, it cannot dive very far below the surface of the water, because it has to keep what is called its "periscope" above the water, or it cannot find its own way about. At the depth which its "periscope" allows, the submarine is quite visible from an aeroplane flying at a considerable distance above; and consequently the aeroplane could warn a possible ship of an attack, or could even deliver a counter attack against the submarine, by dropping a bomb upon it. Under present conditions the submarine could rarely see the aeroplane approaching, and would be practically helpless to defend itself from the bomb.

It is supposed also that aeroplanes will be able to drop bombs over fortifications, towns, and on the decks of men-of-war. The present writer has considerable doubt as to this being accomplished. Bombs might be dropped over towns, such as London, Manchester, or Glasgow, for instance, but that would probably not be allowed. It would rarely get within the necessary distance to drop bombs over forts or ships, if a proper look-out was kept, even in the night, without being subject to attack itself. As its engine and controls are very sensitive indeed, one bullet might put it out of action.

It appears to the writer also that aeroplanes should be of great service to ocean liners. The tragedy of the *Titanic* suggests to him, that if she had carried three or four aeroplanes, that could have scoured the ocean around, as they could have done for 40 miles or so within a very short time, some of the ships that could not reach in time to save the 1400 who were drowned might have rendered some aid.

The Future of the Aeroplane

In the Author's opinion the future of the aeroplane will be difficult to limit. Commencing with a flying speed of 30 miles an hour, speeds of 80 and 90 miles an hour have been reached; and commencing with a few minutes in the air at a time, aviators have remained in the air for several hours. He believes that a regular aeroplane service will be established between all the great cities of Europe, and between the great cities of America, and eventually between Europe and America, Europe and Asia, Asia and America. Lives have been lost and more will be, but the work will go on.

In conclusion, the Author would point out that the consequences of accidents may be minimised if first-aid appliances are carried. What are called "Tabloid" First Aid outfits are now on the market, the cases containing all that is required in the way of bandages, dressings, &c., measuring only from 6 inches to 8 inches by 4 to 5 inches, by 2 inches, so that room should be easily found for one of them.

BIBLIOGRAPHY

Mechanics of the Aeroplane, by Capt. Duchêne, translated from the French. Longmans, Green & Co.
Aerodynamics, by Lanchester. Constable & Co., Ltd.
Aerodonetics, by Lanchester. Constable & Co., Ltd.
Art of Aviation, by R. W. A. Brewer. Crosby Lockwood.
Birdflight as the Basis of Aviation, by Otto Lilienthal. Longmans, Green & Co.
Practical Aerodynamics, by Major B. Baden-Powell.
Aeronautics. Published at *Aeronautics* Office.
Researches and Experiments in Aerial Navigation, by Prof. Langley. Published at Washington.
Problem of Flight, by Chatley. C. Griffin.
Principles of Flight, by Algernon E. Berryman, offices of *Flight.*
Stability in Aviation, by Prof. G. H. Bryan. Macmillan.

INDEX

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