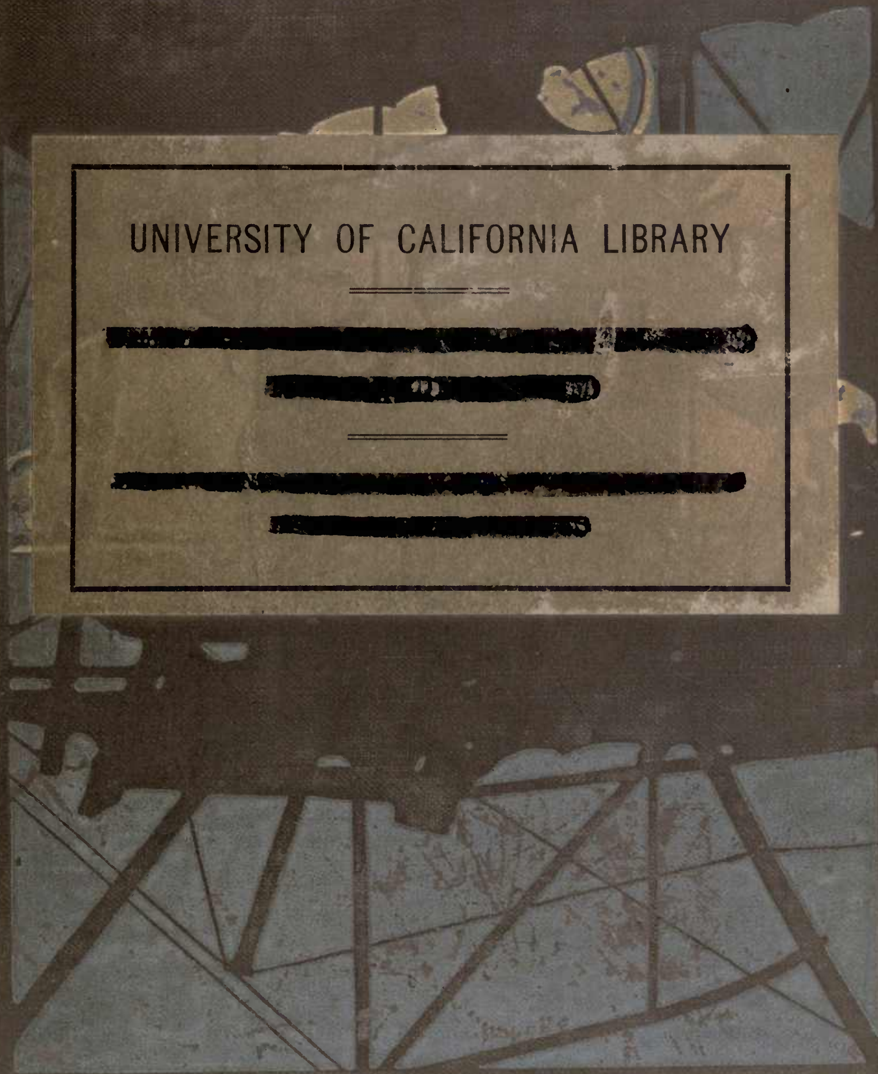
THE NEW ART OF FLYING



WALDEMAR KAEMPFFERT

THE NEW ART OF FLYING

Photograph by Edwin Levick

Fig. 36.—The Hanriot monoplane in flight. The entire framework is covered with canvas to reduce resistance

The New Art of Flying

BY

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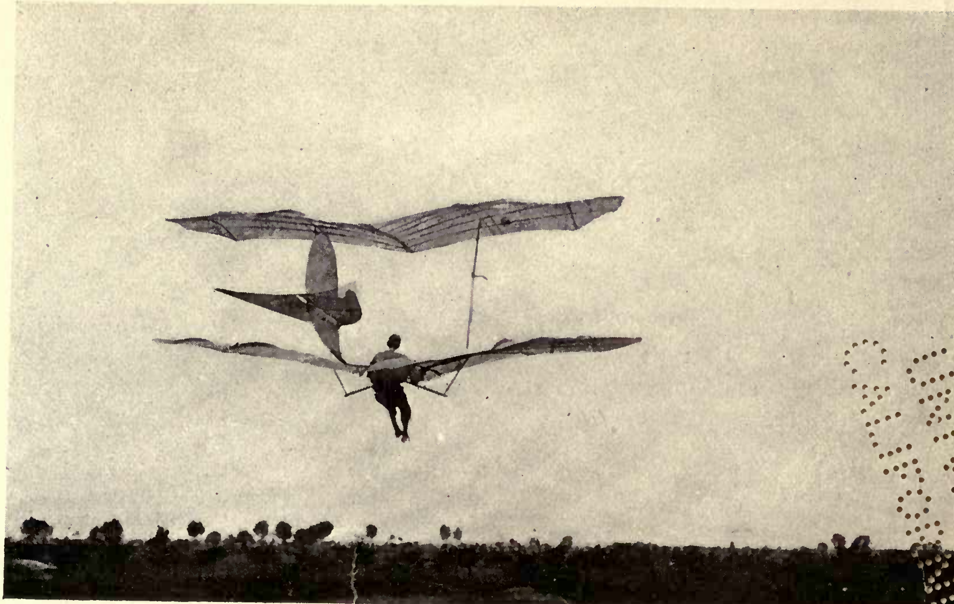

Photograph by Edwin Levick

Fig. 1.—Lilenthal gliding in the machine in which he was killed

PREFACE

When the time comes for some historian of the far-distant future to survey critically the technical achievements of the nineteenth and twentieth centuries and to weigh the comparative economic importance of those achievements, it may be that the invention of the aëroplane flying-machine will be deemed to have been of less material value to the world than the discovery of Bessemer and open-hearth steel, or the perfection of the telegraph, or the introduction of new and more scientific methods in the management of our great industrial works. To us, however, the conquest of the air, to use a hackneyed phrase, is a technical triumph so dramatic and so amazing that it overshadows in importance every feat that the inventor has accomplished. If we are apt to lose our sense of proportion, it is not only because it was but yesterday that we learned the secret of the bird, but also because we have dreamed of flying long before we succeeded in ploughing the water in a dug-out canoe.

From Icarus to the Wright Brothers is a far cry. In the centuries that have elapsed more lives have been lost in aëronautic experimentation than in devising telephones and telegraphs. These tragedies of science have lent a glamour to the flying-machine; so much so, indeed, that the romance rather than the technique of flying interests the reading public. Yet this attitude of wonder is pardonable. Only a few years ago the inventor of a flying-machine was classed, even by scientists, with the misguided enthusiast who spends his life in devising perpetual motion machines or in fruitless attempts at squaring the circle. It is hard to realise that the building of aëroplanes is now elevated to the dignity of a legitimate engineering pursuit.

Although the romantic aspects of aviation have not been ignored in the following pages, it is the chief purpose of this book to explain as simply and accurately as possible the principles of dynamic flight and aëroplane construction, so that an intelligent reader will learn why a machine many times heavier than the air stays aloft for hours at a time and why it is constructed as it is. The limitations imposed by a popular book are such that it is impossible to discuss with anything like thoroughness such difficult matters as equilibrium and stability, the correct proportioning of supporting surfaces to weight and speed, and the resistance encountered in the air by planes in motion. Indeed, these questions are not definitely settled in the minds of technical men. Besides presenting an elementary account of a flying-machine's way in the air, it has been deemed advisable to discuss the screw and the internal-combustion motor as applied to the flying-machine. There can be little doubt that the propeller and the engine offer many a problem for solution before the aëroplane can compete successfully with other forms of locomotion, and a discussion of the driving mechanism of an aëroplane should, therefore, constitute an essential part of even a popular book on flying.

So marked have been the changes that have been made in the construction of well-known biplanes and monoplanes and so many are the new machines that appear almost from week to week that it is almost a hopeless task to present anything like a complete account of existing aëroplanes. Hence it has been deemed advisable to limit the descriptions of types to those machines which have been in a measure standardized.

In the preparation of this volume the author has been ably assisted by several friends to whom he wishes to make due acknowledgment. He is indebted to Mr. Carl Dienstbach for a

critical reading of the entire manuscript before it passed to the press, and for many valuable suggestions; to Mr. C. Fitzhugh Talman, librarian of the United States Weather Bureau, for a painstaking revision of the chapter entitled "The New Science of the Air"; to Mr. H. A. Toulmin for information on the points at issue in the various suits brought by the Wright Brothers for the alleged infringement of their patents; to Francis W. Aymar, Professor of Law in the New York University Law School, for valuable aid in the preparation of the chapter on "The Law of the Air"; and to the Smithsonian Institution and the Wright Brothers for various photographs.

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NEW YORK, N. Y., January, 1911.

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CHAPTER I

WHY FLYING-MACHINES FLY

An aëroplane is any flat or slightly curved surface propelled through the air. Since it is considerably heavier than air, an inquiring mind may well ask: Why does it stay aloft? Why does it not fall?

It is the air pressure beneath the plane and the motion of the plane that keep it up. A balloon can remain stationary over a given spot in a calm, but an aëroplane must constantly move if it is to remain in the air. The monoplanes and biplanes of Blériot, Curtiss, and the Wrights are somewhat in the position of a skater on thin ice. The skater must move fast enough to reach a new section of ice before he falls; the aëroplane must move fast enough to reach a new section of air before it falls. Hence, the aëroplane is constantly struggling with gravitation.

The simplest and most familiar example of an aëroplane is the kite of our boyhood days. We all remember how we kept it aloft by holding it against the wind or by running with it if there happened to be only a gentle breeze. When the wind stopped altogether or the string broke, the kite fell. Above all things it was necessary to hold the kite's surface toward the wind, — an end which we accomplished with a string.

The eagle is an animated kite without a string; it keeps its outspread wings to the wind by muscular power. If we can find a substitute for the string, some device in other words which will enable us to hold the kite in the proper direction, we have invented a flying-machine. The pull or the thrust of an engine-driven propeller is the accepted substitute for the string of a kite and the muscles of an eagle.

If only these simple principles were involved in a solution of the age-old problem of artificial flight, aëroplanes would have skimmed the air decades ago. Many other things must be considered besides mere propelling machinery. Chief among these is the very difficult art of balancing the plane so that it will glide on an even keel. Even birds find it hard to maintain their balance. In the constant effort to steady himself a hawk sways from side to side as he soars, like an acrobat on a tight rope. Occasionally a bird will catch the wind on the top of his wing, with the result that he will capsize and fall some distance before he can recover himself. If the living aëroplanes of nature find the feat of balancing so difficult, is it any wonder that men have been killed in endeavouring to discover their secret?

If you have ever watched a sailing yacht in a stiff breeze you will readily understand what this task of balancing an aëroplane really means, although the two cases are mechanically not quite parallel. As the pressure of the wind on the sail heels the boat over, the ballast and the crew must be shifted so that their weight will counterbalance the wind pressure. Otherwise the yacht will capsize. In a yacht maintenance of equilibrium is comparatively easy; in an aëroplane it demands incessant vigilance, because the sudden slight variations of the wind must be immediately met. The aëroplane has weight; that is, it is always falling. It is kept aloft because the upward air pressure is greater than the falling force. The weight or falling tendency is theoretically concentrated in a point known as the centre of gravity. Opposed to this gravitative tendency is the upward pressure of the air against the under surface of the plane, which effect is theoretically concentrated in a point known as the centre of air pressure. Gravitation (weight) is constant; the air pressure, because of the many puffs and gusts of which even a zephyr is composed, is decidedly inconstant. Hence, while the centre of gravity remains in approximately the same place, the centre of air pressure is as restless as a drop of quicksilver on an unsteady glass plate.

The whole art of maintaining the side-to-side balance of an aëroplane consists in keeping the centre of gravity and the centre of air pressure on the same vertical line. If the centre of air pressure should wander too far away from that line of coincidence, the aëroplane is capsized. The upward air pressure being greater than the falling tendency and having been all thrown to one side, the aëroplane is naturally upset.

Obviously there are two ways of maintaining side-to-side balance, — the one by constantly shifting the centre of gravity into coincidence with the errant centre of air pressure; the other by constantly shifting the centre of air pressure into coincidence with the centre of gravity.

The first method (that of bringing the centre of gravity into alignment with the centre of air pressure) involves ceaseless, flash-like movements on the part of the aviator; for by shifting his body he shifts the centre of gravity. It happened that one of the first modern experimenters with the aëroplane met a tragic death after he had succeeded in making over two thousand short flights in a gliding-machine of his own invention, simply because he was not quick enough in so throwing his weight that the centres of air pressure and gravity coincided. He was an engineer named Otto Lilienthal, and he was killed in 1896. Birds were to him the possessors of a secret which he felt that scientific study could reveal. Accordingly, he spent many of his days in the obscure little hamlet of Rhinow, Prussia. The cottage roofs of that hamlet were the nesting places of a colony of storks. He studied the birds as if they were living machines. After some practical tests, he invented a bat-like apparatus composed of a pair of fixed, arched wings and a tail-like rudder. Clutching the horizontal bar to which the wings were fastened, he would run down a hill against the wind and launch himself by leaping a few feet into the air. In this manner he could finally soar for about six hundred feet, upheld merely by the pressure of the air beneath the outstretched wings. In order to balance himself he was compelled to shift his weight incessantly so that the centre of gravity coincided with the centre of air pressure. Since they rarely remain coincident for more than a second, Lilienthal had to exercise considerable agility to keep his centre of gravity pursuing the centre of air pressure, which accounts for the apparently crazy antics he used to perform in flights. One day he was not quick enough. His machine was capsized, and his neck was broken. Pilcher, an Englishman, slightly improved on Lilienthal's apparatus, and after several hundred flights came to a similar violent end. Crude as Lilienthal's machine undoubtedly was, it startled the world when its first flights were made. It taught the scientific investigator of the problem much that he had never even suspected, and laid the foundation for later researches.

Octave Chanute, a French engineer resident in the United States, continued the work of the ill-fated Lilienthal. Realising the inherent danger of a glider in which the operator must adapt himself to the changing centre of air pressure with lightning-like rapidity, he devised an apparatus in which the centre of air pressure was made to return into coincidence with the centre of gravity, — the second of the two ways of maintaining side-to-side balance. Thus Chanute partly removed the perilous necessity of indulging in aërial gymnastics. In his gliding-machines the tips of the planes, when struck by a gust of wind, would fold slightly backward, thereby curtailing the tendency of the centre of air pressure to shift.

Chanute built six motorless, man-carrying gliders, with three of which several thousand short flights were successfully undertaken. The best results were obtained with an apparatus consisting of two superposed planes, a construction which had been previously adopted by Lilienthal. It remained for the Wright Brothers to provide a more perfect mechanism for controlling the movement of the centre of air pressure.

The principle of sitting or lying still in the aëroplane and, by means of mechanical devices, bringing the centre of air pressure back into alignment with the centre of gravity is now followed by every designer of aëroplanes. The old, dangerous method of shifting weights is quite abandoned. The greatest contribution made by the Wright Brothers to the art of flying was that of providing a trustworthy mechanism for causing the centre of air pressure to return into coincidence with the centre of gravity.

The aëroplane must be balanced not only from side-to-side but fore-and-aft as well. The same necessity exists in the old-fashioned,

Fig. 2.—Chanute trussed biplane glider in flight

single-surface kite. To give it the necessary fore-and-aft stability, we used to adorn it with a long tail of knotted strips of rags. If the tail was not heavy, or long enough, the kite dived erratically and sometimes met its destruction by colliding with a tree. To insure longitudinal stability, many aëroplane flying-machines are similarly provided with a tail, which consists generally of one or more horizontal plane surfaces. Some aëroplanes, however, are tailless, among them the earlier Wright machines. Usually, they are less stable than the tailed variety.

In order to relieve the aviator of the necessity of more or less incessantly manipulating levers, which control centres of air pressure, many inventors have tried to provide aëroplanes with devices which will perform that task automatically. Some of them are ingenious; but most of them are impracticable because they are too heavy, too complicated, or not responsive enough.

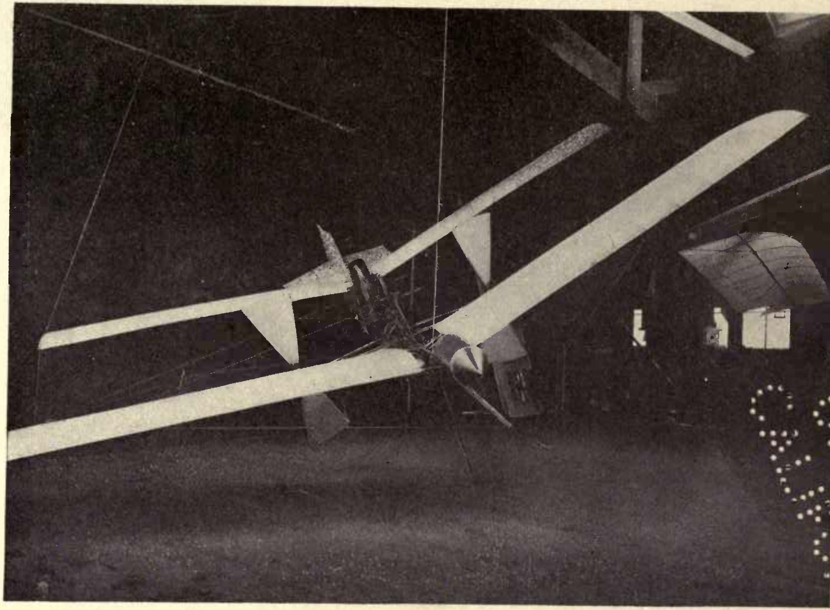
In order to fly, an aëroplane, like a kite or a soaring bird, is made to rise preferably in the very teeth of the wind. What is more, it must be in motion before it can fly. How this preliminary motion was to be obtained long baffled the flying-machine inventor. Eagles, vultures, and other soaring birds launch themselves either by leaping from the limb of a tree or the edge of a cliff, or by running along the ground with wings outspread, until they have acquired sufficient speed. To illustrate the difficulty that even practised soaring birds find in rising from the ground, the late Prof. Samuel P. Langley used to quote the following graphic description of the commencement of an eagle's flight (the writer, one of the founder members of the old aëronautical society of Great Britain, was in Egypt, and the "sandy soil" was that of the banks of the Nile):

"An approach to within 80 yards arouses the king of birds from his apathy. He partly opens his enormous wings, but stirs not yet from his station. On gaining a few feet more he begins to *walk* away with half-expanded, but motionless, wings. Now for the chance. Fire! A charge of No. 3 from eleven bore rattles audibly but ineffectively upon his densely feathered body; his walk increases to a run, he gathers speed with his slowly waving wings, and eventually leaves the ground. Rising at a gradual inclination, he mounts aloft and sails majestically away to his place of refuge in the Libyan range, distant at least five miles from where he rose. Some fragments of feathers denote the spot where the shot has struck him. The marks of his claws were traceable in the sandy soil, as, at first with firm and decided digs, he forced his way; but as he lightened his body and increased his speed with the aid of his wings, the imprints of his talons gradually merged into long scratches. The measured distance from the point where these vanished to the place where he had stood proved that with all the stimulus that the shot must have given to his exertions he had been compelled to run full 20 yards before he could raise himself from the earth."

We have not all had a chance of seeing this striking illustration of the necessity of getting up speed before soaring, but many of us have disturbed wild ducks on the water and noticed them run along it, flapping their wings for some distance to get velocity before they could fly, and the necessity of initial velocity is at least as great with an artificial flying-machine as it is with a bird. From this, we can readily understand why a vulture can be confined in a small cage, which is entirely open at the top.

To get up preliminary speed many methods have been adopted. Langley tried every conceivable way of starting his small model, and at last hit on the idea of launching it from ways, somewhat as a ship is launched into the water. The model rested on a car which fell down at the extremity of its motion and thus released the model for its free flight. On May 6, 1896, he saw his creation really fly like a living thing, the first time in history that a motor-driven aëroplane ever flew.

The Wright Brothers used to obtain their preliminary speed by having their machine carried down the side of a sandhill, partly supported by a head-wind. Their first perfected motor-driven, man-carrying biplane was started on an inclined track. Most aviators of the



Photograph by Smithsonian Institution

Fig. 3.—Langley's steam-driven model, the first motor flying-machine that ever flew

present time, however, mount their aëroplanes on pneumatic-tired wheels, and like the eagle, in the foregoing quotation, run along the ground for a short distance. Aëroplanes have also been dropped into the air from balloons.

Just as a soaring bird uses his legs in leaping into the air or running on the ground to start his flight and also in alighting, so many aëroplanes alight with the wheels that serve them during the brief moments of launching. Sometimes, however, special alighting devices are provided, a conspicuous example of which is to be found in the skids or runners of the Wright machine.

The problem of steering an aëroplane, when it is launched, is solved, as it must be, by two sets of rudders. A steamboat is a vehicle that travels in two dimensions only; hence, it requires only a single, vertical rudder, which serves to guide it from side to side. An aëroplane moves not only from side to side, but up and down as well. Hence, it is equipped with a vertical rudder similar to that of a steamboat's, and also with a horizontal rudder, which serves to alter its course up or down, and which is becoming more widely known as an elevator. Fore-and-aft stability is attained in tailless machines entirely by manipulation of this elevator. Even in tailed machines its use for that purpose is quite imperative.

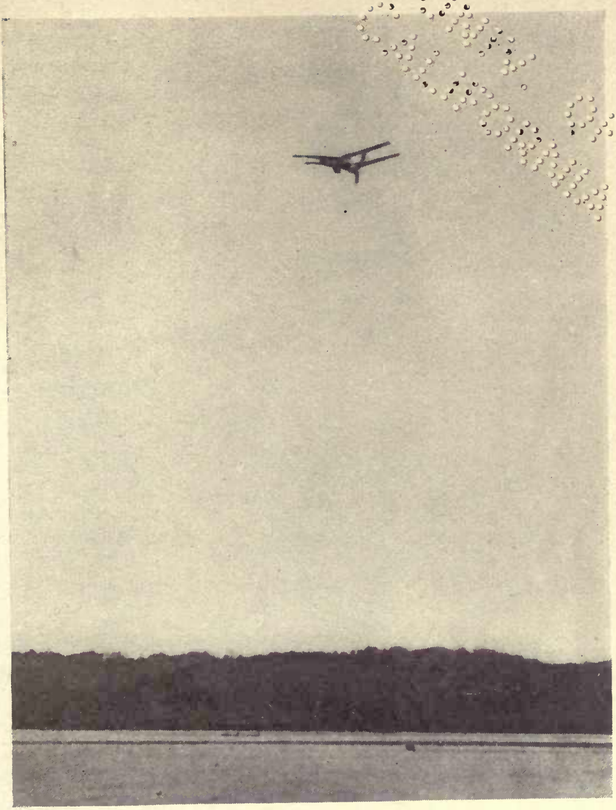
CHAPTER II

FLYING-MACHINE TYPES

THE flying creatures of nature — insects, birds, fishes, and bats — spread wings that lie in a single plane. Because their wings are thus disposed birds may be properly regarded as single-decked flying-machines or "monoplanes," in aviation parlance, and because the earliest attempts at flying were more or less slavish imitations of bird-flight, it was but natural that the monoplane was man's first conception of a flying-machine. Since birds are the most efficient flying-machines known, so far as power consumption for distance travelled and surface supported are concerned, the monoplane will probably always be regarded as the ideal type of aëroplane flying-machine.

It is a circumstance of considerable scientific moment that the wings of a gliding bird, such as an eagle, a buzzard, or a vulture, are wide in spread and narrow in width. Much painstaking experimentation by Langley and others has shown that the best shape of plane is that which is oblong; the span must be considerably greater than the width. In other words, science has experimentally approved the design of a bird's wings. In nature the proportion of span to width varies in different birds. The spread of an albatross' wings is fourteen times the width; the spread of a lark's wings is four times the width, which is the smallest ratio to be found among birds. The albatross is a more efficient flying-machine than the lark. Hence the albatross is a better model to follow and fourteen to one a better ratio than four to one.

Long spans are unwieldy, often too unwieldy for practical, artificial flight. Suppose we cut a long plane in half and mount one half over the other. The result is a two-decked machine, a "biplane." Such a biplane has somewhat less lifting power than the original monoplane, and yet it has the same amount of entering edge. Moreover, the biplane is a little steadier in the air than the monoplane and therefore a little safer, just as a box-kite is steadier than the old-fashioned single-surface kite. Still, the difference in stability between biplane and



From an instantaneous photograph by Dr. Alexander Graham Bell

Fig. 4.—Langley's aërodrome in flight on May 6, 1896, on the Potomac River at Quantico. This is the first photograph ever made of an aëroplane in flight

monoplane is so slight that designers base their preferences for one type or the other on other considerations. Both types are inherently so unstable that it requires a skilled hand to correct their capsizing tendencies.

By placing one plane over another certain structural advantages are obtained. It is comparatively easy to tie two superposed planes together and to form a strong, bridge-like truss, which was first done by Chanute. The proper support of the outstretched surfaces of a monoplane, on the other hand, is a matter of some difficulty.

To correct the inherent instability of both monoplanes and biplanes and to make them safer machines, tails are frequently added. Stability and safety are thus gained at the expense of driving power; for the increased surface of the tail means more resisting surface and therefore less speed. An engine of twenty horse-power will drive a tailless Wright machine; tailed Voisin machines with large, heavy cellular tails have refused to rise at times even when equipped with fifty horse-power motors.

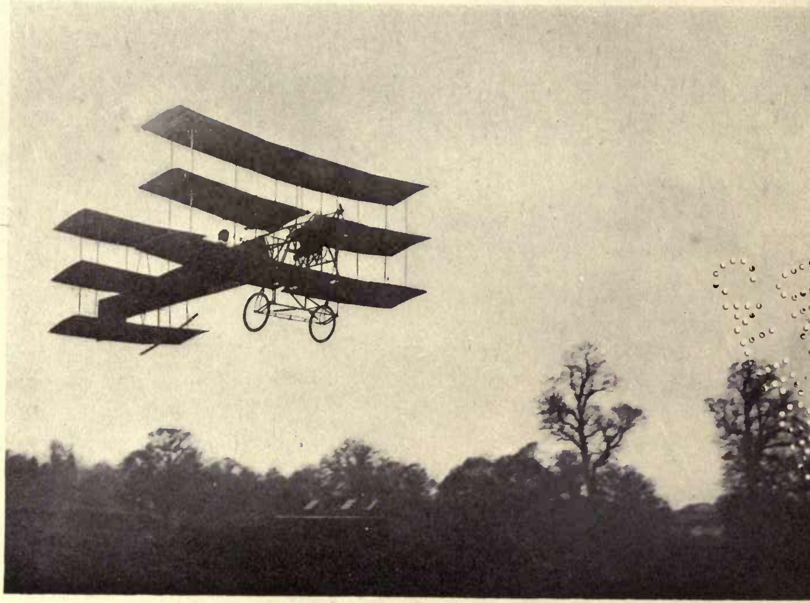
If a monoplane were to fall vertically like a parachute, it would offer the resistance of its entire surface to the fall; if a biplane were to fall, it would offer the resistance of only one of its planes to the fall. Hence the monoplane is a better parachute than the biplane. The point is perhaps of slight value, because if a skilful aviator is high enough when his motor fails him, he can always glide to the ground on a slant which may be miles in length. Paradoxical as it may seem, the greater the distance through which he may fall, the better are an aviator's chances of reaching the ground with an unbroken neck. At a slight elevation from the ground, both monoplanes and biplanes are in a precarious position in case of motor stoppages. There is no distance to glide. Hence they must fall.

Whether the biplane is a better type of machine than the monoplane, it would be difficult, if not impossible, to maintain. It is certain, however, that the biplane has been brought to a higher state of perfection than the monoplane, probably because it was the first successful type of a man-carrying, motor-driven flying-machine. The older the type, the more marked will be the improvements to which it will be subjected. It is curious, too, that most of the pioneer aviators have been advocates of the biplane type. Lilienthal met his death in a biplane. Chanute, who brilliantly continued Lilienthal's work, and the Wright Brothers brought the motorless biplane glider to its highest pitch of perfection. The first flight ever made by a man-carrying, motor-driven machine was that of a Wright biplane. Voisin, Curtiss, and Farman, all of them experienced designers, have performed their most brilliant feats in designing or flying biplanes.

Chanute made many experiments with gliding-machines having more than two superposed surfaces; but he found in the end that the biplane type was most satisfactory. Despite the lessons to be learned from his painstaking experiments, inventors have not been wanting who have worked on the three-deck or triplane principle. One of these is Farman, who designed the Farman-Voisin three-decked machine. Others are A. V. Roe in England and Vanniman in France. Vanniman and Farman have since abandoned their triplane structures, and thus rather confirmed Chanute's conclusions. It is interesting to know that the triplane goes back as far as 1868, in which year an inventor named Stringfellow built a three-decked model.

The many-planed flying-machine was probably carried to its extreme by an Englishman, Mr. Horatio Phillips. Between 1881 and 1894 he made a series of experiments which resulted in his building a multiplane, not unlike a Venetian blind in appearance. It consisted primarily of a series of numerous superposed slats, which had extraordinary lifting power. Perhaps the chief objections to such a multiplane are its weight and its height. Consequently it is less stable in the air than biplanes.

Since an aëroplane, whether it be of single-deck or double-deck construction, must be driven at considerable speed to keep it in the air, and must, furthermore, get up a certain preliminary speed before it can fly at all, some inventors have thought of rotating the planes, as if they were huge propellers, instead of driving them along in a straight line. Such screw-



Photograph by Edwin Levick

Fig. 5.—Roe's triplane in flight. The best engineering opinion is against the triplane because of its large head resistance and consequent low speed

propellers, to push a machine from the ground, are mounted on a vertical shaft, the whole constituting a machine which goes by the name "helicopter." A helicopter should theoretically screw its way up into the air. Because no screw-propeller can possibly support a weight in air with anything like the aëroplane's economy of power, the helicopter has never been a practical success. In a helicopter, the screw-propeller must be designed not only for propulsion but for support as well. As far back as 1812 Ponton d'Amécourt and de la Landelle maintained that the heavier-than-air machine would be supported by a screw, — the "sacred screw," to use d'Amécourt's ecstatic Gallic phrase. They found in the Academician Babinet a stout supporter of their view, and he it was who invented the term "hélicoptère." The familiar little screw-fliers which are whirled into the air by hand or by twisted rubber bands seemed to offer experimental evidence enough in support of any helicopter theories. It was recognised, however, that one screw would cause the entire apparatus to rotate. Hence two screws turning in opposite directions were early recommended.

Thus the rotating effect of one screw was counteracted by the other, and the lifting effects of the two were combined.

The most earnest student of the problem of the lifting screw-flier or helicopter has been Colonel Rénard, of the French Army. It was he who first pointed out in 1903 that the ordinary screw would not answer. A helicopter's screw must not only propel, but must also support, for which reason it must be differently constructed from a screw designed for propulsion only. Rénard even went so far as to plan a composite machine, an apparatus which was a helicopter for lifting itself from the ground and an aëroplane in the air. Thus he hoped to overcome the necessity of that preliminary run which aëroplanes must make in order that they may be launched in the air. His machine would theoretically leap straight up from the ground.

The pathway of aëronautic invention is strewn with wrecked helicopters. Men just as distinguished as Rénard have pinned their faith to the blades of its revolving screws. Among them have been Thomas A. Edison and Emil Berliner. Yet the only perfectly operative screw-flier constructed on the lifting-screw principle is the little toy to which reference has been made. In France, where fashions in aëroplanes are created with the same facility as fashions in clothes, the helicopter still engages the attention of a few enthusiasts, despite the brilliant success of the aëroplane. Cornu is one of these. His machine undoubtedly lifts; but thus far it has not been allowed to display its capabilities in that direction more than two feet from the ground. Bréguet, the inventor of a helicopter aëroplane, is said to have flown in 1908 a distance of sixty-four feet at a height of fifteen feet. He is now building aëroplanes.

Even less encouraging than these experiments with helicopters, have been the efforts of a few misguided aviators who have sought to build what are known as ornithopters — machines that flap wings like a sparrow. It seems very natural to adopt the flapping-wing principle, because all birds depend upon it to a certain extent. Apart from the myth of Daedalus the earliest recorded proposal of this kind was made in 1500, by Leonardo da Vinci, but he does not seem to have made a practical test. The first actual experiment with flapping wings, according to tradition, seems to have been made by a French tightrope dancer named Allard, in the reign of Louis XIV. Allard attempted a demonstration before the court but failed in his strength, fell, and was seriously hurt. Since that time many aviators in ornithopters have broken their wings and sometimes their bones. The most earnest experimenter was Hargrave, who ultimately gave the world the box-kite, the prototype of the biplane. He built eighteen flapping-wing models between 1883 and 1893. With one of these at least, a flight of three hundred and forty-three feet was made in 1891. It must be said that Hargrave relied on flapping wings solely for propulsion and not for support. His efforts to devise an efficient sustaining surface gave us his box-kite. Only a few French inventors still persist in working on the ornithopter principle. The most persistent of these is Adh. de la Hault. His machine, exhibited at Brussels in

Photograph by Edwin Levick

Fig. 6.—Cornu's helicopter or screw-flyer. In this machine the lifting and propulsive force is obtained entirely by screws

1908, has wings that describe, when in motion, a figure-of-eight curve. His results have been meagre.

In order to build a flying-machine with flapping wings, so as to imitate birds exactly, a very complicated system of levers, cams, cranks, and links must be employed, all of which usually weigh more than the wings can lift.

CHAPTER III

THE PLANE IN THE AIR

A ROWBOAT, a mud-scow, a battleship, and a racing yacht, whatever æsthetic differences they may present, are roughly similar in form. The swifter the vessel the finer will be the lines of its hull. Naval architects after some centuries of experimenting have laid down certain rules of construction to be followed in building vessels of a certain class.

The plane surface is to the aëroplane what a hull is to a ship. Like a ship's hull it must be fashioned to cleave the medium through which it must travel with the least possible resistance. Aëronautical engineers have not solved that problem entirely as yet, for the simple reason that flying has only recently become an assured fact. But their experiments have given them certain standards which they invariably follow when they design an aëroplane. Young as the art of flying is, it may well be questioned whether the aëronautical engineer is not in possession of a set of empirical formulæ almost as good as those of the naval architect.

So far as the manner of cleaving their respective media is concerned, there is this important difference between ships and planes: — A vessel is propelled through the water along the line of least resistance, the line of its length; an aëroplane, whether it be a bird or a Wright biplane, is driven through the air at right angles to the line of greatest length or resistance.

What is known as the "entering edge" of an aëroplane, in other words the character of the cutting part of a plane, gives the aëronautical engineer much concern. It is the entering edge that strikes the air first. The lifting-power of a plane gradually dwindles from the entering edge backward. A plane one hundred feet long and one foot wide has greater lifting power than a plane ten feet square, although both planes have exactly the same amount of surface. That explains why the wings of a bird are longer in span than in width, and why the aëroplanes of man are as long and as narrow as possible. If the entire surface of a plane were struck by the air, it would be just as advantageous to employ square planes. But since the air bears directly only on the front or entering edge, we must adopt planes that give us

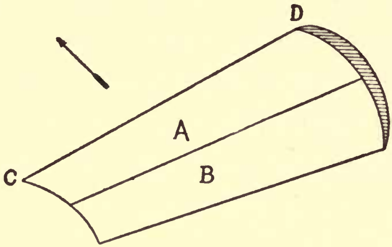


FIG. 7. — *C D* is the "entering edge." The lifting power of the forward half *A* of the curved plane is greater than the lifting power of the rear half *B,* although both are of equal area.

as great an entering edge as possible without making the plane too unwieldy.

Otto Lilienthal demonstrated, after much experiment, that if an oblong surface were curved, the loss in power in the rear half of a plane might be overcome. The investigations of others, notably Horatio Phillips, Prof. S. P. Langley, Sir Hiram Maxim, and the Wright Brothers, have confirmed his opinion. Hence, despite their name, the best aëroplanes of to-day are made not with flat, but with surfaces slightly curved from front to rear (Fig. 7), so that the rear part of a plane can "grip" the air almost as well as the entering edge. De-

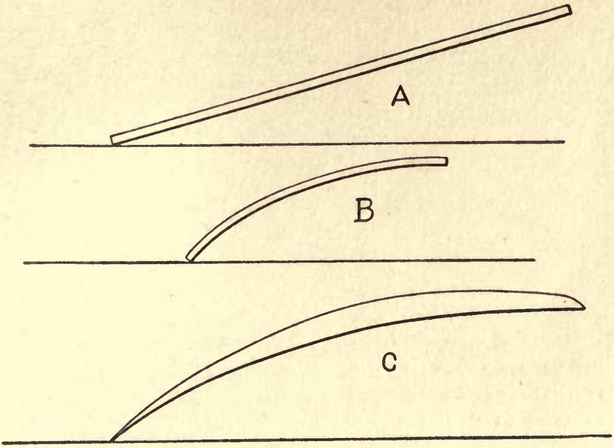
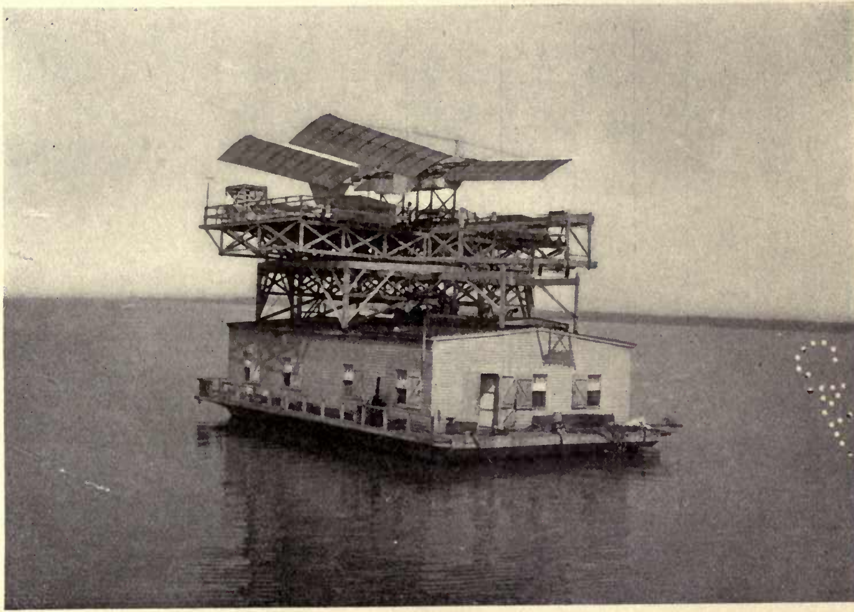


FIG. 8 — *A* is a simple inclined plane; *B*, a curved plane at the same angle of incidence or inclination; *C*, the type of curved plane which has thus far given the best results in the air.

spite the curvature, however, there is an appreciable loss in lifting power, back of the entering edge.

The general shape which a plane should have must be considered as well as the entering edge. Much experimental research has shown that the best plane is not only curved back and down, but is also convex on top. What is more, it has been found that it should be somewhat thicker nearer the front. Just where the thickest part should lie is still a matter of doubt; but most designers place the thickest part at a distance from the front edge not more than a third of the total width of the plane (Fig. 8).

A kite must be held at an angle to the wind if it is to fly. So must an aëroplane. Just what that angle should be varies with the circumstances of flight. The flatter the angle (in other words, the more horizontal the position of the aëroplane) the speedier will be the flying-machine. The greater the angle of the plane, the greater will be the resistance offered and the greater will be the power required to drive the plane. Still, this greater angle will enable the flying-machine to rise more quickly in the air, because the lifting power is greater. It is easy to see that the aviator must select such an angle for his planes that his machine will be as speedy as possible, as economical of power as possible, and that it will have as much lifting power as possible. The angle in practical flying-machines varies usually from one in seven to



Photograph by Smithsonian Institution

Fig. 10.—Langley's device for launching his aërodromes. The machine was mounted on a houseboat, which could be turned in any direction so as to face the wind

one in twenty. What does that mean? It means that a plane having an angle of one in ten will push the air down at one tenth of the forward velocity and that the plane will rise one foot in ten relatively to the forward movement.

An aëroplane driven through the air is acted upon by two forces, — its weight and its horizontal momentum. Because it has weight it is always falling. If its horizontal momentum (its speed) is greater than the rate of its fall, it will stay in the air, which means not only that it has not time enough to fall visibly but that it may even ascend. Suppose that a plane travelling at the rate of ten miles an hour has just sufficient horizontal momentum to prevent its falling. If the speed be increased to twenty miles an hour, the plane will not only be prevented from falling, but will actually rise in the air, because of the plane's angle of inclination. Hence to prevent the plane from rising at a speed of twenty miles an hour, the angle must be flattened. Therefore substantially horizontal flight may be maintained by proper adjustment of speed and angle (Fig. 9).

The angle of incidence varies with the wind, with the power of the motor, with every deviation of the plane from a uniform line, and with every variation of the load. If a machine carries two men, the angle will be greater than if

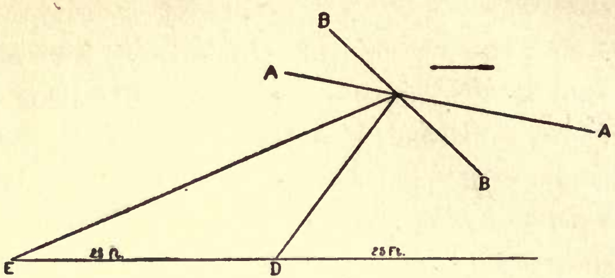
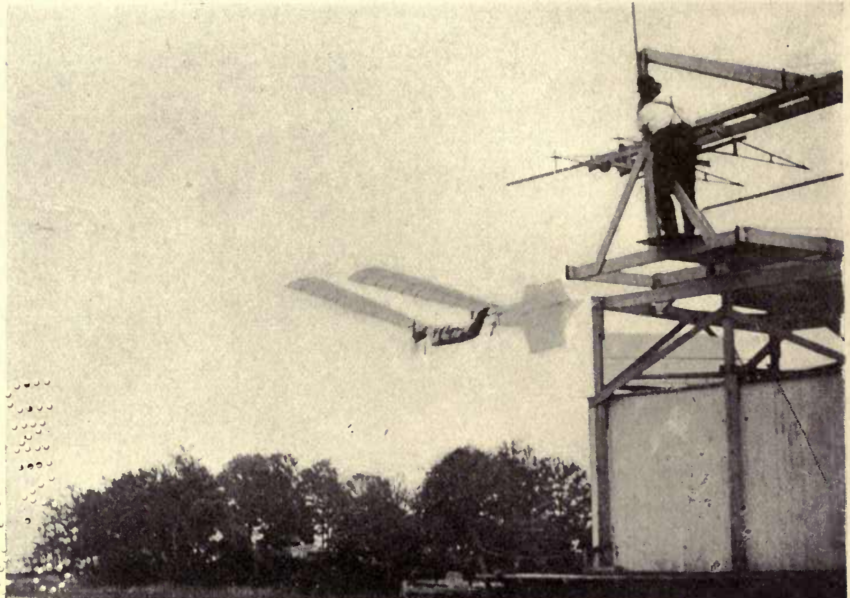


FIG. 9.—The plane *B B* is at a greater angle of incidence than the plane *A A*. If its speed be 10 miles an hour, it will, while travelling horizontally 25 feet, overcome its tendency to fall to *D*. If its speed be 20 miles an hour, it will have 50 feet to travel while overcoming its tendency to fall to *E*. Unless the angle of *B B*, therefore, were decreased to that of *A A* for the greater speed, the plane would not move horizontally but would ascend.

one is carried; when the fuel tank is full the angle will be greater than when the tank is empty, and will vary as the fuel is used. Moreover, when the power of the motor increases or decreases, the speed correspondingly increases or decreases and causes the angle of incidence to increase or decrease. Even with constant power, the speed is different in ascending and descending, and the angle of incidence varies accordingly. The Wright Brothers state that during a flight of one hour the angle of incidence will be either greater or less than any angle which may be termed normal, for more than fifty-nine minutes, and that it will be exactly at the normal angle less than one minute. In their experience the angle of incidence varies in flight throughout a range of ten degrees or more and is particularly great when the wind is turbulent. For that reason, among others, the control of an aëroplane in flight requires incessant vigilance on the part of the pilot.

In most forms of locomotion, increased speed is obtained at the expense of power. When you run, you expend more energy than when you walk. A locomotive driven at high speed utilises more power than at low speed. Paradoxically enough, the aëroplane follows no such rule. The late Professor Langley discovered that the higher the speed of an aëroplane, the less power is required to drive it. Langley was considering surfaces only. Wires and struts must also be considered, and their resistance (increasing with the square of the velocity) is such that, as Herring has pointed out, flight without motor is impossible on account of the resistance offered by wires alone. Theoretically at least, it seemed to Langley that a speed could be reached where the power received would be *nil*. The Wrights and other aviators maintain, however, that there is a close limit to this economy of power with accelerated speed. The early experiments of Langley, Maxim and Chanute seemed to show that at high speed increased lifting power is obtained, but how much the increase may be not all the experimenters agree. Contrary to the early experimenters, the Wright Brothers maintain that there is no practical advantage in increasing speed to obtain increased lifting power. High speed renders it possible to reduce the size and weight of the machine, which in turn means a reduction in atmospheric resistance.

The first glimpse of a flying-machine in the air is a disappointment, not because the flying-machine really flies, but because it apparently flies so slowly. The speed appears less than



Photograph by Smithsonian Institution

Fig. 11.—Langley's model aërodrome photographed immediately after a launch

it really is, and it is only when it is accurately measured that it reaches the hoped-for figure. The speed of many of the early biplanes was not much above thirty miles an hour, and most of the modern biplanes probably do not exceed forty miles. Monoplanes now travel often at a speed of not less than sixty miles. Many of the Blériot monoplanes make considerably over seventy miles an hour on a straight line. At Reims, in 1910, over seventy miles an hour was attained. It is evident that in the near future eighty miles an hour on a straight course is well within the bounds of probability.

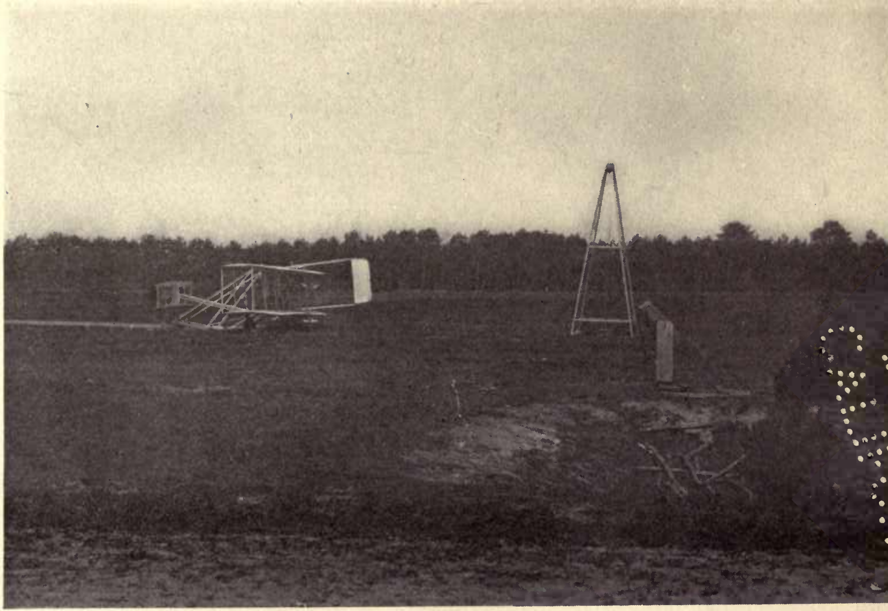
In an aëroplane speed is of more importance than any other vehicle, because the aëroplane is far more affected by the wind. A boat, to be sure, is affected by both tide and wind, but not to such an extent as the aëroplane. A strong tide runs only about two knots, while the speed of a fast boat is some ten times this, so that her speed is reduced only ten per cent when running against the tide. An aëroplane, however, is very much more influenced, simply because an ordinary breeze has a velocity of fifteen miles an hour, a strong wind thirty to forty miles an hour, and a gale, sixty miles an hour. The aëroplane, in order to be a serviceable vehicle of sport, must be able to make good speed against a thirty-mile wind. In other words, it should be able to obtain a velocity of sixty or seventy miles an hour, under favourable conditions. Such fast flying, however, complicates the problem of starting and alighting. Landing at high speed is especially dangerous. As long as the method of alighting is what it is now, that is, as long as the machine runs along the ground for some distance, it can hardly be safe to land at speeds in excess of those used at present. It is evident, therefore, that it may be necessary to devise a machine which will fly over a considerable range of speed, so that it can be slowed down before landing. The minimum speed at which an aëroplane will fly is dependent chiefly on the ratio of wing surface to weight. Therefore, to fly slowly we must have large wings in proportion to the weight. Small wings, on the other hand, give high speed, and the small wings on Blériot and Wright racers seem to be very small indeed.

In order that the aëroplane may have a variable speed, it must either have large wings, so designed that they can be driven fast without resistance, or else we must have some means of reducing the surface of the wings in the air. In the former case, the angle of incidence of the wings is reduced, which would seem to be at least theoretically obtainable, whatever may be the difficulties in making the curves of the wings suitable for various speeds.

Reefing the wing surfaces is a still better method of obtaining variable speeds, but the practical difficulties are formidable. Furling a wing when travelling at forty miles an hour in the air can hardly be easy. Taking in sail in a gale of wind on a boat has its difficulties, and an aëroplane travels at the speed of a gale. For all that, we find that attempts are made, even now, to build machines on this principle.

Before we can advance much farther in aëroplane construction we must conduct more systematic investigations of various kinds of supporting surfaces. Several laboratories are now engaged in such researches, but the results of their labours will hardly be available for some years to come.

It is the general practice of ship-builders to test new forms of hulls by towing models of a few yards in length through the water and by measuring the resistance opposed to their motion. No large ocean steamer is now constructed without such preliminary experiments. Tests with aëroplane models are still more necessary, because in the air we are, as yet, more or less inexperienced. In both cases one of the chief objects of study is the total resistance to motion, and the discovery of the form which will reduce this resistance to the lowest possible point. Other important questions concern the distribution of pressure and skin friction in their dependence upon the form and character of surface. The investigation of stability and steering qualities also requires experiments with models, which may likewise give interesting information on the lifting power or kite action of an aëroplane when inclined to the horizontal. It is necessary to study thoroughly the magnitude and direction of the resultant force on single surfaces of



Photograph by Edwin Levick

Fig. 13.—Starting derrick and rail of the Wright Brothers. The machine is about to be hauled up on the rails

various forms, on combinations of surfaces, and finally on complete aëroplanes, as well as the stability and steering qualities of these combinations. It is easier and cheaper to learn from models all that they can teach us than to make the experiments with large and expensive craft, which has been the practice in the past. It is a question, however, how far the results obtained from models can be applied to the large vessels. Even small models of ships' hulls, which are tested in towing tanks, do not give absolute results. In aëroplanes, the method may be still more untrustworthy because the aërial craft is completely surrounded by the medium through which it travels and because the carriage generally creates more disturbance in the air than the model, a disturbance sufficiently great to make exact measurements impossible. By substituting for the towing carriage a cord wound on a windlass, this objection is removed, but it remains very difficult to distinguish sharply between the comparatively small air resistances and the great force of inertia of the heavy model. M. Eiffel has made some excellent experiments with bodies freely falling through the air. The method frequently employed of carrying the model around in a circle by means of a long rotating arm, or on a whirling table, is open to the objection that the model is always moving in air which has been disturbed by its last passage. There is still a third method, which consists in maintaining the model at rest in a current of air produced, for example, by a blower. The mutual action between the model and the air is exactly as in the former system, if the condition of the moving air before it strikes the model is as uniform as that of still air. The trustworthiness of results obtained by this method depends, therefore, upon obtaining a uniform current free from eddies, which end can be attained by the employment of various appliances. When a uniform current has been secured, the advantages of this method are great and obvious. The duration of the experiment is unlimited, and the model can be attached to its support much more easily and securely than if it were in motion. Furthermore, the difficulties produced by the acceleration and inertia of the model on a measuring apparatus are here avoided. The model is continuously in sight, so that any irregularities can be at once detected. This system has been adopted in the Goettingen Experimental Institute, planned and directed by Professor Prandtl.

CHAPTER IV

STARTING AND ALIGHTING

In a previous chapter it has been pointed out that like every soaring bird an aëroplane must be in motion before it can fly. Even the early dreamers appreciated the fact. How that preliminary leap into the air is to be effected gave Langley no little concern. With the motorless gliders of Lilienthal, Pilcher, and Chanute, it was no difficult matter for the aëronaut to launch himself into the air. He simply carried his apparatus to the top of a hill, grasped the handle-bar, ran down the hill at top speed for a short distance, and then drew up his legs, like any bird. Thus he would slide down the air for several hundred feet as if upon an invisible track.

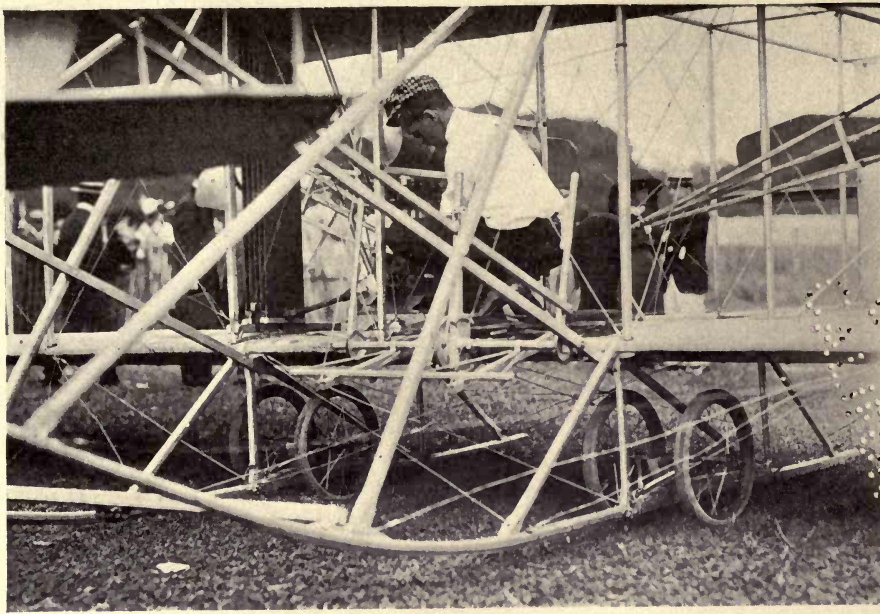
When Langley succeeded in building a small, motor-driven model of a flying-machine, the problem of launching his contrivance long baffled him. Eventually he invented a launching device, which has served as a pattern for later inventors. The difficulties which beset him were eloquently and lucidly described in an article from his pen, published in McClure's Magazine for June, 1897. The whole problem is there so well and so simply presented that we cannot do better than to let Mr. Langley set it forth himself, even though launching a flying-machine is now regarded as a simple matter:

"In the course of my experiments I had found out . . . that the machine must begin to fly in the face of the wind and just in the opposite way to a ship, which begins its voyage with the wind behind it.

"If the reader has ever noticed a soaring bird get upon the wing he will see that it does so with the breeze against it, and thus whenever the aërodrome [1] is cast into the air it must face a wind which may happen to blow from the north, south, east or west, and we had better not make the launching station a place like the bank of a river, where it can go only one way. It was necessary, then, to send it from something which could be turned in any direction, and taking this need in connection with

[1] Langley's term for an aëroplane flying-machine, signifying "air-runner."

the desirability that at first the airship should light in the water, there came at last the idea (which seems obvious enough when it is stated) of getting some kind of a barge or boat and building a small structure upon it which could house the aërodrome when not in use, and from whose flat roof it could be launched in any direction. Means for this were limited, but a little "scow" was procured, and on it was built a primitive sort of house, one story high, and on the house a platform about ten feet higher, so that the top of the platform was about twenty feet from the water, and this was to be the place of the launch. This boat it was found necessary to take down the river as much as thirty miles from Washington, where I then was — since no suitable place could be found nearer — to an island having a stretch of quiet water between it and the main shore; and here the first experiments in attempted flight developed difficulties of a new kind — difficulties which were partly anticipated, but which nobody would probably have conjectured would be of their actually formidable character, which was such as for a long time to prevent any trial being made at all. They arose partly out of the fact that even such a flying-machine as a soaring bird has to get up an artificial speed before it is on the



Photograph by Edwin Levick

Fig. 14.—Combined wheels and skids employed on the later Wright machines

wing. Some soaring birds do this by an initial run upon the ground, and even under the most urgent pressure cannot fly without it.

"To get up this preliminary speed many plans were proposed, one of which was to put the aërodrome on the deck of a steamboat, and go faster and faster until the head-wind lifted it off the deck. This sounds reasonable, but it is absolutely impracticable, for when the aërodrome is set up anywhere in the open air, we find that the very slightest wind will turn it over, unless it is firmly held. The whole must be in motion, but in motion from something to which it is held until that critical instant when it is set free as it springs into the air.

"The house boat was fitted with an apparatus for launching the aërodrome with a certain initial velocity, and was (in 1893) taken down the river and moored in the stretch of quiet water I have mentioned; and it was here that the first trials at launching were made, under the difficulties to which I have alluded.

"It is a difficult thing to launch a ship, although gravity keeps it down upon the ways, but the problem here is that of launching a kind of ship which is as ready to go up into the air like a balloon as to go off sideways, and readier to do either than to go straight forward, as it is wanted to do, for though there is no gas in the flying-machine, its great extent of wing surface renders it something like an albatross on a ship's deck — the most unmanageable and helpless of creatures until it is in its proper element.

"If there were an absolute calm, which never really happens, it would still be impracticable to launch it as a ship is launched, because the wind made by running it along would get under the wings and turn it over. But there is always more or less wind, and even the gentlest breeze was afterward found to make the airship unmanageable unless it was absolutely clamped down to whatever served to launch it, and when it was thus firmly clamped, as it must be at several distinct points, it was necessary that it should be released simultaneously at all these at the one critical instant that it was leaping into the air. This is another difficult condition, but that it is an indispensable one may be inferred from what has been said. In the first form of launching piece this initial velocity was sought to be attained by a spring, which threw forward the supporting frame on which the aërodrome rested; but at this time the extreme susceptibility of the whole construction to injury from the wind and the need of protecting it from even the gentlest breeze had not been appreciated by experience. On November 18, 1893, the aërodrome had been taken down the river, and the whole day was spent in waiting for a calm, as the machine could not be held in position for launching for two seconds in the lightest breeze. The party returned to Washington and came down again on the 20th, and although it seemed that there was scarcely any movement in the air, what little remained was enough to make it impossible to maintain the aërodrome in position. It was let go, notwithstanding, and a portion struck against the edge of the launching piece, and all fell into the water before it had an opportunity to fly.

"On the 24th another trip was made and another day spent ineffectively on account of the wind. On the 27th there was a similar experience, and here four days and four (round-trip) journeys of sixty miles each had been spent without a single result. This may seem to be a trial of patience, but it was repeated in December, when five fruitless trips were made, and thus nine such trips were made in these two months and but once was the aërodrome even attempted to be launched, and this attempt was attended with disaster. The principal cause lay, as I have said, in the unrecognised amount of difficulty introduced even by the very smallest wind, as a breeze of three or four miles an hour, hardly perceptible to the face, was enough to keep the airship from resting in place for the critical seconds preceding the launching.

"If we remember that this is all irrespective of the fitness of the launching piece itself, which at first did not get even a chance for trial, some of the difficulties may be better understood; and there were many others.

"During most of the year of 1894 there was the same record of defeat. Five more trial trips were made in the spring and summer, during which various forms of launching apparatus were tried with varied forms of disaster. Then it was sought to hold the aërodrome out over the water and let it drop from the greatest attainable height, with the hope that it might acquire the requisite speed of advance before the water was reached. It will hardly be anticipated that it was found impracticable at first to simply let it drop without something going wrong, but so it was, and it soon became evident that even were this not the case, a far greater time of fall was requisite for this method than that at command. The result was that in all these eleven months the aërodrome had not been launched, owing to difficulties which seem so slight that one who has not experienced them may wonder at the trouble they caused.

Photograph by Edwin Levick

Fig. 15.—Blériot starting from the French coast on his historic flight across the English Channel

"Finally, in October, 1894, an entirely new launching apparatus was completed, which embodied the dozen or more requisites, the need for which had been independently proved in this long process of trial and error. Among these was the primary one that it was capable of sending the aërodrome off at the requisite initial speed, in the face of a wind from whichever quarter it blew, and it had many more facilities which practice had proved indispensable."

Langley's account has a certain historical interest, because never before had a motor-driven machine been brought to such a pitch of perfection that it could fly, if once launched. After his repeated failures, Langley finally succeeded in launching his craft from "ways," as shown in Fig. 11, somewhat as a ship is launched into the water, the machine resting on a car, which fell down at the end of the car's motion.

A launching device identical in principle was afterwards employed to start the man-carrying machine built by Langley for the United States Government. Once, according to Major Macomb, of the Board of Ordnance, "the trial was unsuccessful because the front guy post caught in its support on the launching car and was not released in time to give free flight, as was intended, but, on the contrary, caused the front of the machine to be dragged downward, bending the guy post and making the machine plunge into the water about fifty yards in front of the house boat." Of another trial Major Macomb states . . . "the car was set in motion and the propellers revolved rapidly, the engine working perfectly, but there was something wrong with the launching. The rear guy post seemed to drag, bringing the rudder down on the launching ways, and a crashing, rending sound, followed by the collapse of the rear wings, showed that the machine had been wrecked in the launching; just how it was impossible to see."

Because it was never launched, the machine never flew. The appropriation having been exhausted, Langley was compelled to abandon his tests. The newspaper derision which greeted him undoubtedly embittered him, shortened his life, and probably set back the date of the man-carrying flying-machine's advent several years. Langley's trials have been here set down at some length to show the practicability and impracticability of various launching methods and to demonstrate that his machine was far from being the failure popularly supposed. No man has contributed so much to the science of aviation as the late Samuel Pierpont Langley.

That his work was not lost on the Wright Brothers at least, is evidenced by the manner in which they attacked the difficulty of getting up starting speed. The Wright Brothers invented an arrangement, which was simpler than Langley's, more efficient, and not so likely to imperil the aëroplane. As illustrated in Figures 12 and 13, it consisted in its early stage of an inclined rail, about seventy feet long; a pyramidal "derrick"; a heavy weight arranged to drop within the derrick; and a rope which was fastened to the weight, led around a pulley at the top of the derrick, passed around a second pulley at the bottom of the derrick and over a third pulley at the end of the rail, and then secured to a car. The car was placed on the rail, and the aëroplane itself on the car. When a trigger was pulled, the weight fell, and the car was jerked forward. So great was the preliminary velocity thus imparted that the machine was able to rise from the car in a few seconds.

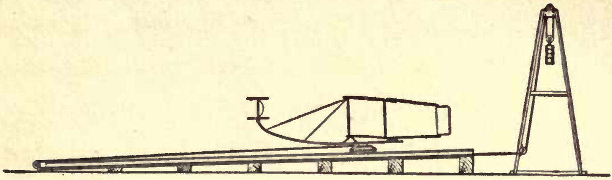
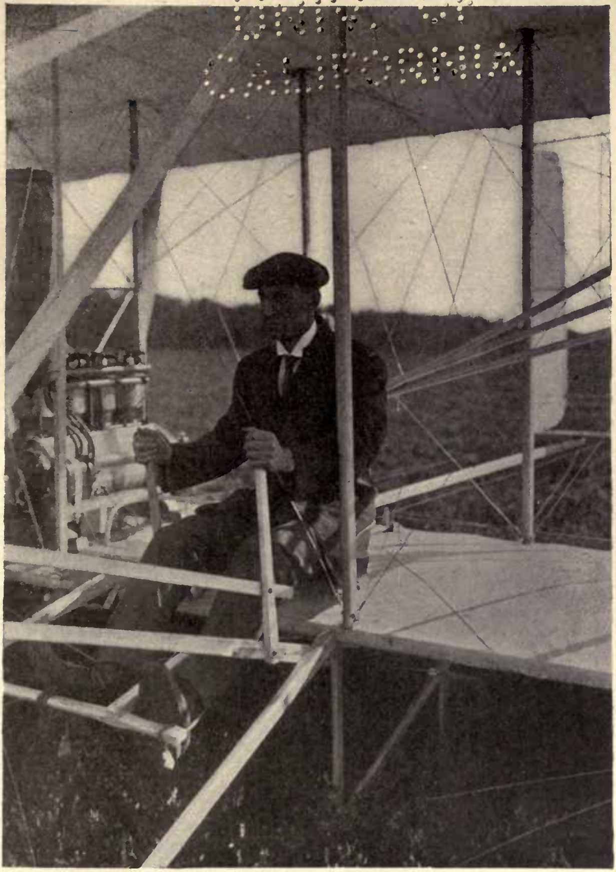


FIG. 12.—The special launching device invented by the Wright Brothers. The device consists of an inclined rail, about seventy feet long; a pyramidal derrick; a heavy weight arranged to drop within the derrick; and a rope, which is fastened to the weight, passed around a pulley at the top of the derrick, then around a second pulley at the bottom of the derrick over a third pulley at the end of the rail, and finally fastened to a car running on the rail. The car is placed on the rail, and the aëroplane on the car. When a trigger is pulled, the weight falls, and the car is jerked forward. So great is the preliminary velocity thus imparted that the machine is able to rise in a few seconds from the car, which is left behind.

Neither a falling weight nor a starting carriage on rails can be carried with an aëroplane. Hence, a machine thus launched must always return to its derrick. Clearly, an aëroplane which can start up under its own power is preferable to one which is wedded to a starting derrick or any other extraneous launching apparatus. Inasmuch as more power is required for starting by running on the ground (i. e., for accelerating the machine) than for actual flight, the Wright Brothers continued to employ their starting rail long after other aviators had adopted wheels. The result was that they could equip their machine with motors of far less power than their rivals.

Even before the Wright Brothers threw aside all secrecy and flew publicly in France and the United States during the summer of 1908, Curtiss and Farman had made short flights on machines which were mounted on pneumatic-tired wheels. Their machines would run on the wheels for several hundred feet. When sufficient velocity had been attained the pilot would give a slight upward tilt to the elevating rudder, and the machine would leave the ground. The only essential was a fairly smooth, fairly hard piece of ground for the preliminary run. So successful has this system been that in somewhat improved form it is embodied in every modern aëroplane. Even the Wright Brothers, who long persisted in using the starting derrick in the face of the obvious advantages of wheels, abandoned the starting derrick as soon as they had increased the power of their motors. In Fig. 14 one of their later machines is pictured, mounted on wheels.

Although starting wheels enable the aviator to rise from any suitable piece of ground, he pays for that advantage in engine power. A well-made machine, having ample power to fly, but dependent only on its engine and rubber-tired wheels for its initial run, may be unable to rise if the ground is too rough. The engine cannot overcome the loss due to friction. On hard asphalt the cyclist can readily attain a speed of twenty-five miles an hour in a few seconds; on a ploughed field, he may labour hard and yet not make more than ten miles an hour. The aëroplane is in the same position as the bicycle. To start a flying-machine on rough ground requires more power than is afterwards needed for propulsion. Hence we find that the earlier Wright machines, although they could rise only from the perfect surface of a starting rail, were fitted with engines of remarkably low power.



Photograph by Edwin Levick

Fig. 20.—Mr. Wilbur Wright in the old type Wright biplane

The wheels on which the preliminary run is made may also serve the aviator in alighting. After he shuts off his engine he glides down and runs on the wheels until his momentum is expended. The shock may be sufficient to wreck a machine piloted by an unskilled hand, and the run may be long, unless some form of brake is provided. Recognising these disadvantages early in the course of their experiments, the Wright Brothers fitted their aëroplanes with skids or runners on which the machine alighted. The shock is almost imperceptible, and the machine stops in the course of a few yards without the assistance of a brake. Many machines are now equipped with skids similar to those embodied long ago by Herring and by the Wright Brothers in their early models.

Starting wheels and alighting skids are not easily combined in the same machine. The skids must be elevated sufficiently to clear the ground in making the preliminary run, and yet they must become effective as soon as the machine touches the ground. For that reason the wheels are usually connected with springs, which are compressed as the aëroplane strikes the ground so as to allow the skids to perform the function for which they are designed.

In the Farman biplane, for example, the wheels are mounted on the skids and are attached to rubber springs. When the machine alights the wheels yield, and the skids come into play.

In the Sommer biplane, the framework is carried on two large wheels at the front and two smaller wheels at the rear. The front wheels are attached by rubber springs to two skids, built under the frame. As in the Farman machine, the wheels yield by virtue of this spring mounting.

In Santos-Dumont's monoplane "Demoiselle," springs are dispensed with. The machine starts on two wheels in front and the shock of alighting is broken by a skid at the rear.

An arrangement similar to that of Santos-Dumont is to be found in the Antoinette machines. The mounting consists of two wheels at the front and a skid at the rear. No springs are provided for the wheels.

In the Curtiss and Voisin biplane machines, as well as in some others of minor importance, no skids at all are employed. The machine starts and alights on the same set of wheels, and is usually stopped by brakes. On the whole the combination of wheels and skids seems to be more desirable, particularly for a heavy machine.

CHAPTER V

HOW AN AËROPLANE IS BALANCED

DROP a flat piece of cardboard from your hand. It will fall. But as it falls its surface will offer a certain resistance, so that it becomes in effect a parachute. The amount of its resistance will

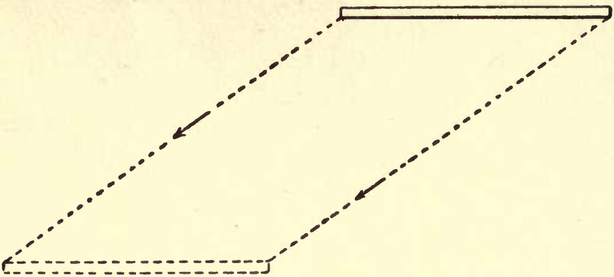


FIG. 16. — Path of an aëroplane driven forward but with a speed too low for horizontal flight, and with too flat an angle.

depend on the amount of its surface. If the cardboard be driven to the left, as shown in Fig. 16, it will still fall, but along an inclined path. In other words it will fall while advancing and advance while falling.

Suppose that this same piece of cardboard, this aëroplane, as we may call it, is inclined to the wind and that it is driven along a horizontal path *B* in the direction of the arrow *A* as shown in Fig. 17. If it were not driven forward the cardboard plane would fall by reason of its weight. But since it is driven forward and since it is inclined to the air, it offers resistance, which means that pressure is exerted upward against

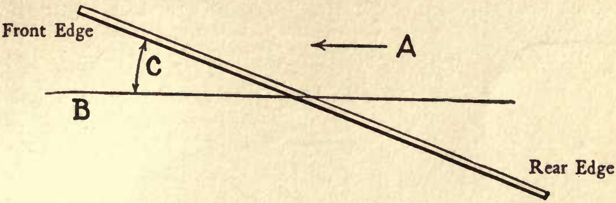


Fig. 17. — Path of a plane inclined at the angle *C* to the horizontal. The arrow *A* indicates the direction of travel. If the speed is sufficient the plane will rise because of the upward inclination of the plane.

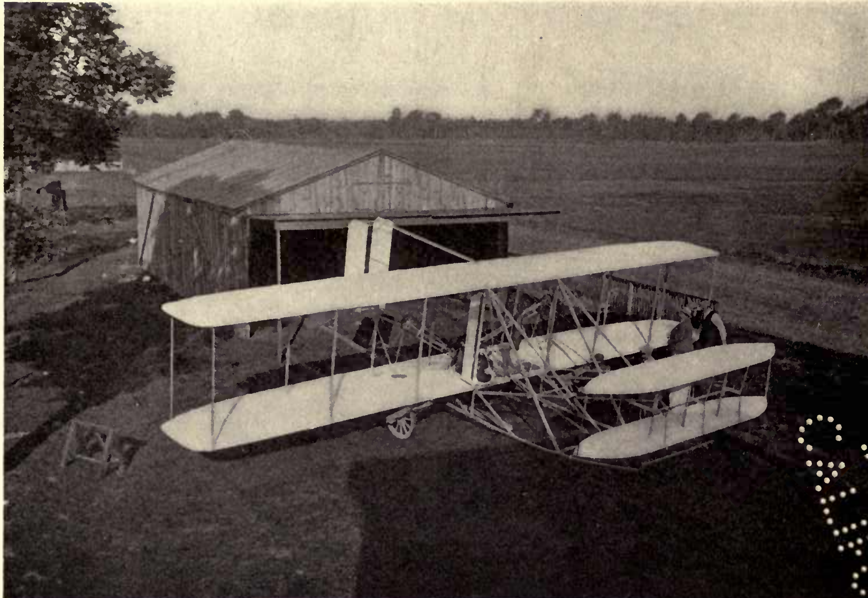
its lower surface. The driving power, whatever it may be, overcomes the resistance or pressure; yet the effect of the resistance or pressure is to keep the plane up in the air. So, the plane tends to slide up diagonally on the resisting air; gravity (weight) tends to draw the plane down toward the earth; and the diagonal sliding action tends to move the plane farther from the earth. This climbing effect is obviously dependent on the angle of the plane.

If the angle is large, it is great; if the angle is small, it is slight. Given a very high speed of propulsion, a speed greater than the falling tendency, and the plane is bound to rise. Given a speed of propulsion less than the falling tendency and the plane will sooner or later settle to the ground. Horizontal flight can therefore be maintained by proper adjustment of speed and angle.

This angle at which the plane moves against the air is known as the "angle of incidence." It is positive, because it has a tendency to lift. If the plane were tilted forward or dipped, the sliding effect would be earthward. Indeed, so marked would be this effect that the plane would reach the ground much more quickly than if it fell simply by its own weight. In that case the angle of incidence is negative, because it depresses.

It is therefore evident that an advancing aëroplane may be caused to travel up or down simply by making the angle of incidence positive or negative.

During flight, a Wright or Curtiss or Blériot machine is subjected to every whim of the air.



Photograph by Edwin Levick

Fig. 21.—The first type of Wright biplane, showing the general disposition of the main planes, forward horizontal rudders and rear vertical rudders

These incessant variations of the air must all be counteracted; otherwise the machine will capsize.

It happens during flight that the aëroplane, because of the wind's caprice, will drop more on one side than on the other. To maintain his balance, the aviator must in some way lift the falling side or lower the rising side, or do both. It was this problem that long baffled the inventor of aëroplane flying-machines. The whole art of machine-flying is summed up in its successful solution. To the Wright Brothers of Dayton, Ohio, belongs the full credit of having devised the first and thus far the most efficient means of solving that problem, a means now embodied in almost every successful flying-machine.

Suppose that the plane *A* in Fig. 18 is provided at each side with tips *C* and *D*, hinged so that they can be swung up or down. If these two tips (*ailerons* the French call them) are swung so that they lie flush with the main plane *A*, they have no effect whatever beyond adding to the amount of aëroplane surface. Suppose that the near side of the plane drops. In that case, the tip *C* is thrown down as shown in Fig. 18. What happens? More resistance is offered to the air at that side and greater upward pressure is consequently exerted, so that the plane is restored to its former position

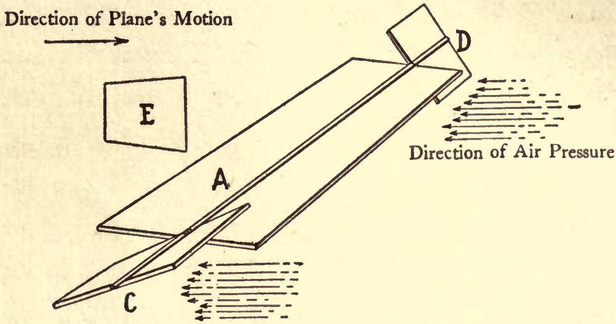


FIG. 18. — How a plane is laterally balanced by means of ailerons and a vertical rudder.

The plane *A* is provided with hinged tips *C* and *D* and with a vertical rudder *E*. The tips are swung in opposite directions to correct any tipping of the plane, and the vertical rudder *E* is swung over to the side of least resistance (the side of the tip *D* in the example here given) in order to prevent the entire machine from rotating on a vertical axis.

of equilibrium. To assist in this restoration, the tip *D* at the farther side of the plane can be tilted down, so that the angle of incidence is negative or depressive. Hence the far end of the plane is lowered while the near end is raised. In all flying-machines this dropping of one tip and raising of the other is effected simultaneously by a system of cables and levers. When the plane's balance has been regained, the tips are swung so that they lie flush with the plane *A*, and become virtually part of the plane.

As a result of inclining the tips at opposite angles, the near side of the plane offers more resistance to the air than the far side. Hence the near side will be retarded and the far side accelerated. This will cause the entire plane to swerve from its course. It was a brilliant discovery of the Wright Brothers to correct this swerving by means of a vertical rudder *E*, which is thrown over to the side of least resistance — the far side in the particular instance pictured in Fig. 18. The wind pressure on the rudder exerts a counteracting force at the rear of the machine and opposes the tendency of the machine to turn. Hence the vertical rudder in flying-machines serves not nearly so much for steering as for preventing the spinning of the machine.

The actual controlling method devised by the Wrights is shown in Fig. 19. Instead of one plane, the Wrights employ two superposed planes *A* and *A′* trussed together. In front or rear is a horizontal rudder or elevator to steer the machine up or down, which rudder in the example before us (an old Wright type although the principle is the same in the new) consists of two superposed planes, 5 and 6, and which is operated by the lever *F′* through the medium of connecting rods. In the

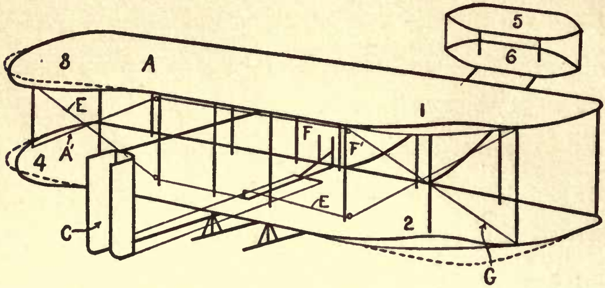


Fig. 19.—The system of control on an old Wright model.

rear is the vertical rudder *C*, which serves to steer the machine from side to side and to coact with the planes *A* and *A′* in keeping the machine on its course. Instead of employing pivoted tips like those shown in Fig. 18, the Wrights warp the corners of the planes *A* and *A′*. Thus, when the corners 1 and 2 are elevated, the corners 3 and 4 are depressed. This simultaneous elevation and depression of corners is produced by a cable *E*, attached to a lever *F′*. By throwing the lever from side to side the planes are warped. The vertical rudder *C* is connected by tiller ropes with the same lever *F′*, and is swung by moving the lever F′ back and forth. Hence the planes are warped and the vertical rudder properly turned by the one lever *F′*. The photograph reproduced in Fig. 20 shows Mr. Wilbur Wright seated in his machine, with his hands on the controlling levers. Fig. 21 pictures the Wright machine on the ground and shows the disposition of the main planes, horizontal or elevation rudders, and vertical rudder. Fig. 22 depicts an instruction machine with an extra lever for the pupil.

Some of the machines which Mr. Glenn H. Curtiss has flown are similarly provided with two superposed main planes *A* and *B*, as shown in Fig. 23, with a box-like rudder in front and with a rear vertical rudder *D*. The front horizontal rudder is swung up or down by means of the rod *R* connected with the wheel *N*, the wheel being pushed or pulled by the pilot for that purpose. The same wheel *N*, when rocked like the pilot wheel of a steamboat serves to swing the vertical rudder *D* by drawing on one or the other of two tiller ropes, *S.* In his earlier machines, as, for example, the one illustrated in Fig. 24, Curtiss employed supplementary plane tips, very much like those represented in Fig. 18. In his later machines, however, one of which is shown in Fig. 25, he

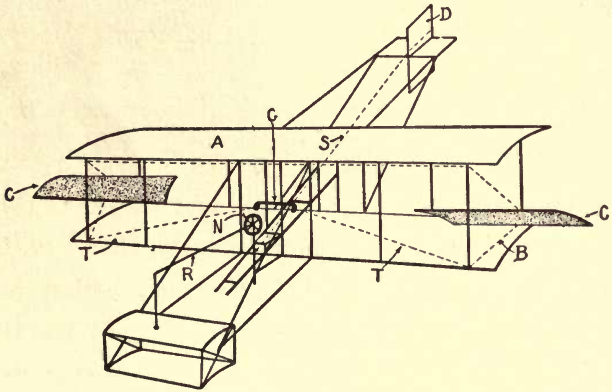


FIG. 23. — The Curtiss system of control.

has transferred the tips from the sides of the main planes to positions between the main planes, beyond which they project, as indicated by the letters *C C* in Fig. 23. Despite the transfer their purpose still remains the same. To swing the supplementary planes *C C* in opposite directions, cables *T T* are connected with the seat-back *G*, which is movable from side to side and which partly encircles the pilot's body. By throwing his body from side to side the pilot swings the planes *C C* in opposite directions. The effect is the same as if the main planes *A B* were warped, as in the Wright machine. Whether or not it is necessary to throw over the vertical rudder when the balancing planes *C C* are swung is the question at issue in the patent infringement suit instituted by the Wright Brothers against Curtiss. The Wrights claim that Curtiss cannot fly unless the vertical rudder is operated simultaneously with the balancing planes. Curtiss claims that he can. Much testimony has been taken on both sides. A United States Circuit Judge thought that the preponderance of expert evidence was on the side of the Wrights, particularly since Curtiss himself admitted that he did sometimes use the vertical rudder to offset the swerving of the machine caused by changing the inclination of the balancing planes. A preliminary injunction was therefore issued, which, on appeal, however, was dissolved. Whether or not Curtiss can fly without simultaneously operating his vertical rudder and his balancing planes

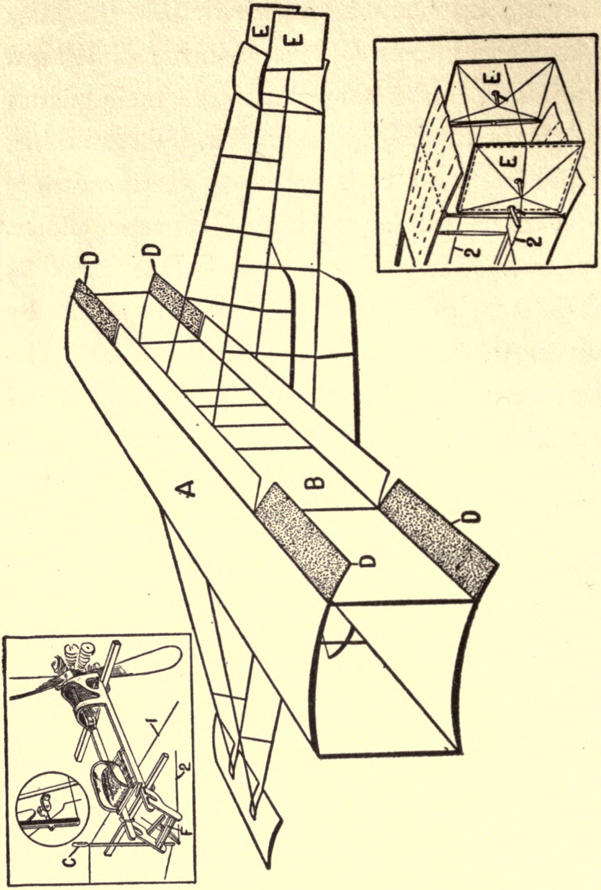


FIG. 26.—The system of ailerons and rudders devised by Henry Farman for maintaining fore-and-aft and side-to-side balance.

will be decided when the question of infringement is settled at the final hearing.

In the Farman biplane, which the Wright Brothers allege likewise infringes their patent, the ailerons, as illustrated in Fig. 26, form part of the main planes *A B*. They are the hinged flaps *D D* at the rear corners of the main planes. The inclination of the ailerons *D D* is varied by means of cables leading to the lever *C*. By moving the lever *C* from side to side, the ailerons are moved up and down in opposite directions. To the rear of the main planes two adjustable rudders *E E* are placed, from which two wires lead to a tiller *F* operated by the pilot's feet. When the aëroplane tips to the left, for example, the pilot swings his control-lever *C* to the right, thus pulling down on the flaps on the left-hand side of the planes and creating more lift on that side. The right-hand flaps remain horizontal, held out by the air pressure. When the machine is at rest on the ground, the flaps hang down vertically, as shown in Fig. 27. In Fig. 28 Mr. Farman is shown seated in his biplane. His hand grasps the lever by means of which both the ailerons or flaps and the forward horizontal or elevation rudder are operated.

In his later machines Mr. Curtiss has provided ailerons similar to those of Farman, as shown in Fig. 29.

The Blériot monoplane, which is also involved in this Wright litigation, is outwardly at

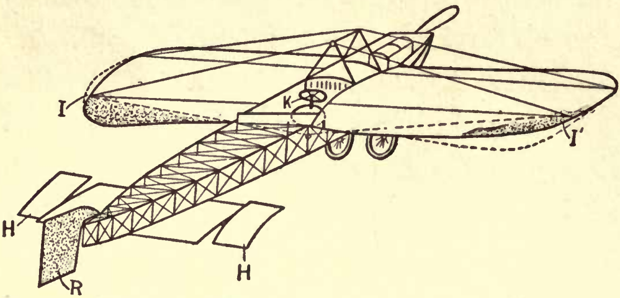


FIG. 30. — The Blériot system of control.

least more like the Wright machine in the mechanism for maintaining side-to-side balance. Its single supporting plane is warped at the sides by a lever and a system of cables, as shown in Fig. 30. The single supporting plane is rigidly trussed along its front edge, but a cable is attached to one rear corner at *I* and passes downward, and toward the centre to a pulley *F* (Fig. 31) actuated by a lever *K*, and upward to the opposite rear corner of the plane *I'* (Fig. 30). By moving the lever *K* to one side, the cable pulls down the side rear portion of the

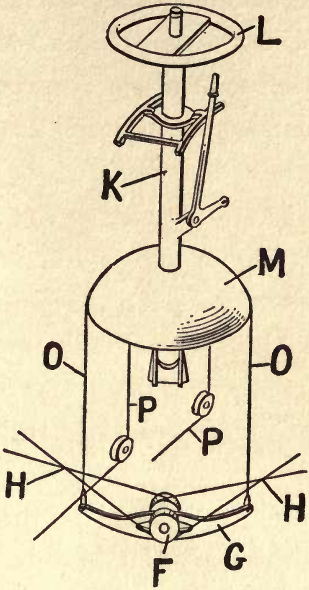
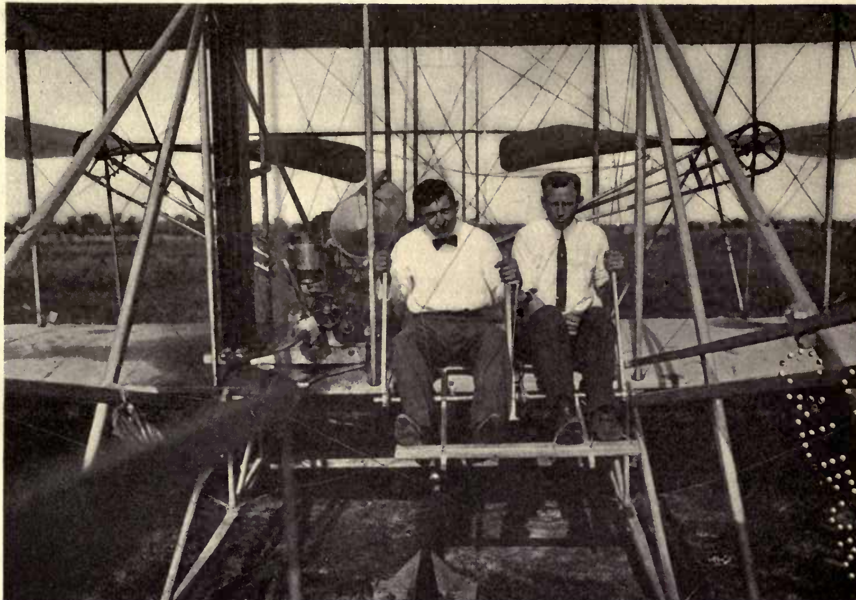


Fig. 31. — The steering and control column of the Blériot monoplane. The wheel *L*, the post *K*, and the bell-shaped member *M* form one piece and move together. Wires *O* connect the bell with the yoke *G*, carrying the pulley *F*, around which the wires *H* running to the flexible portions of the supporting planes are wrapped. By rocking the post and bell from side to side in a vertical plane the wires *H* are respectively pulled and relaxed to warp the planes. By moving the post *K* back and forth the horizontal rudder is operated through the wires *P*. These various movements of the post can be effected by means of the wheel *L*, which is clutched by the aviator's hands, or by means of the bell *M*, which can be clutched by the aviator's feet if necessary.

plane at one tip to a greater angle of incidence than the normal plane of the body of the aëroplane, and permits the opposite side rear portion to rise to an angle of less incidence. Thus the whole plane is warped, and the portions lying at the opposite tips are presented to the air at different angles of incidence. The vertical adjustable rudder *R* (Fig. 30) is located at some distance to the rear of the main plane, and wires lead from it to a tiller operated by the feet. When the pilot warps the plane he swings the rudder to prevent the machine from spinning. By moving the lever *K* back and forth the horizontal rudder is rocked up and down.

In the Antoinette monoplane the horizontal or elevation rudder and the stabilising mechanism are quite independent. The vertical rudder consists of two vertical triangular surfaces at the rear. They are moved jointly by means of wire cables running from a tiller worked by the aviator's feet. When this tiller, which moves in a horizontal plane, is turned to the left, the aëroplane will turn to the left. The elevation rudder in the Antoinette mon-



Photograph by Tresslar

Fig. 22.—A machine devised by the Wrights for the instruction of pupils

oplane consists of a single triangular horizontal surface placed at the extreme rear. It is governed by cables leading from a wheel placed at the aviator's right hand (Fig. 32). To ascend, the wheel is turned up. This causes a decrease in the inclination of the elevation rudder relatively to the line of flight, and the machine, therefore, rises. Side-to-side balance was at one time maintained by ailerons, as shown in Fig. 33. Latterly it is maintained by warping the outer ends of the main plane very much as in the Wright machine. But the front ends are movable and the rear ends rigid throughout in the new Antoinette, while the opposite is the case in the Wright biplane. The wheel at the aviator's left hand, through cables and a sprocket gear, placed at the lower end of the central mast, controls the warping. For correcting a dip downward on the right the right end of the wing is turned up, and at the same time the left end is turned down, thus restoring balance.

Warping a plane and rocking an aileron are not the only ways of maintaining side-to-side balance. The late Professor S. P. Langley discovered that by cutting a plane in two and arranging the two parts so that they would form a rather wide V when viewed from the front or rear ("dihedral angle" is the proper technical term), a certain amount of automatic stability would be obtained. He constructed his own successful small models on that principle. Blériot, too, adopted it in at least one of his earlier machines. Although wasteful of power it is still a conspicuous feature of many French machines of the present day. Even in some recent biplanes, notably the racing Farman, it is to be found.

Still another way of obtaining a certain amount of automatic stability is to employ vertical surfaces to prevent tilting and to distribute the pressure more evenly over the main surfaces. An example is to be found in the earlier Voisin machine, which is a biplane divided into cells by vertical curtains or partitions (Fig. 34). In practice, these partitions are found inadequate, for which reason the pilot of this Voisin type must right his machine by steering with the rudder. Thus, if the machine cants up on the left and down on the right, he steers to the left. This brings the right side up again because it is suddenly called upon to travel more quickly through the air than the left side, increased speed resulting in increased elevation. This Voisin type is one of the few constructions that does not fall within the scope of the Wright patent. Farman, who was one of the first pilots that ever tried a Voisin, abandoned it for the aileron machine, which bears his name. In the new Voisin machines (Fig. 35) no cells at all are to be found, but instead ailerons similar to those adopted by Farman. On the whole it must be confessed that the most successful machines at the present time are those in which the side-to-side balance is maintained either by warping the wings or by means of ailerons.

Sometimes the vertical surfaces are distributed along the frame of the machine in the form of keels. Although they contribute a certain stability, it cannot be denied that they also increase the resistance and lower the speed. To prevent this so far as possible, and yet to retain whatever advantages they may have, it is customary to taper them. Examples of such tapering keels will be found on the Antoinette and Hanriot monoplanes (Fig. 36, Frontispiece). In a few years keels will probably disappear altogether. The advantages hardly offset the disadvantages. No special arrangement or design of keels has really ever succeeded in insuring automatic stability. Even now the best designers confine them to the extreme rear of the machine, where they act somewhat like a bird's tail.

Mr. F. W. Lanchester, the distinguished English authority, has suggested that automatic stability can be insured by driving the aëroplane at speeds higher than those of the gusts, that are so liable to upset it. Just as the "Lusitania" at twenty-five knots dashes through waves and winds that would drive a fishing-smack to cover, so the high-speed aëroplane, in his opinion, would sail on, undeterred by the fiercest blast. Sixty miles an hour is the minimum speed that a machine should have, if his idea is correct. Moreover, he believes that, if the aëroplane is to have any extended use, it must travel very much faster than the motor-car.

Another means of attaining automatic sta-

Fig. 24.—Glenn H. Curtiss winning the Scientific American Trophy on July 4, 1908

bility consists in varying the angle of incidence by rocking the whole plane on a horizontal axis, which is done by Esnault-Pelterie.

The foregoing explanation of stability and stabilizing devices applies only to side-to-side balance. Fore-and-aft balance can be obtained, as in birds, by tails, such as are found in the Curtiss, Blériot, Antoinette, Santos-Dumont, Esnault-Pelterie, and indeed most machines.

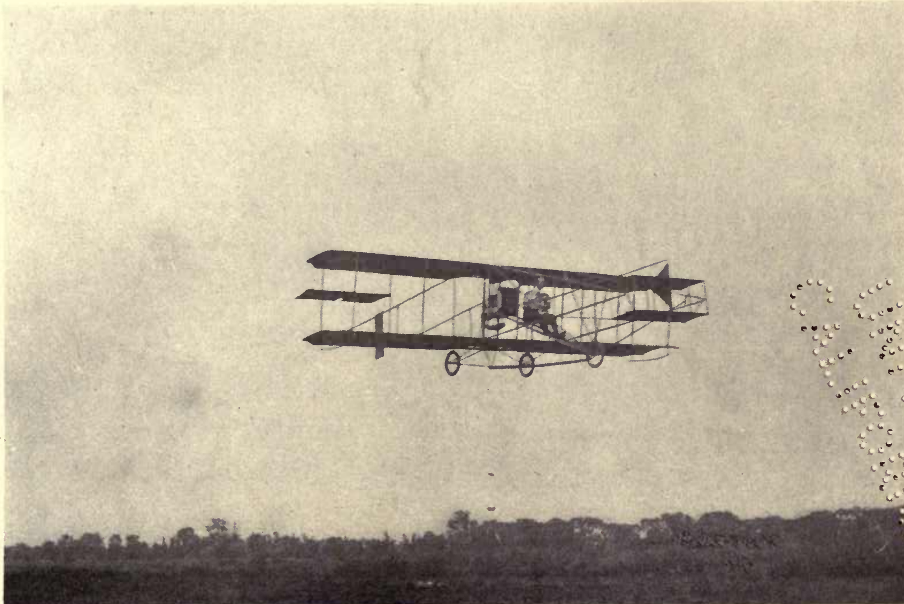
The tail may be either a single horizontal surface or a cell, like a box kite. Almost every machine that now flies is provided with a tail to secure steadiness in flight. In the new Wright biplanes (Fig. 38) a single horizontal surface is used at the rear of the machine, a surface which also serves as an elevation rudder; for the Wrights have removed from the front of the machine those two parallel horizontal surfaces, which, in the early days of their work, were to them like the antennæ of an insect, a means of feeling their way. The Wrights were the first who ever placed the rudder in front, and their example was quickly followed by Curtiss, Farman, Sommer, Voisin and other biplane makers. Whatever advantages this forward position of the horizontal rudder may have, it is certain that it increases the tendency of the machine to pitch in flight, because of the long lever-arm provided by the rods connecting the forward rudders with the main framework. When the Wrights reversed themselves and removed the horizontal rudder from the front and placed it at the rear, where it performed not only its old function, but also served as a tail (an instrument with which the earlier Wright machines were not provided), their example was promptly followed by Voisin (Fig. 35), Bréguet, Goupy, Caudron Frères and other constructors. It is safe to predict that in the future most biplanes will be provided with rear horizontal stabilising and elevating surfaces.

From the very first, monoplanes have been provided with rear horizontal or elevation rudders, probably because such is the example offered by every bird and because the late Professor Langley adopted them after much experimenting. The Blériot, Antoinette and other monoplanes have rear horizontal rudders and also tails.

The tail corrects the see-saw motion or pitching of a flying-machine in flight. The further back that it is placed the greater will be the steadying effect. If placed too far back, however, a "dead centre" will be reached. If there is no tail the pilot must manipulate the horizontal rudder to check the see-saw motion. The Wrights have taken out a patent for a mechanical device, which maintains fore-and-aft stability automatically. In this device the human brain is supplanted by the pressure of the air on a plane. Compressed air is substituted for muscular action. Lateral stability is automatically maintained by means of a pendulum. The plane and pendulum open valves which admit compressed air to an engine operating the horizontal or elevation rudder and warping mechanism.

To relieve the pilot of the physical strain of more or less constantly warping planes or manipulating ailerons, it was suggested long before the day of the Wrights that the flying-machine be provided with some automatic device which would prevent any capsizing tendency. The more important of such appliances are moving weights, pendulums, and gyrostats. A gyrostat is any rapidly rotating body, which, by virtue of its rotation, resists any force tending to move it from its plane of rotation. The greater the weight and the higher the speed of the gyrostat the greater must be the force expended to shift it from its plane of rotation. Hence if a gyrostat could be mounted on an aëroplane it certainly would tend to resist any unbalancing force, such as a gust of wind. Paul Regnard in France is said to have conducted very successful experiments with gyrostatically controlled aëroplanes. Roberts in England has also made more or less encouraging tests. In his machine the gyrostat is applied as shown in Fig. 37.

The pilots of present machines object to any device that will relieve them entirely of all hand control. They would much prefer an automatic device which is immediately thrown out of operation when the hand-devices are manipulated. It is argued that a machine must be humoured, that with an automatic device such as the gyrostat, it is impossible to accommodate the machine to variations in the wind.



Photograph by Edwin Levick

Fig. 25.—Glenn H. Curtiss in one of his flying-machines, equipped with balancing-planes between the main planes

Moreover, there is the objection that the machine must be elevated rapidly in starting, with a fairly large angle of incidence, but must afterwards assume a fairly flat angle for horizontal flight, with all of which a steadily running gyrostat would seriously interfere. Soaring down a steep angle with motors at full speed could hardly be accomplished with a gyrostat running at a fixed rate, for it is the gyrostat's tendency to resist movement. Besides, there is always the possibility that the motor which drives the gyrostat may stop, so that the aviator is helpless if no hand-controlled devices enable him to prevent rocking from side to side and pitching fore and aft.

The pendulum, as we have seen, has been suggested by the Wrights as well as by other inventors to relieve the aviator of his present duties. The underlying idea is that a freely suspended weight will always tend to hang down, and that it would be an easy matter to connect with it elevation rudders and ailerons, in such a manner that pitching fore and aft, or rocking from side to side could be controlled by the effort of the pendulum to assume a perfectly normal position relatively to the earth. The pendulum, however, will hardly be likely to attain the desired end. It cannot control a flying-machine automatically, as Professor Prandtl has pointed out. The very force which causes an aëroplane to change its horizontal position in flight also retards it, accelerates it, or inclines it from side to side. Consequently a pendulum, which has the momentum of the entire machine, will follow the direction of the aëroplane's inclination and, so far from hanging down, will deviate from the vertical. The result will be, curiously enough, that it will always maintain its position relatively to the planes, whatever their inclination fore-and-aft and side-to-side may be. Hence the pendulum is inoperative. Furthermore, when an aëroplane is rounding a curve at the rate of from forty to sixty miles an hour, centrifugal force would completely nullify the action of the pendulum.

If a gyrostat is to be used, it is likely that it will be combined with some system of hand control, so that the aviator can depend upon the one or the other, as circumstances may dictate.

Photograph by Edwin Levick

Fig. 27.—The Farman biplane. The ailerons are the flaps on the planes, which, as shown in this picture, hang down almost vertically when the machine is at rest

But how this combination would really improve the situation it is difficult to see. Automatic control is necessarily complicated. Hand control is admittedly dependent upon a cool head and an expert hand. Moreover, an automatic device must be made as small and as light as possible, for the aëroplane as it now stands is a machine in which the weight of every part has been reduced to a minimum. Can control mechanism, dependent upon a gyrostat, be made sufficiently light to meet the requirements of present construction? The more one considers the question, the more likely are we to believe that the best automatic machine is a well-trained hand.

Any one who has seen a skilled man steering a small boat in a heavy sea must realise that there is no possibility of making any automatic device which would take his place, and that any attempt to make the steering automatic by such means as a gyrostat would mean the certain swamping of the boat in a sea through which it could be steered quite simply by hand. The aëroplane is very much in the position of this small boat.

The danger of hand control is to be found in the possibility of making a false move. Locomotive engineers, signal men, automobile chauffeurs, are all of them in a position where a false move means a bad accident. Yet for all that, the number of errors which are made is comparatively small. A ship is dependent upon the engines and skill of the men in the pilot house; yet it is but rarely that we hear of shipwrecks due to bad judgment in the wheel house. All things considered, it is very likely that aëroplanes will be hand controlled for years to come.

CHAPTER VI

MAKING A TURN

In straightaway flight an aëroplane is balanced to a certain extent by the main supporting surfaces (the large spread of which counteracts sudden inclination) and also by the position of the centre of gravity, which lies below the supporting surfaces in many machines. But when the vertical rudder is thrown over to swing the machine around, new forces come into play.

When a line of soldiers wheels around a street corner the man at the inner end of the line does little more than mark time; the man in the centre of the line marches along at a steady pace; while the man on the outside all but runs. In order that the line may be straight the movement must be progressively faster from the inner to the outer end. An aëroplane as it turns horizontally is in exactly the same predicament as a line of soldiers. The outer end of the machine must move faster than the inner end.

The accompanying illustration, Fig. 39, will make this clearer. Let us assume that the arc to be described is sixty feet in diameter, and

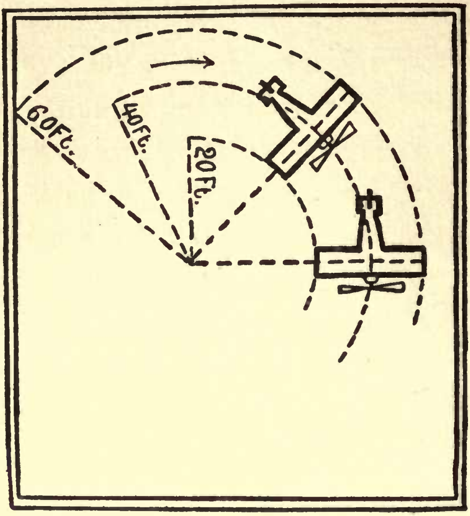


FIG. 39.—An aëroplane of 40 feet spread of wing rounding an arc of 60 feet radius. Since the outer side of the aëroplane must travel over a given distance in the same time that the inner side must travel a considerably shorter distance, gravitation must be opposed to centrifugal force in order that the turn may be effected with safety.

that the aëroplane has a spread of forty feet. The outer end of the machine must describe its large arc of sixty feet radius while the inner end is describing its small arc of twenty feet radius. Evidently the outer end must travel considerably faster than the inner.

As the speed of an aëroplane increases, its lifting power also increases. Hence the more rapidly moving outer end of an aëroplane will be subjected to a greater lifting effort than the slowly moving inner end, and hence the entire machine is canted at a more or less sharp angle on a turn. This natural canting or banking has its advantages. It counteracts the effects of centrifugal force, which are unavoidable in any rotary movement.

What centrifugal force means we see when a weight at the end of a cord is whirled around. If whirled fast enough, the weight will describe a circle, because the centrifugal force is very much greater than the force of gravitation. If the whirling be slackened below a certain critical point, the weight will drop back to the hand. A flying-machine is like the whirling stone. It has a very large centrifugal force as it turns. So great is that force that it must be checked by the force of gravitation, in other words, the weight of the machine. The more the machine is heeled over, the more marked will be the action of gravitation. Hence the natural canting of the machine on a curve is of advantage in counteracting the effect of centrifugal force.

If the canting be very pronounced, it is possible that gravitation may overcome the centrifugal force, so that the machine will slide down to the ground. To forestall that possibility the aviator may either sweep his circle on so long a radius that there will be but little canting, or he may employ wing-warping devices or ailerons to counterbalance the canting action. Since most aëroplanes are provided with either warping devices or ailerons, it is the usual practice to depend upon them in turning. The result is that we see skilful pilots swinging in an arc at a speed that cants their machines at an angle which may be more than seventy degrees to the horizontal and which almost causes the spectator's heart to stop beating, so perilous does the exploit seem to the eye.

The inquiring reader may ask: How does wing-warping or the manipulation of ailerons prevent the machine from slipping down? The principle involved is exactly the same as that

Photograph by Edwin Levick

Fig. 28.—Henry Farman seated in his biplane. His hand grasps the lever by which the ailerons are operated

which underlies the balancing of the machine in straightaway flight when it is subjected to capsizing gusts. As soon as the pilot wheels, he increases the angle of incidence on the inner end and hence the upward pressure, with the result that the tendency of the inner end of the machine to fall is checked. Simultaneously the angle of incidence of the outer side is decreased and the downward pressure increased, with the result that the tendency of the outer side to rise is checked.

All this sounds very easy; yet, even after a successful aëroplane had been invented, many machines were wrecked before the trick of making a turn was learned. It took the French two years to learn the art of turning. Indeed, a wealthy Parisian, named Armengaud, offered a prize to the first Frenchman who performed the feat. Henry Farman won that prize so recently as July 6, 1908. The Wright Brothers spent the whole flying season of 1904 in learning how to sweep a circle when the wind was blowing. Octave Chanute, the only engineer who was allowed to see them at work during that period of apprenticeship, gives this interesting account of their trials and tribulations:

"I witnessed a flight at Dayton on October 15, 1904, of 1,377 feet, performed in twenty-four seconds. The start was made from level ground, and the machine swept over about one-quarter of a circle at a speed of thirty-nine miles an hour. The wind was blowing diagonally to the starting rail at about sixteen miles an hour.

"After the machine had progressed some five hundred feet and then risen about fifteen feet it began to cant over to the left and assumed an oblique transverse inclination of fifteen to twenty degrees. Had this occurred at an elevation of, say, one hundred feet above the ground, Orville Wright, who was in the machine on this occasion, could have recovered an even balance even with the rather imperfect arrangement for control at that time employed. But he felt himself unable to do so at the height then occupied and concluded to come down.

"This was done while still turning to the left, so that the machine was going with the wind instead of against it, as practiced where possible.

"The landing was made at a speed of forty-five to fifty miles an hour, one wing striking the ground in advance of the other, and a breakage occurred, which required one week for repairs. The operator was in no wise hurt.

"This was flight No. 71 of the 1904 series. On the preceding day the brothers had made alternately three circular flights, one of 4,001 feet, one of 4,902 feet, and one of 4,936 feet, the last covering rather more than a full circle."

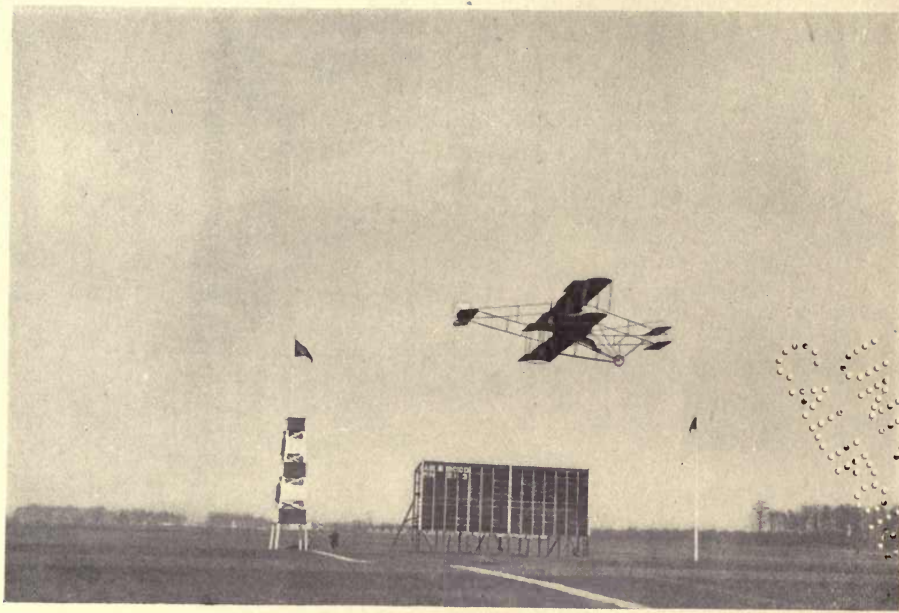
A steady wind is imperceptible to the man in a flying-machine, and turning is effected as easily with as against the wind. When the wind is unsteady not only is balancing difficult but turning also, since the machine must be simultaneously balanced and turned. The two operations are more or less confused. When the wind is very gusty the pilot may find it harder to turn and travel with the wind instead of against it.

A sharp turn on an aëroplane is like one of those moments on a yacht when you slack away quickly on the main sheet and prepare for the boom to jibe. There is none of the yacht's hesitancy, however; for the machine slides away on the new slant without a quiver. An inexperienced passenger on an aëroplane is tempted to right the machine, as it swings around and tilts its wings, by throwing over his body toward the descending side. In a canoe or on a bicycle it would be natural to use the body. In an aëroplane the movement is unnecessary because the machine does its own banking.

In the Curtiss and Santos-Dumont machines any such instinctive movement on the part of the aviator to right the careening machine actuates the ailerons or wing-warping devices in the proper way. In the Curtiss biplane, as we have seen, the seat-back is pivoted and is connected by cables with the ailerons. Hence, should the pilot involuntarily throw his weight over to right the machine, the ailerons are tilted to regulate the pressure on the planes in the proper manner.

The effect of the vertical rudder in turning varies with the speed of the aëroplane relatively to the speed of the wind. The higher the speed of the aëroplane the more marked is the influence of the vertical rudder on its course.

The form that the vertical rudder assumes is various. In monoplanes it consists of a



Photograph by Edwin Levick

Fig. 29.—One of the new Curtiss biplanes in flight. The machine is fitted with ailerons similar to those of the Farman machine pictured in Fig. 27

single vertical surface, mounted at the rear of the machine: in biplanes it usually consists of a pair of parallel vertical surfaces, as in the Wright machine. Occasionally these parallel vertical surfaces form the sides of a box, as in the Voisin and Farman machines, the top and bottom of the box serving as horizontal stabilising surfaces, as in the old cellular Voisin biplane.

CHAPTER VII

THE PROPELLER

FEATHERING paddles, somewhat like those to be found on steamboats, beating wings, like those of a bird, sweeps or oars have all been suggested as means for propelling the flying-machine; but the screw propeller is the only device that has met with any success. The screw propeller is the most important adjunct of the aëroplane, and also the most deficient. The circumstance is remarkable because the screw or helical rotating propeller was associated with schemes of aërial navigation no less than four centuries ago, and by no less a personage than the great artist-mechanician, Leonardo da Vinci, at the end of the fifteenth century.

Leonardo da Vinci's propeller was a screw or helix of a single " worm " or thread — practically all " worm " — comprising an entire convolution, of which the modern equivalent would be a single-bladed screw, blades being a much later development. It is not difficult to imagine how the original screw propeller came to be of the single "worm" type, and why one complete turn of the "worm" should be deemed essential. These were matters of subsequent development, the departures being suggested by experiment and trial.

It was first discovered by actual comparative trials that half a convolution of the "worm" was fully as efficient as a whole turn, and then that a quarter turn was more efficient than half. But with this curtailment of the helix a formidable difficulty arose. It had now developed into a one-bladed screw; it was unsymmetrical and, consequently, unbalanced. Centrifugal force and one-sided thrust jointly interposed, with poor results.

Eventually it dawned on the minds of the pioneer experimenters that to produce a more efficient, symmetrical, and compact screw propeller — while employing only a fraction of a convolution — two or more "worms," now reduced to blades, were necessary.

No perfect definition of a screw propeller has ever been given. It is usually defined as an organ which, by pressing upon a fluid, propels the vehicle to which it is attached. In a sense, the screw propeller may be regarded as a rotating aëroplane, with an angle of incidence, known as its "pitch," and a "camber," which is its curve. But the propeller differs from the aëroplane in that the blades are continually passing over the same spot many times in a second in air already disturbed. This is one reason why the propeller offers a far more difficult problem than the plane.

By the "pitch" of a propeller is meant the theoretical distance that the propeller would move forward in one revolution in a solid. Because a propeller revolves in air, a very thin and yielding medium, it loses a certain amount of power, which loss is known as its "slip." If the propeller in one revolution moves forward theoretically six inches, but actually only three inches, the loss of power or "slip" is fifty per cent. The slip varies with different speeds. To find the best pitch, the best curvature, the best diameter, the best speed, is the problem that confronts the propeller designer.

The ideal aërial propeller is one that can move through the air without friction. If the ideal could be attained, the entire power of the motor would be transformed into useful work, and a maximum thrust would be transmitted to the propeller shaft. The actual aërial propeller

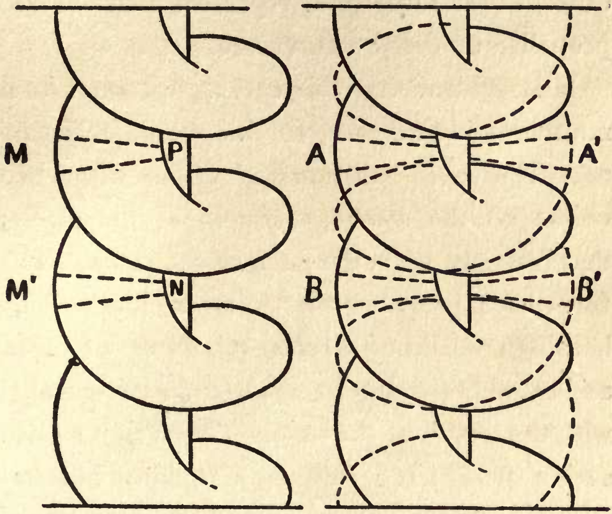


FIG. 41.—A single-threaded and a double-threaded screw. A two-bladed aëroplane propeller may be conceived to have been cut from a double-threaded screw, *i. e.,* the sections *A* and *A′* and the sections *B* and *B′*.

falls far short of that ideal. Its blades are not plane, but are curved in a manner skilfully designed to obtain a maximum efficiency. In order to give an idea of this curvature and its possible variations, consider a vertical section of an Archimedes screw (Fig. 41). Let us study the small slice, *M*. This small element is not a plane surface, but has a curvature which depends upon the pitch of the screw and its radius. Two such elements attached, opposite each other, to the same shaft represent a two-bladed propeller of definite curvature.

It is evident that this curvature cannot be a matter of indifference, for it is intimately connected with the distance *A B*, between two points on the same generatrix of the screw; that is to say, upon the pitch of the screw. The form of a propeller blade can be imitated by holding one end of a rectangular strip of paper and twisting the other end about an axis parallel with the length of the strip. The Wrights form such a surface in deforming aëroplanes in steering. If the aëroplane were attached to a fixed vertical axis, it would revolve about this axis like an ordinary propeller during a turn. The true screw-propeller in its simplest and most efficient type is but a very short length cut from a two-thread screw, in which the thread is relatively very deep, with a pitch equal to about two thirds of its diameter. A twist or curve in a propeller blade is necessary because the hub

Photograph by Edwin Levick

Fig. 32.—In the Antoinette monoplane the horizontal or elevating rudder is operated by means of a vertical hand-wheel by the pilot's right hand. The aviator here pictured is Hubert Latham

and the outer edge of the blade revolve at different speeds. The outer edge of the blade clearly must sweep through a greater distance in a given time than the hub. In order that all parts may theoretically grip the air equally, the angle is steeper at the centre than at the outer edge. In practice the hub portion has a much lower efficiency than the outer edge of the blade.

Just how many blades the propeller should have once gave us much concern. Some air-propellers have two blades, some three, some four. It is now generally conceded that nothing is to be gained by three and four blades, and that the two-bladed propeller is indeed the most efficient.

The Ericsson propeller (marine) was formed of a short section of a 12-thread screw of very coarse pitch and proved very inefficient. The aërial fan propeller of Moy (not a screw) had six broad vanes enclosed in a hoop and was but little better. The same remark applies to the propellers of Henson, Stringfellow, Linfield, Du Temple, and many others. Even the first propeller fans used by

Langley on his earliest aërial model were six-bladed. In his subsequent and highly successful model aërodrome the twin propellers were two-bladed true screws, as also were those of the Maxim machine.

It is a significant fact that the conspicuous successes have all been achieved with two-bladed propellers. All recent systematic and comparative experiment points to the fact that a two-bladed propeller is the most efficient, and, at the same time, fortunately, the simplest and lightest.

Authorities are not in accord on the proper position of the propeller. Most of them, however, hold, with Sir Hiram Maxim, that the proper position is in the rear. Blériot (Fig. 46), Levavasseur (who builds the Antoinette machine), and many monoplane designers mount the propeller in front. In its usual position just in advance of the centre, the front propeller interrupts the entering edge. To obviate this, some monoplane builders, among them Santos-Dumont and Blériot (in his passenger-carrying monoplane XII), place the engine and pilot below the plane.

On the position of the propeller Maxim says:

"Many experimenters have imagined that a screw is just as efficient placed in front of a machine as at the rear, and it is quite probable that in the early days of the steamship a similar state of things existed. For several years there were steamboats running on the Hudson River, New York, with screws at their bows instead of at their stern. Inventors of, and experimenters with, flying-machines are not at all agreed by any means as to the best position for the screw. It would appear that many, having noticed that a horse-propelled carriage always has the horse attached to the front, and that their carriage is drawn instead of pushed, have come to the conclusion that in a flying-machine the screw ought, in the very nature of things, to be attached to the front of the machine, so as to draw it through the air. Railway trains have their propelling power in front, and why should it not be the same with flying-machines? But this is very bad reasoning. There is but one place for the screw, and that is in the immediate wake, and in the centre of the greatest atmospheric disturbance. . . . If the screw is in front, the backwash strikes the machine and certainly has a decidedly retarding action. The framework, motor, etc., offer a good deal of resistance to the passage of the air, and if the air has already had imparted to it a backward motion, the resistance is greatly increased."

When mounted in front, the screw *draws* the machine along. Hence the front propeller is sometimes called a "tractor screw." When the screw is mounted in the stern, as in a ship, it *pushes* the machine along (Fig. 48) and is then truly a *propeller*.

The question of position is not yet settled by any means. The propeller at the rear has a free discharge, but, on the other hand, its feed is disturbed. In front it has a clear feed, but is hampered in discharging, and also modifies the streams impinging on the supporting planes, as Maxim points out.

The number of the propellers is also a moot point. Kress, a well-known experimenter, believed that there should be at least four propellers, so attached that their shafts could be directed to different angles. Thus, he imagined, they could be employed to sustain the machine in the air without driving it forward. This is the helicopter or screw-flier principle,

Photograph by Edwin Levick

Fig. 33.—The Antoinette monoplane of 1909 in which ailerons were employed to control the machine laterally

briefly considered in the chapter on flying-machine types.

The Wrights have always advocated the use of two propellers rotating in opposite directions (Fig. 44). There is always the danger, however, that one propeller may break down and that the machine may be imperilled. Indeed, an accident of that kind occurred during the official tests of the Wright machine at Fort Myer, Virginia, in 1908. A propeller struck a loose guy-wire and broke. The biplane crashed to the ground. Orville Wright, the pilot, was painfully injured, and Lieutenant Selfridge, a passenger, was killed. It must be stated, however, that had the machine been higher, Mr. Wright would probably have glided down in safety.

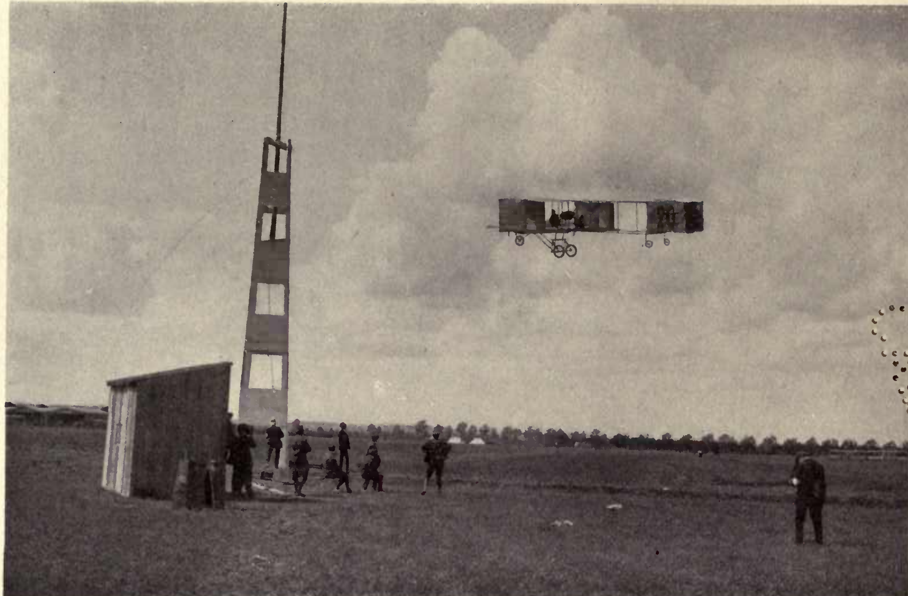
Should propellers be of very small diameter and high speed, or of large diameter and low speed? Both systems have their advocates. We know something about the power of heavy gales; and when we consider that an aëroplane propeller is capable of producing a little cyclone, it is easy to conceive of its exerting sufficient force to drive a 1,000-pound aëroplane at high velocity. Flying-machines have attained a speed of seventy miles an hour. In order to do this, the propellers must have turned fast enough to have produced a current of air considerably more than this velocity, because the fluidity and elasticity of the air are sufficient to cause a considerable "slip" of the propellers, which reduces their efficiency to a large extent. Hence even the slowest of propellers (the Wright) turns at the fairly high speed of four hundred revolutions a minute, while the swiftest turns at the rate of about fifteen hundred revolutions a minute, which is about the speed of an electric fan. A high-speed Chauvière propeller is a mere glittering disk of light about eight feet in diameter. The blades move so fast that it is possible to cast a shadow upon them; for the eye cannot perceive the interval which elapses before another blade has taken the place of that which has left a given spot. The phenomenon is simply one of the persistence of retinal images; but it serves to drive home the enormous speed of some aëroplane propellers.

It is generally believed that much better results could be obtained by the use of propellers of fifteen or twenty feet diameter rotating slowly. But there are two disadvantages involved in this feature of construction, which make its adoption in the machines of the future rather doubtful. The first is the greatly added weight of so big a propeller; and the second, the difficulty of building a good chassis high enough to enable the propeller to clear the ground.

Like the marine turbine, the aërial engine runs too fast for the best propeller speeds. The Wright brothers overcame this difficulty by the somewhat unmechanical expedient of chain gearing, one chain being crossed. A French firm has utilised the half-time cam-shaft of the engine, suitably enlarged, to drive the propeller, thus getting a speed reduction of two to one, but the Blériot, Antoinette, Farman, Voisin, and indeed most types continue to drive the propeller directly without reduction. It is probable that the direct drive will prevail, for any form of gearing, however simple, introduces an element of risk with doubtful benefits. At present there is scarcely any machine which has the propeller well under control, so that it can be stopped and started and altered in speed, without stopping the motor. This is due, of course, to the weight of clutches, change-speed gears, etc. Probably some enterprising engineer may produce a suitable gear for this purpose before long.

In this outline we have used the word "efficiency." How is efficiency determined, may well be asked. The true efficiency of a propeller driving an aëroplane is the ratio between the work of propulsion and the energy consumed, the work of propulsion being the product of the travel of the aëroplane multiplied by the resistance opposed to its forward movement. The efficiency is measured at a fixed point by causing the propeller to revolve, without advancing or receding, and measuring the thrust produced, in the direction of the axis, by a given horse-power.

The conditions of the experiment are very different from those of rapid flight through the air, in which the friction between the air and the propeller is enormously increased; no account is taken of the resistance opposed by the



Photograph by Edwin Levick

Fig. 34.—Voisin machine of 1909. Machines such as this are no longer made

air to the forward movement of the aëroplane. In fact, no work of propulsion is performed or even imitated, the sole result being a thrust which may be employed for propulsion. Under these conditions the propeller is comparable with a lever which supports a motionless weight and thus exerts a stress, but performs no work. For this reason absolute reliance cannot be placed on the results of many propeller tests.

A fair imitation of the conditions of flight as they directly affect the propeller itself can be obtained by placing the propeller in a tube in which an air current of any desired velocity is produced by blowers. Some experimenters mount the propeller so that it revolves freely in air and yet drives a boat or a road vehicle.

Some of the best results obtained, in recent times, of thrust for horse-power applied are: Maxim, nine pounds; Langley, about seven pounds; Spencer (with a Maxim type propeller), six pounds; Farman, and other experimenters in France, six pounds (about).

It is now a widely recognised fact that the aërial propellers at present in use are lamentably inefficient. Most aëroplane successes, except those of the Wrights, are achieved at an enormous cost; for the propellers waste probably more than half the power applied.

A propeller of large diameter and slow revolution is more efficient than one of small diameter and high speed, a circumstance borne out especially in the case of the Wright machine, in which more thrust is obtained per unit of power than in any other type (Fig. 43).

We are beginning to realise that the abuse lavished on the motor should be bestowed in very large measure on the propeller. The internal-combustion engine fitted to the aëroplane must have all the vital parts cut to the narrowest margin, and must be worked at very nearly break-down rate in order to produce an enormous amount of surplus power wasted by the screw. For this reason all our more serious investigators are carrying out scientific experiments to determine propeller efficiency. Perhaps when they have completed their work we may be able to build a propeller which will drive a flying-machine with something like economy of power.

The construction of the aërial propeller is the more delicate, because it depends to a large extent upon the peculiarities of the vessel to which it is to be attached. The methods employed in all establishments are the same; yet a Chauvière propeller is very different from a Wright propeller.

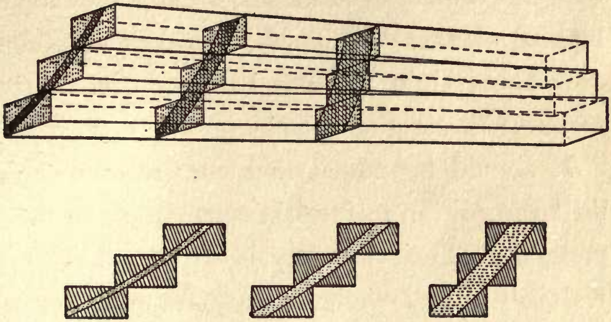


FIG. 42. — How the Wright propeller is cut from three planks laid upon one another fan-wise.

A Wright propeller is made of American spruce and is of very light construction. The extremities of the blades are covered with canvas, which is varnished with the rest, for the purpose of increasing the rigidity of the thin outer ends. The whole propeller is built up of three planks arranged as shown in Fig. 42, so that they overlap like the sticks of a fan, to an extent which diminishes as the distance from the hub increases. The superfluous parts of the wood, represented by the darker and triangular areas of the upper diagram in Fig. 42, are then cut away, and the curvature is tested at every point by patterns.

Chauvière propellers are made of ash, fumed oak, and walnut, and include six or seven overlapping planks. The finished propeller contains only about eight and one half per cent of the wood of the original planks.

It should be added that constructors show little disposition to furnish exact details of their methods. Their industry is so new that they jealously guard their secrets, for which reticence they cannot be blamed.

Propellers are also made of metal. In these the blades are soldered or riveted to the arms, which are steel tubes riveted to the hub. The blades are shaped by hammering them upon a form. In some cases they are cast, or twisted into shape, but this construction is not so good.

CHAPTER VIII

AËROPLANE MOTORS

Marvel as we may at the wonderful ingenuity displayed in the modern flying-machine, we have still much to learn from soaring birds. Little as we know of the efficiency of curved surfaces in the air, we know still less how to drive those surfaces without an inordinate expenditure of power, fuel, and lubricant. We have only to compare the amount of energy expended by the great flying creatures of the earth with that expended by our machines to realise how much we have to learn.

The late Professor Langley long ago pointed out that the greatest flying creature which the earth has ever known was probably the extinct pterodactyl. Its spread of wing was perhaps as much as twenty feet; its wing surface was in the neighbourhood of twenty-five square feet; its weight was about thirty pounds. Yet this huge creature was driven at an expenditure of energy of probably less than 0.05 horse-power.

The condor, which is preëminently a soaring bird, has a stretch of wing that varies from nine to ten feet, a supporting area of nearly ten square feet, and a weight of seventeen pounds. Its approximate horse-power has been placed by Professor Langley at scarcely 0.05. The turkey-buzzard, with a stretch of wing of six feet, a supporting area of a little over five square feet, and a weight of five pounds, uses, according to Langley, about 0.015 horse-power. Langley's own successful, small, steam-driven model had a supporting area of fifty-four feet, and a weight of thirty pounds. Yet it required one and a half horse-power to drive it. How much power is required to fly at high speeds in machines may be gathered from the fact that although Blériot crossed the Channel with a 25 horse-power Anzani motor, and the Wright machine uses a 25–30 horse-power motor, aëroplanes usually have engines of 50 horse-power and upwards. When we consider that one horse-power is equal to the power of at least ten men, we see that even the smallest power successfully used in an aëroplane represents the combined continuous effort of more than two

Photograph by Edwin Levick

Fig. 35.—The Voisin biplane of 1910. The old cellular construction is abandoned. Instead of vertical curtains between the main planes Farman ailerons are adopted

hundred men. To be sure, our flying-machines are very much larger than any flying creature that ever existed; but comparing their weights and supporting surfaces with the corresponding elements of a bird, their relative inefficiency becomes immediately apparent. Mr. F. W. Lanchester has expressed the hope that some day we may learn the bird's art of utilising the currents and counter-currents of the air for propulsion, so that we may ultimately fly without wasting power.

Aëroplanes are driven by what are known as "explosion engines" or "internal combustion engines." The fuel is not used externally, as in the steam-engine, but is fed to the engine in the form of an explosive gas. The gas is detonated within the engine to drive a piston. Most of these internal combustion engines operate on what is known as the Otto four cycle. A complete cycle comprises four distinct periods, which are diagrammatically reproduced in the accompanying drawings (Figs. 49, 50, 51, and 52).

During the first period (illustrated in Fig. 49) the piston is driven forward, creating a vacuum in the cylinder and simultaneously drawing in a certain quantity of air and gas. During

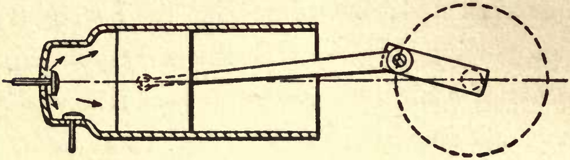


FIG. 49.

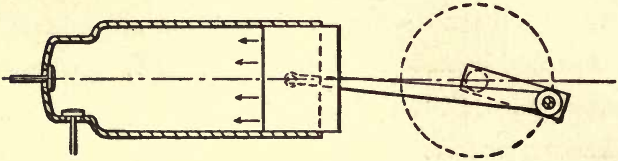


FIG. 50.

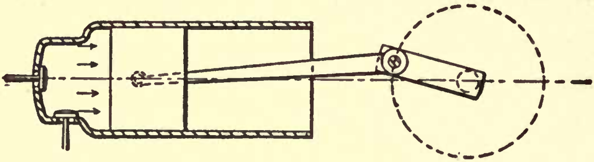


FIG. 51.

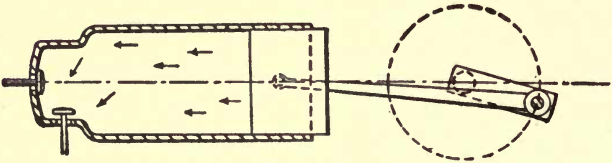


FIG. 52.

FIGS. 49, 50, 51, and 52. — The four periods of a four-cycle engine. During the first period (Fig. 49) the explosive mixture is drawn in; during the second period (Fig. 50) the explosive mixture is compressed; during the third period (Fig. 51) the mixture is exploded; and during the fourth period the products of combustion are discharged.

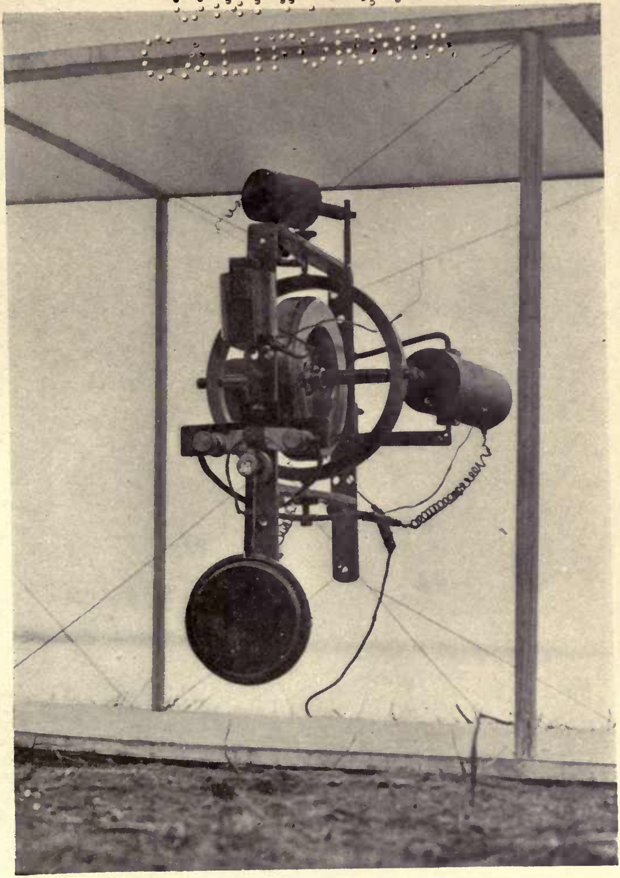
the second period the piston returns to its initial position; all the admission and exhaust valves are closed; and the mixture of air and gas drawn in during the first period is compressed. The third period is the period of explosion. The piston having reached the end of its return stroke, the compressed mixture is ignited by an electric spark, and the resulting explosion drives the piston forward. During the fourth period the exploded gases are discharged; the piston returns a second time; the exhaust valve opens; and the products of combustion are discharged through the opened valve. These various cycles succeed one another, passing through the same phases in the same order.

The fuel employed in the internal combustion engines of aëroplanes is gasoline, called petrol in England, which is volatilised, so that it is supplied to the engine in the form of vapour. In order that it may explode, this vapour is mechanically mixed with a certain amount of air. To obtain what is called cyclic regularity and to carry the piston past dead centres, a heavy fly-wheel is employed, the momentum of which is sufficient to keep the piston in motion on the return stroke.

Since considerable heat is developed by the incessant explosions, the cylinders naturally become hot. To cool them, water is circulated around them in a "water-jacket," or else a fan is used to blow air against them.

The memorable experiments of Professor Langley on the Potomac River gave rise to the idea that only an engine of extreme lightness could be employed if the flying-machine was ever to become a reality. Since his time biplanes have lifted three and four passengers besides the pilot over short distances. While the ultimate achievement of dynamic flight was due to the lightness of the internal combustion motor in relation to the power developed, subsequent experiment has demonstrated how the efficiency of the sustaining surfaces can be increased so as to diminish head resistance and to make extreme lightness in the motor desirable only on the score of freight-carrying capacity. The original motor used by the Wrights was comparatively heavy for the power developed.

Saving of weight in the motor permits the construction of a more compact and controllable machine than would be possible if the sustain-



Photograph by Edwin Levick

Fig. 37.—Gyrostat mounted in an aëroplane according to the system of A. J. Roberts. The gyrostat is controlled by a pendulum which swings to the right or to the left, according to the tilt of the aëroplane

ing surfaces were designed to carry considerable dead weight. To gain freight-carrying capacity the weight of the motor must be kept low. The fuel needed for a six-hour flight, for example, is equal in load to an engine weighing three pounds per brake horse-power, assuming that the hourly fuel consumption is one half a pound per horse-power. Clearly the motor must be light if the flight is to be long.

There are various ways of securing lightness in a motor. One way is to increase the power developed by cylinders of a certain size. Another is to reduce the weight for a given cylinder capacity by the use of thin steel cylinders and by constructing the parts as lightly as possible. A third way is to arrange the cylinders in such a manner that more than one connecting-rod is assigned to each crank with a consequent reduction in the weight of the crankcase. A fourth way is to cool the cylinders with air instead of water.

Many motor builders have abandoned the fly-wheel because it is the heaviest part of the engine. In order that the motor may run steadily without a fly-wheel and may be properly balanced, it has been necessary to rearrange the cylinders and to increase their number. The whole subject was recently considered by an anonymous writer in *Engineering* (London). The following lucid paragraphs on the arrange-

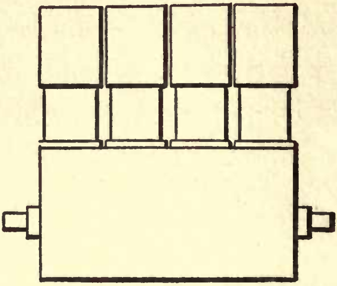
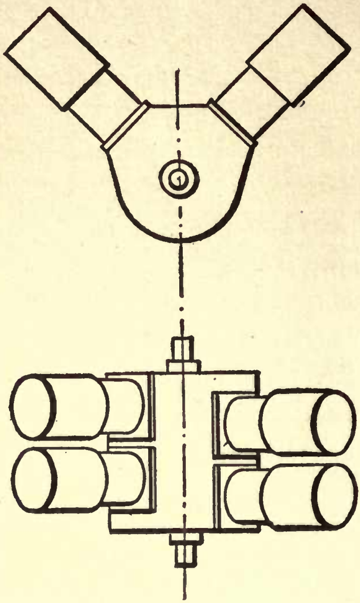


FIG. 53. — The usual arrangement of the four cylinders of a four-cylinder engine.

ment of cylinders in present aëroplane motors present his views:

"The weight of an engine consists principally of the cylinders and pistons on the one hand, and the crank, crank shaft, etc., on the other. Roughly speaking, the weight of the cylinders will be proportionate to the cube of the dimensions. That is to say, if the cylinders are arranged vertically in a row, for instance, the weight of the crank case, shaft, etc., will be practically proportionate to the cylinder capacity. If we can mount the cylinders in such a manner that we can get a great cylinder capacity with a very short crank case, we shall, however, save weight. If, for instance, we start with the vertical four-cylinder engine of the ordinary type, as shown in Fig. 53, the crank case has necessarily to be as long as the length over the cylinders. In this and the following figures the valves are omitted for the sake of clearness, and in all the figures the cylinders are the same size, so that the size of crank case necessary for a given cylinder capacity can easily be seen.

"Two common plans for reducing the length and weight of the crank case are to place the cylinders either diagonally, as in Figs. 54 and 55, or horizontally opposed, as in Fig. 56. In either of these arrangements the length of the crank case, etc., is almost halved, and a considerable saving of weight is effected. Any of these arrangements can be made with two, four, six, eight, or more cylinders. In the case of the diagonal engine the impulses are not evenly divided with two or four cylinders, though they can be so with six, if the angle between the cylinders be made one hundred and twenty degrees. With eight cylinders at ninety degrees the impulses are evenly divided, and this is the most usual number. In this type each diagonal pair of cylinders is connected with one crank. The diagonal engine, with the cranks at ninety degrees, can be balanced for all practical purposes, even where there are only two cylinders, by placing a balance weight opposite the crank



FIGS. 54 and 55. — Side and plan views of a four-cylinder engine with diagonally-placed cylinders.

equal to the weight of the whole rotating parts and the reciprocating parts of one cylinder. With four cylinders the cranks are usually placed opposite, but balance weights are still necessary to avoid a rocking moment. With eight cylinders the cranks are set so that the two end ones are opposite the two middle ones, and no balance weights are required.

"In the case of the opposed horizontal engine the two connecting rods work on opposed

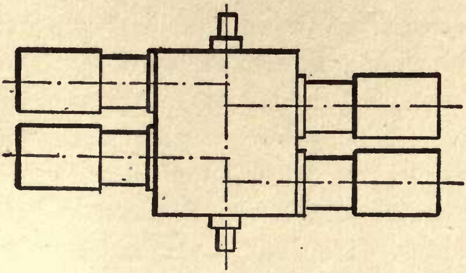


FIG. 56

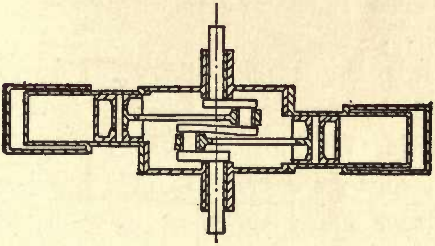


FIG. 57.

FIGS. 56 and 57.—Engine with horizontally opposed cylinders.

cranks, as in Fig. 57. In this case the engine, even the two-cylinder, is in many ways better balanced than the vertical or diagonal types, as the error in balancing, due to the angle of the connecting rods, is allowed for. If only two cylinders are used, there is, however, a very small rocking moment, due to the fact that the cylinders are not actually opposite each other; but this is usually a negligible quantity. . . . With four cylinders the rocking moment is balanced. The impulses in the horizontal opposed engine are always evenly divided, whether two, four, or eight cylinders are used.

"Comparing the horizontal opposed with the diagonal engine, the former appears to have all the advantages, as the impulses are more even with a small number of cylinders, and the balance better. The latter point will enable somewhat shorter connecting rods to be used without excessive vibration, thus lightening the engine. . . .

"While the crank case, etc., is distinctly lightened by these arrangements, it can be still more reduced if the cylinders are all arranged radially on to one crank. This has been done in a great many different ways by different makers. For comparison, with the previously-mentioned four-cylinder engines, a four-cylinder radial engine is shown in Figs. 58 and 59, the cylinders being the same size as before. It will be seen that in this case the crank case and shaft are very much shorter and lighter than in any of the previous arrangements. In practice four is not a good number of cylinders, as the impulses cannot be evenly divided, and an odd number of cylinders must be used to effect this. This type of engine can be satisfactorily balanced as long as the cylinders are evenly spaced round the crank case, for all the pistons are attached

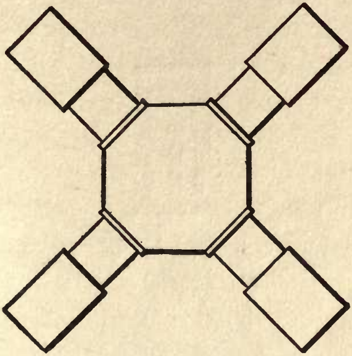


FIG. 58

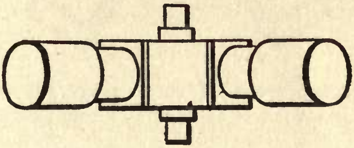


FIG. 59.

FIGS. 58 and 59.—Engine with four cylinders radially arranged.

to one crank pin, and therefore form one revolving weight, which can be balanced by a suitable balance weight.

"When many cylinders are used it is impracticable actually to put all the connecting rods to work onto one crank pin, as either the big ends would have to be very narrow, or the crank pin impracticably long. This can, however, be got over by the arrangement shown in Fig. 60.

"Probably the greatest difficulty in making the radial engine satisfactory is that of lubrica-

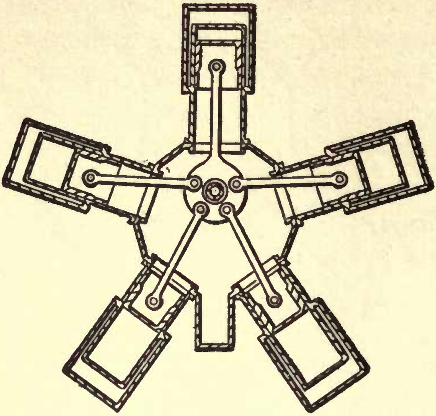


FIG. 60. — Arrangement of connecting-rods of an engine with four radial cylinders.

tion. This is a matter which does not seem to have had nearly as much attention paid to it as it needs. . . . The even distribution of the oil to the various cylinders of a radial engine is very difficult, and further, however well it might be managed when the engine is running, as soon as it stops the oil runs into the lower cylinders, and probably fouls the plugs, so that it is difficult to start it again. In order to get over this, the engine has occasionally been mounted on its side, with the crank shaft vertical, the propeller being driven through bevel gear. If it is desired to run the propeller slower than the engine, there is no great objection to this, and there is little doubt that the slow-running propeller is much the more efficient. Another plan is to modify the arrangement of the cylinders. Thus in

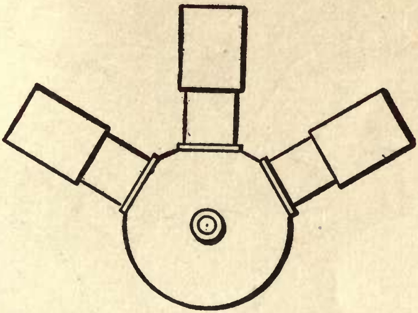


FIG. 61. — Arrangement of cylinders and crank case of one type of three-cylinder engine.

one make of three-cylinder engine the cylinders are all at the top of the crank case (Fig. 61), all the connecting rods leading to one crank pin. In this case it is impossible to divide the impulses evenly, and the balancing is not so good. In practice this type of engine is made with inside fly-wheels of considerable weight, and runs well, but the fly-wheels necessarily add to the weight. Another plan is to put all the cylinders at the top of the crank case, and to place those which should have been at the bottom in a complete radial engine on a crank opposite to the others, as shown in Fig. 62.

"In some cases the radial engine is made with the crank shaft fixed and the cylinders revolving. As constructed by the Société des Moteurs Gnôme, this type (Fig. 46) has given very good results, but it may be doubted

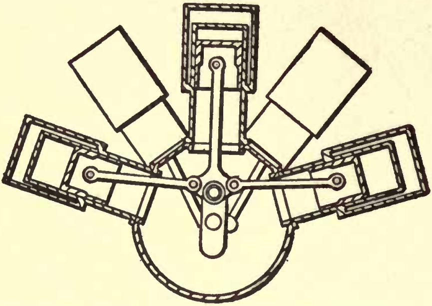


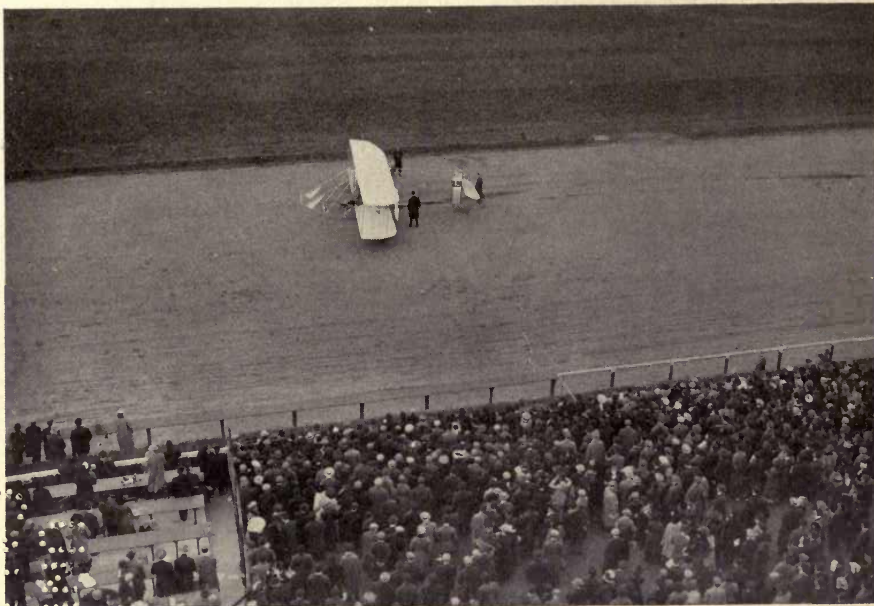
FIG. 62. — Disposition of cylinders crank case and connecting-rods in one type of engine.

whether they are due simply to making the cylinders revolve. A very small amount of consideration will show that the radial engine will be of the same weight whether the cylinders revolve or the crank shaft, all other details of construction being, of course, assumed to be the same. This being so, the only way in which the revolving cylinders can be an advantage is either by obtaining a lighter construction of cylinder or crank case, or else by increasing the power obtained from a given sized cylinder. There does not seem any reason for supposing that revolving the cylinders secures either of these results.

"The advantages of the revolving cylinders are: (1) That they act as a fly-wheel, and (2) that they render air-cooling more efficient. Where the propeller is directly coupled, however, no fly-wheel is required in any case. No doubt there is a distinct advantage in the air-cooling from the fact that the cylinders revolve, but it is not likely to be very great.

"Assuming that the ends of the cylinders are fifteen inches from the crank shaft, and the engine runs at twelve hundred revolutions per minute, the ends of the cylinders move through the air at about ninety-five miles an hour. When the engine with fixed cylinders is placed just behind the propeller, it probably always works in a current of air moving sixty miles an hour or more, so it will be seen that the difference is not so great as might be expected. In practice the power given per cubic inch of cylinder capacity by the Gnôme engine is very small, and there seems no reason to doubt that the same power could be obtained from fixed cylinders of smaller size. The good results appear to be due to the fact that the weight of the parts is reduced by machining practically all parts, including the cylinders and crank case, from steel forgings to such an extent that the engine weighs only 0.35 pounds per cubic inch of cylinder capacity. It seems probably that with fixed cylinders at least equally good results could be obtained if the same amount of trouble and money were spent."

The prime difficulty with the radial rotating engine shown in Fig. 46 is the lubrication, and until some means of reducing the consumption of lubricating oil is devised, the rotating cylinder motor must have at least that compensating defect. On occasions such as a flight from Chicago to New York for a prize the use of large quantities of lubricating oil may not matter, but in an everyday motor for the aëroplane in the hands of the "chauffeur," or whatever his aërial equivalent may be called, the lubrication must be relied upon more than in the motor car; for while failure in the one case means only inconvenience, in the other it may entail disaster.



Photograph by Edwin Levick

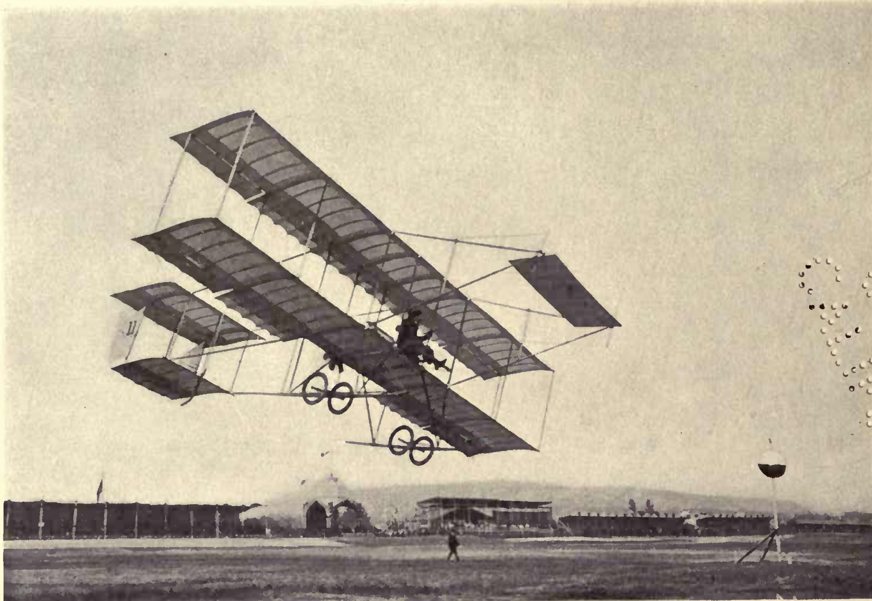
Fig. 38.—The new Wright biplane in which the horizontal or elevating rudder is mounted in the rear

The horse-power required for flight varies to a certain extent as the speed. Hence the factor that governs the maximum velocity of flight is the horse-power that can be developed on a given weight. At present the weight per horse-power of featherweight motors appears to range from two and one quarter up to seven pounds per brake horse-power. A few actual figures are given in the following list:

Antoinette	5 lbs. per brake horse-power.
Fiat	3 " " " " "
Gnôme	under 3 lbs.
Metallurgic	8 lbs.
Rénault	7 "
Wright	6 "

Automobile engines, on the other hand, commonly weigh 12 pounds to 13 pounds to the brake horse-power.

Because lightness and durability are opposite qualities, and because the more trustworthy a machine must be, the heavier must be its construction, it may well be inferred that the aëroplane motor is not a model either of durability or trustworthiness. The aëroplane builder appears, at present, willing to tolerate very little reliability, largely because the aëroplane is still in the hands of record-breakers and prize-winners, rather than of ordinary tourists. In making records the start takes place when the motor is ready. In a race it takes place at some determinate time, and if the motor be not ready, then the chance is lost. The record is also the result of frequent trials; a race is gained or lost in one. Thus, if one motor will make an aëroplane fly fifty miles whenever required and without unreasonable tuning up, but another makes it fly one hundred miles once out of ten attempts, the latter takes the record, though on its nine failures it may have broken down in a few miles, and may have required hours tuning up for each trial. If, however, the aëroplane is ever to be of the slightest practical use, the reliability of the engine must not only be brought up to that of the racing machine, but very much beyond it. This lack of reliability was strikingly evinced in the famous *Circuit de l'Est* of 1910, a circular cross-country race which started from Paris and finished there, and which included the towns of Troyes, Mezières,



Photograph by Edwin Levick

Fig. 40.—A Farman biplane making a turn. The entire machine is canted so that its weight is opposed to the centrifugal force generated by rounding an arc at high speed

Douai, and Amiens. The contest was remarkable because the airmen were expected to perform what they had never attempted before. They had to fly over a given course on specified days without being able to choose weather conditions most favourable to them. Eight machines started from Paris, but after the second day the only competitors left were Leblanc and Aubrun on their Blériot monoplanes. The failures of the others were due solely to engine troubles.

A *résumé* of aëroplane motors compiled by Warren H. Miller is appended below in the concise form of a table of comparative costs and weights per horse-power based on the fifty horse-power size. It will be noticed that the Clément-Bayard is by far the heaviest, in spite of using aluminium for the case, thus adding to the already large amount of proof that for equal strength steel is always lighter than aluminium. The table also brings out the increased cost necessitated by multiplication of cylinders, to obtain increased horse-powers at light weights. The Anzani, with only three cylinders, is by far the cheapest, but its weight is about midway between the Clément and the Gnôme, the lightest of them all.

TABLE OF FRENCH AVIATION MOTORS

Make	H. P.	Weight per h. p.	Cost per h. p.	Speed.
Antoinette . . .	50	3.84 lbs.	$48.00	1,200
Anzani	50	4.6 lbs.	20.00	1,400
Gnôme	50	3.36 lbs.	52.00	1,200
E. N. V.	40	3.85 lbs.	37.50	1,500
Clément-Bayard	40	6.05 lbs.	47.50	1,500
R. E. P.	40	3.96 lbs.	70.00	1,500
Wright	25	7.2 lbs.	——	1,400

CHAPTER IX

THE NEW SCIENCE OF THE AIR

So far as the earth is concerned, the sun is very much in the position of a man who practically utilises only a single cent out of a fortune of $22,000,000 and throws the rest away; for only 1/2,200,000,000 of the sun's heat ever reaches us. That pittance must be conserved, for which reason the earth is wrapped in a wonderful, transparent, and invisible garment which we call the air and which serves the very utilitarian purpose of keeping the world warm. Of the thickness of that wrapping we know but little. Perhaps it may extend outward from the earth for a distance of two or three hundred miles if we may judge from observations of meteor trains and auroras. Some idea of its depth may be gained by stating that if this planet were a globe only six feet in diameter, the air would be not much more than two inches thick. The texture of this gaseous garment and its peculiar relation to the sun have but recently been made the subject of rigorous investigation; for only in our own day has it been perceived that the vagaries of the weather may thus be satisfactorily explained and a system of weather forecasting devised more far-reaching and accurate than that which at present serves us.

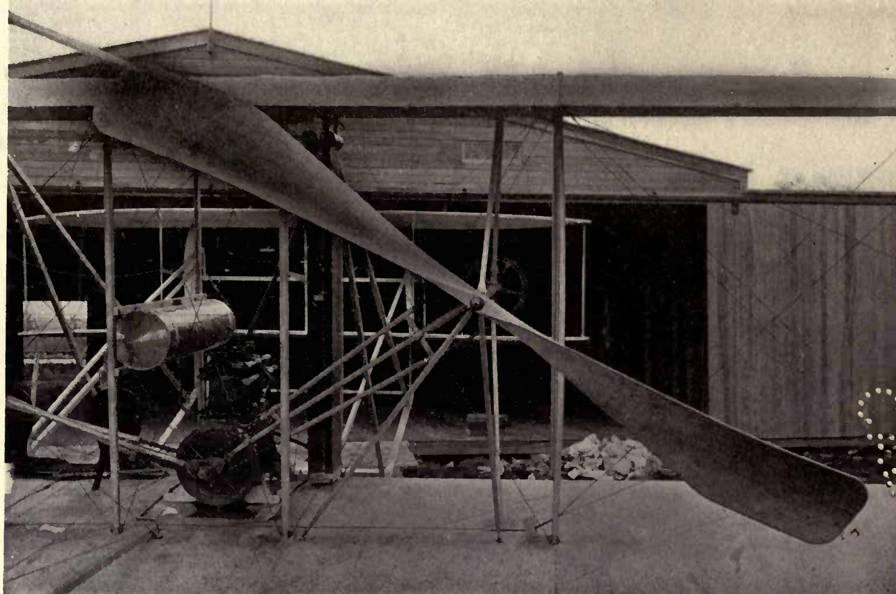
One step in this investigation is the study of the physical attributes with which the air is endowed. The air has a weight which fluctuates from day to day and from hour to hour. It is sometimes warm and sometimes cold, sometimes moist and sometimes dry, sometimes calm and sometimes turbulent. All this our senses taught us long ago. But so crude are our senses that they can never tell us exactly how much it weighs at a given moment, how wet it is, how fast it moves, and how warm or cold it is. The physicist has, therefore, been constrained to devise subtler senses. He has given us a remarkable balance which is known to every one as a barometer and which weighs the air to a nicety; a delicate measurer of moisture, which he calls a hygrometer; a motion or wind recorder, known as an anemometer; and a heat-measurer in the form of the familiar thermometer. These responsive artificial senses have been used on the surface of the earth for many years, and by their means are gathered the main facts upon the basis of which the weather bureaus at home and abroad venture to predict the morrow's weather.

Because we have learned practically all there is to learn of the lower air and because weather forecasters have in the past ignored the upper levels of the air, levels which unquestionably have their influence on the weather, it was felt that some effort must be made to measure the thickness of the earth's invisible wrapping and to determine the weight, temperature, velocity, and moisture of the air miles above us.

In order to accomplish this task it was essential to invent an artificial arm which would grasp the sensitive barometer, thermometer, hygrometer, and anemometer devised by the physicist and hold them for us in the upper reaches of the air. The problem of providing such an arm was not easily solved. In fact, it is not completely solved even now, for which reason the hand of science has not yet succeeded in touching the uppermost layer of air

— the hem of the earth's mysterious robe. Meteorological observations with manned balloons have been made sporadically for much more than a century. An ascent was made by Jeffries, at London, in 1784, with a remarkably complete equipment of meteorological apparatus. Hardly a year passes but that experiment is repeated. Because a human being cannot breathe the tenuous air of great altitudes and live, the experiment has sometimes proved fatal. To overcome the difficulty, the meteorologist has torn a leaf from the book of the marine biologist, who plumbs the deep sea with scientific instruments and brings to the surface living facts for subsequent study. The meteorologist, accordingly, now sounds the air, as if it were a great invisible ocean at the bottom of which we live.

The artificial arm that reaches upward has assumed the form either of a kite or of a small unmanned balloon, and thus it has become possible to elevate to great heights the mechanical senses that weigh the air, feel its moisture and its heat, and note its motion. The men to whom most of the credit is due for all that has



Photograph by Tresslar

Fig. 43.—A Wright propeller. Wright propellers turn at comparatively low speeds (400 revolutions a minute). They have an estimated efficiency of 76 per cent.

been gleaned in the last few years are Teisserenc de Bort, of France, Prof. A. Lawrence Rotch, of the United States, and Dr. Richard Assmann, of Germany.

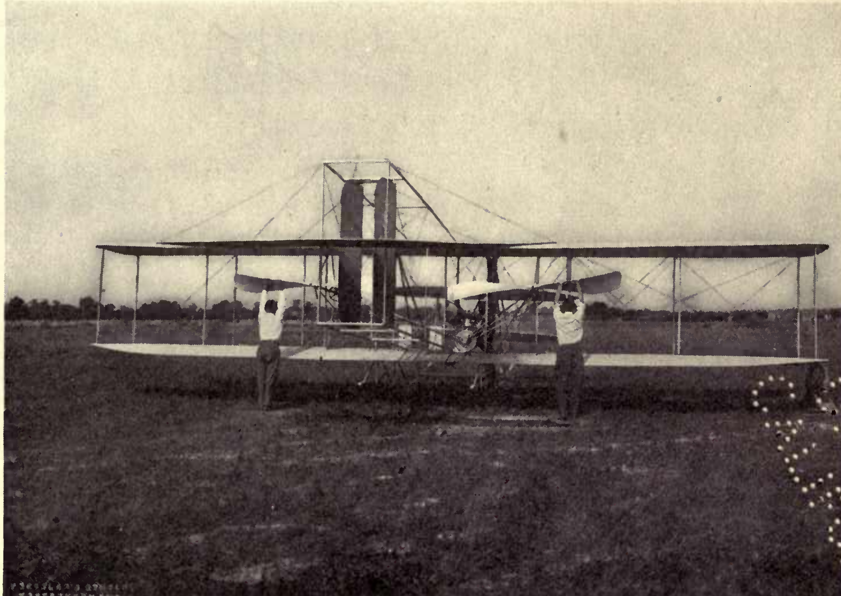
During the past decade the work has been taken up by the official meteorological services of the world, and is now carried on systematically under the direction of an international commission, appointed by the International Meteorological Committee. This commission has a permanent office at Strassburg, and holds triennial meetings in different cities, in which meteorologists from all civilised countries participate. The next meeting will take place at Vienna, in 1912.

In the United States, in addition to the admirable work done at Blue Hill, by Professor Rotch and his staff, regular observations of the upper air are carried on by the Weather Bureau at the Mt. Weather Observatory, near Bluemont, Va., and the data obtained are telegraphed daily to Washington, for the information of the official weather-forecasters.

In Europe there are now several institutions devoted entirely to this branch of investigations. The most elaborate of these is the Royal Prussian Aëronautical Observatory at Lindenberg, not far from Berlin, and Germany has observatories of similar character, on a somewhat smaller scale, at Hamburg, Aachen, Friedrichshafen, and elsewhere. The observatory at Friedrichshafen is unique in possessing a small steamboat which plies the waters of Lake Constance and is especially equipped for sending up kites and balloons. Other "aërological observatories," as the institutions of this character are now called, are situated at Trappes, near Paris; Pavia, Italy; and Pavlovsk, Russia; while in the British Isles the chief centre for aërological observations is the Glossop Moor Observatory, near Manchester. Similar observatories exist in subtropical regions, in Egypt and India. A very important station is located on the peak of Teneriffe, in the Canary Islands. In the southern hemisphere upper-air researches are now regularly carried on at two places, viz., in Samoa; and at Cordoba, in the Argentine Republic. In addition to these fixed observatories, mention should be made of the aërological work now frequently carried out by exploring expeditions, especially in the polar regions.

The scientific projection of the human mind to the upper atmosphere was not achieved merely by the invention of instruments and means for elevating them. Our eyes could not read the instruments when they were suspended in the air, and so it became necessary to make the artificial senses self-recording. Ingenious scientific artisans have provided the barometer, thermometer, hygrometer, and wing-gauge with clock-driven fingers that write a continuous, colourlessly impersonal, and therefore unbiassed story of atmospheric happenings at great heights, — a story which, to those who are versed in the hieroglyphic script in which it is written, gives a coherent account of the conditions that prevail at various elevations. The unselfish inventive genius which has been displayed in devising these self-recording instruments would have been richly rewarded had it been applied to the needs of every-day life.

The lifting power of kites and balloons is limited, for which reason the instruments are made of feathery lightness and are ingeniously combined. The combination is generically known as a "meteorograph." Thus the thermometer and barometer are merged into a meteorograph specifically known as a "barothermograph," a contrivance which is provided with two automatic hands, one of which writes down the weight (pressure) of the air and the other its temperature. Sometimes the barometer, thermometer, and hygrometer are joined in a single instrument, which notes the humidity as well as the pressure and temperature. When the instruments return to the ground, their records inform the meteorologist of the height of the kite or balloon at any given minute during its ascent and of the temperature and barometric pressure at that particular minute. Because no ink has been found which will not freeze in the bitter cold of the upper air, the writing fingers of these instruments trace their story on smoked cylinders. At lower levels special inks and paper can be employed. Samples of air have been collected by Teisserenc de Bort at heights which no human being can ever hope to reach, by devices that operate as if they were endowed with brains. To explain this



Photograph by Tresslar

Fig. 44.—The Wright machine is driven by two propellers driven in opposite directions by chains connecting the propeller shafts with the motor shaft

remarkable feat, it may be stated that at a predetermined altitude the barometer was made to complete an electric circuit (just as we push a bell-button), whereupon a little hammer fell and broke a closed, exhausted glass tube. Air rushed into the tube, and the glass was thereupon automatically sealed by a current which heated a platinum wire coiled around the broken end of the tube, thereby fusing the glass.

These are but a few of a long list of scientific inventions which might be cited and of which the world hears nothing. Meteorology has more than one unheralded Edison and Tesla, men who labour year after year in scientific obscurity, and who deem themselves richly rewarded if their instruments aid in the discovery of some new atmospheric phenomenon which may illumine the very dark subject of meteorology.

The elevation of these instruments by kites has probably been carried to the greatest perfection by Prof. A. Lawrence Rotch, of the Blue Hill Meteorological Observatory at Hyde Park, Massachusetts. His exploration of the lower four miles of air is the most complete that has yet been made. The kites employed by him, and, for that matter, by most air explorers, are of the open box type, which every boy now flies in preference to the old-fashioned single-surface contrivance distinguished by its long tail of rags knotted together. For meteorological purposes, however, the box kite assumes dimensions that utterly dwarf its toy prototype. Some of the Blue Hill kites measure nine feet in length. Despite the great lifting capacity imparted by its expansive surface, an air-exploring kite could not attain a considerable height if it were held only by hemp. A cord or rope would necessarily be so heavy and thick that a kite would be severely taxed in pulling it up. Hence it is the practice to employ fine piano-wire, which is both strong and light.

So powerful is the pull of a large kite that human muscles are hardly able to cope with it. An engine-driven winch is therefore utilised to haul in the long line. Devices are employed to register the pull of the kite and the length of the wire in use. Often it happens that as much as ten miles of line may be paid out. The elevation of the kite is determined in clear weather from data obtained by means of special optical instruments (theodolites) placed on the ground. At night and in hazy weather the meteorograph readings themselves must be depended upon.

Four miles may be considered the maximum height that a kite is capable of attaining. To explore the air above that limit and above the six miles that mark the end of human endurance in manned balloons, the "sounding-balloon" is employed, of which the most skilful use has been made by Teisserenc de Bort and by Dr. Richard Assmann.

The balloons are filled with hydrogen gas, which expands with increasing elevation. The degree of inflation therefore depends upon the height to be attained. Thus, if the balloon is to reach a point where the air is one half as dense as it is at the level of the sea, the gas-bag is half filled. If at the objective point the density of the air is one fourth the density at the level of the sea, the bag is filled only one fourth. Obviously, if very great heights are to be attained, heights where the air is exceedingly rare and thin, the balloon's capacity must be great and the construction wonderfully light. Paper balloons were, therefore, adopted by Teisserenc de Bort. Latterly, however, Assmann's India-rubber balloons, varying in diameter from three to five feet, have come into use, because they reach greater heights. At the maximum elevation of the balloon the expansion of the hydrogen gas is so powerful that the balloon bursts. Retarded in their fall by a parachute, the instruments glide gently down to the ground. Instead of a parachute a slightly inflated auxiliary balloon may be employed which does not explode, and which has sufficient buoyancy to prevent a too rapid descent of the instruments and to indicate the position of the basket in a thicket or at sea. To the basket in which the instruments are contained a printed notice is attached which offers a reward for their return. More than ninety-five per cent of the sounding-balloons liberated find their way back to the observatories. Indeed, the zeal of the finder is sometimes such that he even takes the trouble to polish the smoked cylinder on which the records are traced.

Sounding-balloons reach astonishing eleva-

Photograph by Edwin Levick

Fig. 45.—The Santos-Dumont "Demoiselle" monoplane is the smallest flying-machine that has ever flown successfully with a man. In the later "Demoiselles" fabric propellers are supplanted by wooden screws of the usual type

tions and generally travel at railroad speed. Often they rise to heights of over fifteen miles

Provisional Selection of Dates for International Aërological Observations

(*From "Wiener Luftschiffer Zeitung,"* Dec. 1, 1909, *with corrections subsequently announced by the International Commission for Scientific Aëronautics*)

	1910	1911	1912	1913
January	6	5	3–5	3
February	2–4	2	1	6–8
March	3	1–3	7	6
April	14	6	11–13	4
May	11–13	4	2	5–10
June	2	May 31–June 2	6	5
July	7	6	1–6	3
August	8–13	3	1	6–8
September	1	4–9	5	4
October	6	5	2–4	2
November	2–4	9	7	5–7
December	1	6–8	5	4

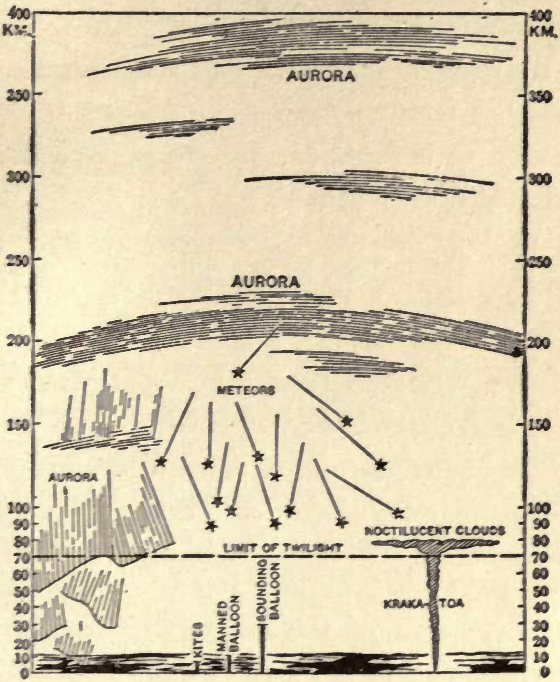
In general, observations are made on the first Thursday of each month. Once a year observations on an especially extensive scale are made during six successive days; this is the so-called "International Week" and is the occasion of special aërological expeditions, in which the naval vessels of many countries participate. The month in which the International Week occurs varies from year to year. Shorter series of observations, covering three days, are made during other months — as shown in this table.

The results of the international observations are collected and published by the International Commission for Scientific Aëronautics, which has its headquarters at Strassburg.

and cover distances of seven and eight hundred miles at the rate of forty to eighty miles an hour. A paper balloon will reach its greatest height in about six hours; a rubber balloon, in three hours.

Ascents with kites and sounding-balloons are regularly made on agreed dates by the air-exploring stations of the entire world. The dates noted in the table on page 145 were chosen for kite and balloon ascents for the years 1910 to 1913, inclusive.

As a result of many hundred flights made by kites and sounding-balloons by day and by night, in fair weather and foul, in spring and summer, in autumn and winter, over land and sea, in the tropics and within the arctic circle, we know that even in midsummer we live in a comparatively thin stratum of warm air. We know, too, that if we could transport ourselves to a height of ten miles and live in the bitter cold, thin air which would there surround us, we should find the aspect of the heavens wonderfully changed. The sky would no longer appear azure and suffused with light. By day as well as by night it would appear strangely black. Like brilliant points pricked in a sable canopy, the stars would shine both at noon and at midnight. They would shine, moreover, not with the scintillation to which we are accustomed but with relentless steadiness. The sun would blaze



From Das Wetter

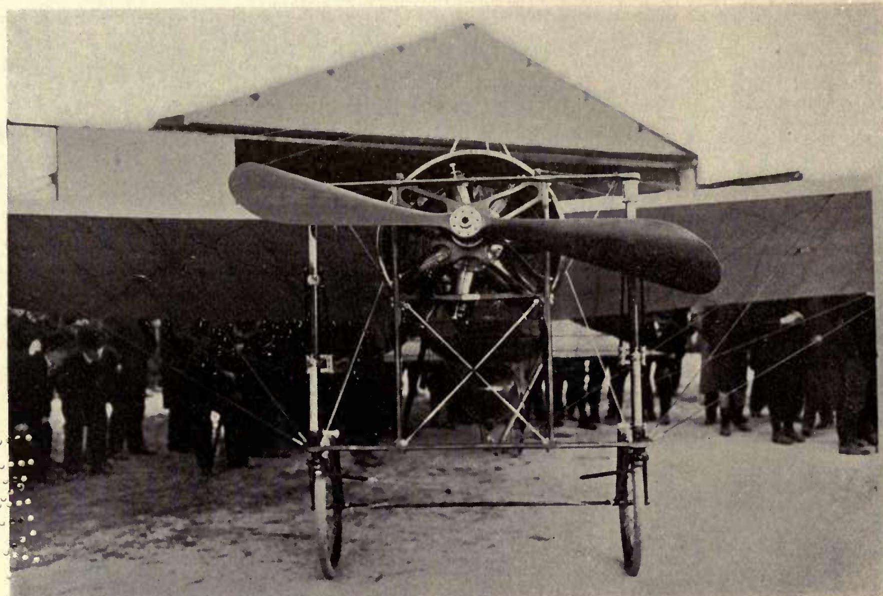
FIG. 68. — The extent of the atmosphere in a vertical direction. Heights in kilometres.

so fiercely in that cloudless sky of jet that the human skin would blister under its rays. So tenuous would be the air that it could not propagate sound. I could not call to my friend and be heard, even though my hand touched his.

Much of this might have been guessed without the aid of the elaborate machinery that has been invented to explore the air. Much, however, has been discovered that was undreamed of in our meteorology, — among other things, that the air is stratified above us in three more or less distinct layers.

The lowermost of these layers, the layer in which we live and which extends upward for about two miles from the surface of the earth, is a region of turmoil, warm to-day and cold to-morrow. This is the region of whimsical winds, of cyclones and anti-cyclones, of cool descending currents and warm ascending currents. All our weather forecasting is at present based upon what can be learned from the general circulation of the air in this lowermost layer, the layer in which men navigate the air.

Beginning at the two-mile level that marks the end of the lowermost layer and extending upward for a distance of some five miles, we find a second stratum of air, — a stratum less capricious, and one in which the air grows



Photograph by Edwin Levick

Fig. 46.—A Blériot monoplane showing a seven-cylinder, fifty-horsepower rotary Gnôme motor. The motor spins around with the propeller at the rate of about 1400 revolutions a minute

steadily colder and drier with increasing height. The lowest temperature thus far recorded is 152° below the Fahrenheit freezing point. Whatever thermal irregularities there may be are caused by wide temperature changes on the surface of the earth and by the reflection of solar heat by the clouds. Here the air moves in great planetary swirls, produced by the spinning of the earth on its axis, so that the wind always blows in the same eastward direction. The greater the height the more furious is the blast of this relentless gale.

Last of all comes a layer which was discovered by Teisserenc de Bort and Dr. Richard Assmann almost simultaneously, and which is generally called the "isothermal stratum" because the temperature varies but little with altitude. The lower part of the isothermal layer shows a slight increase in temperature with increasing height. Hence this part of the isothermal layer is sometimes referred to as the "inversion layer," or region of the upper inversion.

Above the inversion layer the vertical temperature gradient is practically zero; i. e., there is little or no change of temperature with altitude. Teisserenc de Bort now calls the isothermal layer "stratosphere," and the use of this latter name is increasing.

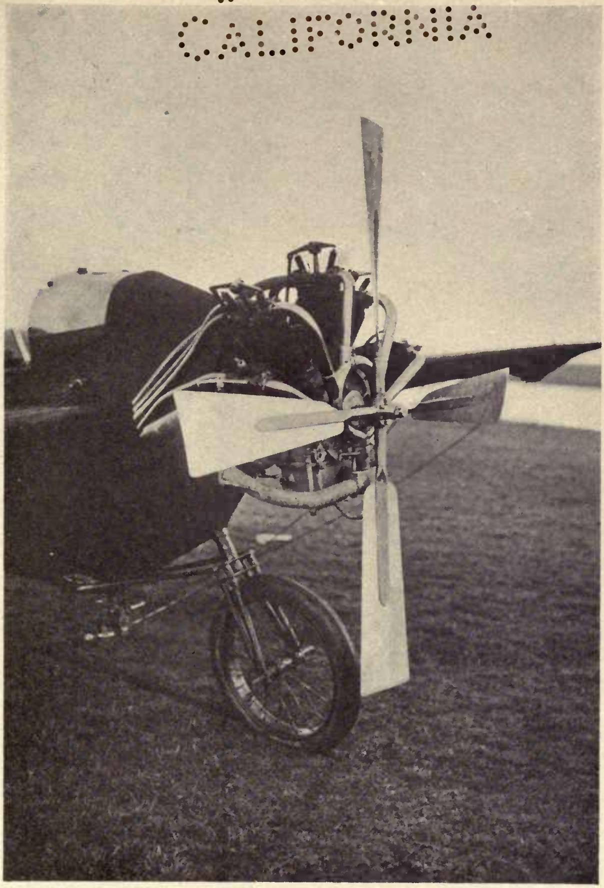
Although the air is warmer than in the layer immediately below, the temperature lies far below the Fahrenheit zero and may be placed somewhere near 100° below the Fahrenheit freezing point in middle latitudes. Here we have a region of meteorological anomalies which have not yet been satisfactorily explained. In passing from the second to the isothermal layer, the wild blasts of wind are stilled to a breeze, the velocity decreasing from twenty-five to eighty per cent. The air no longer whirls in a planetary circle. Indeed, the wind may blow in a direction quite different from that in the second layer. Whatever may be the moisture of the air below, it is always excessively dry in the permanent inversion layer. Just where this isothermal layer begins depends on the season, the latitude, the barometric pressure, and perhaps on other factors still unknown. Just where it ends no one knows; for although sounding balloons have risen to heights of over eighteen miles, its upper limit has not yet been discovered. In summer time the isothermal layer over middle latitudes begins at a height of about seven miles above the earth. We know that the higher it lies the colder it is, that the lower it lies the warmer it is. We know, too, that there is no bodily shifting up and down of warm and cold masses of air in that mysterious region. The result is that a current ascending from the lower level spreads out when it encounters the "permanent-inversion" layer as if a solid barrier had been interposed.

Up to the height of the "permanent-inversion" layer the temperature falls at a rate which increases somewhat with altitude, but which may be placed roughly at rather over ½° C. per hundred metres (say 1° F. per three hundred to four hundred feet), so that on a hot summer's day with a temperature of 90° Fahrenheit at the earth's surface, a man could place himself in fairly cool surroundings if he could rise only fifteen hundred feet. Because of the constant upheavals to which the air is subject in its lower levels, this average rate of temperature reduction, as we ascend, is not often observed. It may even happen that for a short distance the thermometer may rise and not fall at all. Ultimately, the temperature drops at a uniform rate until it reaches a point lower than that reported by any North-pole explorer.

To these fluctuating temperatures in the lowermost layer clouds and rain are due. Warm air tends to rise and to cool as it rises. The cooling air in turn condenses its water vapor into clouds. This process, as well as others that need not be considered here, leads ultimately to the precipitation of the condensed water of atmosphere, as rain, snow, or hail.

The three layers of air which have been disclosed to us by the sensitive instruments of modern meteorology intermingle but slightly. The one floats upon the other as oil floats upon water. Of the great ocean of air at the bottom of which we move and live, three fourths by mass lie below the isothermal layer. All our storms, our clouds, and all dust, except such as may be of volcanic or cosmical origin, are phenomena of the lower two layers.

When the meteorologist has fully discovered



Photograph by Edwin Levick

Fig. 47.—The motor and the propeller of a R. E. P. (Robert Esnault-Pelterie) monoplane. Robert Esnalt-Pelterie has abandoned this four-bladed metal propeller for the more efficient two-bladed wooden propeller

the influence which the upper region exerts upon the lower, there is reason to hope that he will be able to foretell the weather not merely a day but perhaps a week or more in advance, and to prepare charts which will be as useful to the aviator as the charts which warn the mariner of shoals and reefs.

The currents in the various levels of the atmosphere are of as much importance to the aviator as are the ocean currents to the mariner. Hence the necessity of charting the sea of air with scientific care, and hence the value of the work here outlined. The International Commission for Scientific Aëronautics has already accumulated sufficient data to chart aërial routes, comparable with the ocean routes laid down by the various hydrographic officers of the world. Every government will have a special branch of research and will distribute information for aëronauts. The daily weather reports will be amplified to suit the flying man.

Thus far more interest has been shown in Europe than in this country in this matter of vital importance to the aëronaut. A detailed analysis of the wind data available for the

German Empire was undertaken by Dr. Richard Assmann at the instance of the "Motorluftschiff-Studiengesellschaft," founded by the Kaiser. That society, whose name translated into English reads "Society for the Study of Motor Airships," recently published the results of Assmann. The Italian Aëronautical Society has performed a similar service for Italy. Such data will be useful to the aëronaut in selecting sites for practising grounds or for aërial harbours, or in choosing the seasons most appropriate for experiment.

Dr. Richard Assmann, director of the Royal Prussian Aëronautical Observatory of Lindenberg, in an article entitled "The Dangers of Aërial Navigation and the Means of Diminishing Them," contributed to the *Deutsche Zeitschrift für Luftschiffahrt*, describes the aëronautical weather service that he is organising, and of which Lindenberg Observatory is to be the centre. According to Dr. Assmann at least three similar tentative schemes have already been put into execution in the German Empire. The first was undertaken by the Lindenberg Observatory in 1907, during trial trips made by the "Parseval" airship. Observations of the upper air currents were made simultaneously at five stations by means of pilot balloons and communicated to the crew of the airship, who were thus materially aided in guiding their craft. The second similar undertaking was Dr. Linke's special weather service for aëronauts, conducted at the Frankfort Aëronautical Exposition of 1910. The third aëronautical service was organised by Dr. Polis, at Aachen. It is still in existence, and is intended especially for the benefit of the aëro clubs of the Rheinland. Its usefulness was demonstrated during the army manœuvres in West Prussia in 1910.

Next to the United States, Germany has probably the best organised weather service in the world. It is therefore not astonishing that Germany should be better prepared than any other European state for the adaptation of modern meteorological science to the needs of the airman. Lindenberg Observatory is now equipping the Public Weather Service stations with the apparatus needed for daily observations of the upper air, not primarily for the purpose of improving the weather forecasts, but in order to lessen the dangers of aërial navigation, — dangers, in Assmann's opinion, largely avoidable and to which the loss of twenty valuable lives in Germany during 1910 may be attributed. At the present time the navigator of the air launches his craft with no more knowledge of the meteorological conditions in the upper air than can be surmised from those depicted in the ground-service weather map. The day is not far distant when he will have a weather map all his own.

In Dr. Assmann's plan, a number of the Public Weather Service stations are to be furnished by the Lindenberg Observatory with a theodolite, an inflating-balance for determining the ascensional force of the balloons, a sufficient number of balloons, and the necessary graphic tables for rapidly working up the observations.

At 8 A. M. every day, assuming the weather is favourable, the stations will be expected to send up a pilot balloon and to trace its course with the theodolite as long as possible. The observation will then be worked up — a matter of barely a quarter of an hour for a practised observer — and telegraphed to Lindenberg.

Photograph by Edwin Levick

Fig. 48.—Henry Farman seated in his biplane with three passengers

Here the observations received from all other stations will be assembled and re-distributed in a single telegram sent to each of the coöperating stations. If they arrive in time, the telegrams can be utilised in connection with the ordinary daily weather forecast, as well as for the preparation of special forecasts and warnings for airmen. At Lindenberg the regular observation with a kite or capture balloon is made daily at 8 A. M., and in summer an observation is also made about 5 or 6 A. M. Assmann also proposes to conduct daily observations at Lindenberg with a pilot balloon at 11 A. M., and, whenever necessary, another about 2 P. M., so that soundings of the air to an altitude of several miles will be made three or four times a day within a period of six to nine hours. Thus valuable information will be gathered which ought to enable the weather forecaster to warn airmen of impending changes in the lower atmosphere, on the basis of actually occurring rapid changes in the upper atmosphere.

That the German Public Weather Service stations will ultimately be supplemented with stations especially erected for the purpose at the larger aviation fields and the like, would seem to follow from the work now done at the experimental observatory at Bitterfeld, from the erection of the aëronautical observatory on the Inselberg, near Gotha, from the probability of the erection of the long-promised aërological station at Taunus, and lastly, from the contemplated installation of aërological stations at nautical schools on the coast.

The difficulty of following pilot balloons in hazy weather and at dusk leads Assmann to propose the utilisation of balloons of two sizes, the smaller and cheaper to be used when it is evident that the state of the sky will not permit the balloon to be followed with the theodolite to a great distance. Observations at night could be made by illuminated balloons, but at considerable expense.

Undoubtedly there will be many days on which few, if any, observations can be secured with pilot balloons, so that only the observations made at stations equipped with captive balloons and kites will be available. In order to meet this serious difficulty, Assmann is considering the plan of supplying a few selected stations with a central and easily manageable kite outfit.

Thus far the plan outlined by Dr. Assmann has been approved only for a limited part of the Empire. Political heterogeneity still hampers imperial undertakings in Germany. Ultimately, however, the field of observations will be extended to include the south German states, where some very important stations are located, chief among which is the admirably equipped station at Friedrichshafen on Lake Constance.

Assmann himself realises that his plan cannot hope to provide detailed information and forecasts of local conditions except in so far as may be inferred from the general outlook. Some experiments which were recently made in Germany, after the appearance of Dr. Assmann's article, show that it is feasible to secure a corps of special thunderstorm observers who can report by telegraph and telephone, and who are numerous enough to enable the weather forecaster to follow the progress of sudden atmospheric disturbances across the country, and to give timely warning to the aëronaut to avoid them.

Apart from enlightening the aëronaut on the condition of the atmosphere, it will be obviously necessary to provide the equivalent of automobile road maps, — something that will tell the man of the air where he is. It is very difficult to recognise even familiar country from above. During his flight down the Hudson River, Curtiss decided to alight on what looked to him like a fine green field. Swooping down, he found that his green field was a terrace, an unavoidable error in judgment which might have cut short his triumphal flight. With a map on a scale of half an inch to the mile, showing the lines of the roads and the shapes of the villages, it would seem easy enough to ascertain one's whereabouts; but the aviator travels quickly and a full equipment of half-inch maps would be a serious item in the weight of his load. The man in a balloon is often above clouds, and when he views the earth again it is very difficult and frequently impossible to pick up the route again. The aviator in a flying-machine is more favourably placed. He knows his

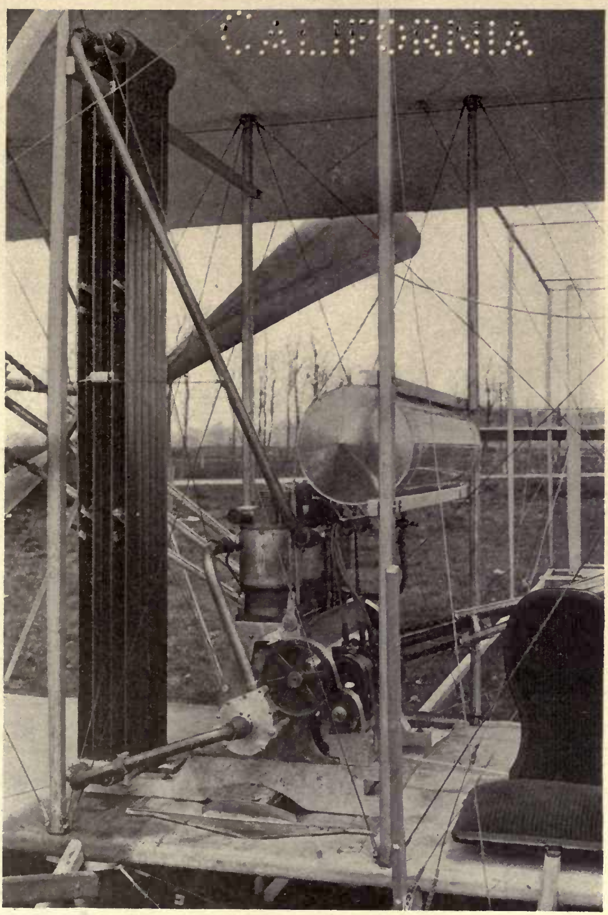


Fig. 63.—Motor of the Wright biplane

direction approximately, although he is often unable to make proper allowance for the drifting effect of the wind. If caught by varying currents or by storms above the clouds, he easily loses track of the course. There will be need of large distinctive ground marks for day and lights for night at distances of ten miles apart, marks which will correspond with those on an air-chart. Zeppelin proposes maps showing heights by colours, and marks indicating the influence of streams, marshes, and woods on the static equilibrium of the airship. The scale he suggests is three miles to the inch. Colour is the main consideration. In the opinion of Mr. Charles Cyril Turner, an English aëronaut, the colours should approximate to the colours of the landscape as seen from above. The roads should be white, the water blue, the fields light green, woods a darker green, habitations grey, and railways black.

Besides guiding the aërial traveller on his way some means must be devised of conveying useful information to him. It will often be of great importance to know the strength and exact direction of the wind. Skimming the air at the rate of fifty miles an hour, the aviator will find it difficult if not impossible to make these observations. The German Aërial Navy League has suggested that special light-houses be constructed for that purpose. These are to send a long beam of light in the direction in which the wind is blowing. For day flights it will probably be necessary to have a long arrow painted white and swinging on a pivot so that it can be turned in the proper direction.

CHAPTER X

THE PERILS OF FLYING

FROM what has been said in the foregoing chapter it may well be inferred that a man who attempts to fly in the unsteady lower stratum of the atmosphere in which we live is almost in the same position as a drop of quicksilver on an exceedingly unsteady glass plate. Unlike the drop of quicksilver, however, he is provided with a more or less imperfect apparatus for maintaining a given course on the unsteady medium to which he trusts himself.

Were it not that the whirling maëlstroms, the quiet pools, the billows and breakers of the great sea of air are invisible, the risks of flying would perhaps not be so great. Only the man in the air knows how turbulent is the atmosphere even at its calmest. "The wind as a whole," wrote Langley a decade ago, "is not a thing moving along all of a piece, like the water in the Gulf Stream. Far from it. The wind, when we come to study it, as we have to do here, is found to be made of innumerable currents and counter-currents which exist altogether and simultaneously in the gentlest breeze, which is in reality going fifty ways at once, although, as a whole, it may come from the east or the west; and if we could see it, it would be something like seeing the rapids below Niagara, where there is an infinite variety of motion in the parts, although there is a common movement of the stream as a whole."

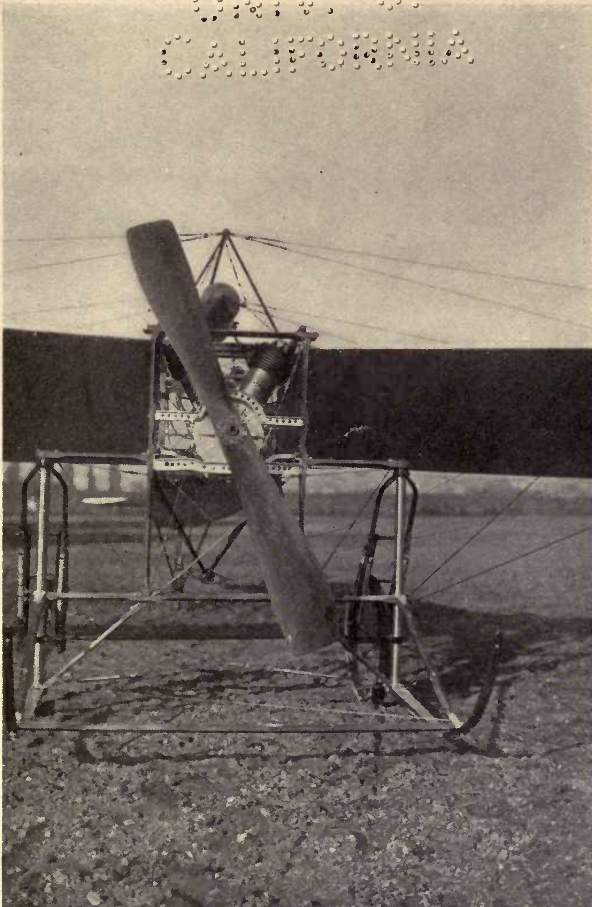
Through these invisible perils the airman must feel his way in the brightest sunshine, like a blind man groping his way in a strange room. He can tell you that against every cliff, every mountain side, every hedge, every stone wall, the air is dashed up in more or less tumultuous waves. The men who crossed the English Channel found that against the chalk cliffs of Dover a vast, invisible surf of air beats as furiously as the roaring, visible surf in the Channel below,— a surf of air that drove nearly all of them out of their course and imperilled their lives. There are whirlpools, too, near those cliffs of Dover, as Moisant used to tell. He was sucked down into one of them within two hundred feet of the sea. His machine lurched heavily, and it was with some difficulty that he managed to reascend to a height at which he could finish the crossing of the Channel.

Sometimes there are descending currents of air with very little horizontal motion, just as dangerous as the breakers. Into such maëlstroms the pilot may drop as into unseen quicksands. On his historic flight down the Hudson River, Curtiss ran into such a pitfall, fell with vertiginous rapidity, and saved himself only by skilful handling of his biplane. A less experienced pilot would have dropped into the river. A sudden strong gust blowing with the machine would have a similar effect.

Such are the concentration of mind and the dexterity required by very long cross-country flights that a man's strength is often sapped. During the *Circuit de l'Est* of 1910, in which the contestants were compelled to fly regardless of the weather, the German, Lindpaintner, had to give up because of physical and nervous exhaustion. Another competitor crawled under his machine, as soon as he alighted, and went asleep. Wilbur Wright has been credited with the remark: "The more you know about the air, the fewer are the chances you are willing to take. It 's your ignorant man who is most reckless."

Because of the air's trickiness, starting and alighting are particularly difficult and dangerous. More aëroplanes are wrecked by novices in the effort to rise than from any other cause. As a general rule a new man tilts his elevating rudder too high, and because he has not power enough to ascend at a very steep angle, he slides back with a crash. In high winds even practised airmen find it hard to start. During the meeting at Havre in August, 1910, Leblanc and Morane were invited to luncheon at Trouville. Like true pilots of the air they decided to keep their engagements by travelling in their machines. At half past eleven they ordered their Blériots trundled from their sheds. Twice they were dashed back by the wind before they succeeded in taking the air. An untried man would have wrecked his machine in that wind.

The pneumatic tired wheels on which a machine runs in getting up preliminary speed serve



Photograph by Edwin Levick

Fig. 64.—Two-cylinder Anzani motor on a Letourd-Niepce monoplane

also for alighting, as we have seen. When a monoplane glides down at the rate of forty-five miles an hour and strikes the ground, some disposition must be made of its energy. Usually skids or runners, like those of a sled, are employed for that purpose, the bicycle wheels giving way under the action of springs, so as to permit the skids to arrest the machine. Men like the Wrights can bring an aëroplane to a stop without spilling a glass of water; but your unpractised hand often comes down with a shock that makes splinters of a high-priced biplane.

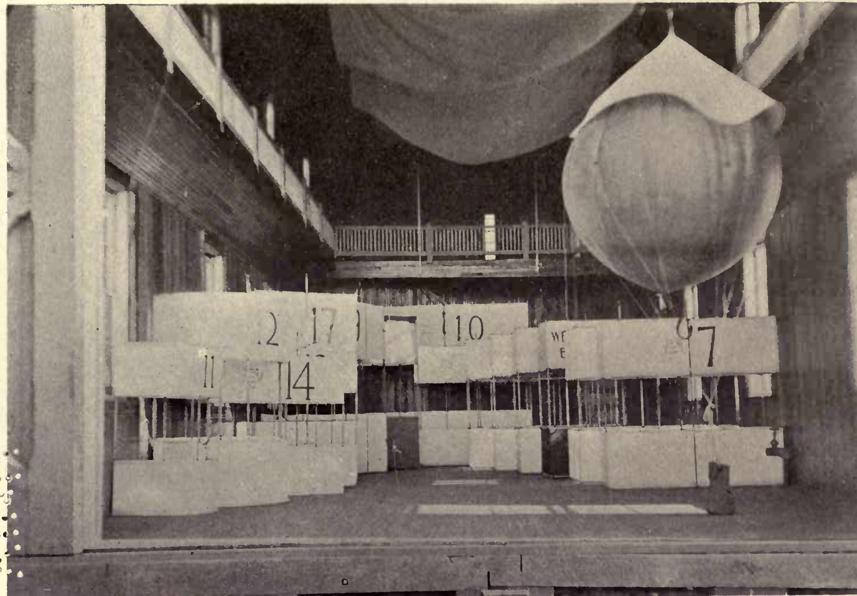
Inexperience in the correct manipulation of stabilising devices is a fruitful cause of accidents, — perhaps the most fruitful. The manipulation of these corrective devices is no easy art. Machines and necks have been broken in the effort to acquire it. Man and aëroplane must become one. The horizontal rudder, which projects forward from many biplanes, is like the cane of a blind man. With it the pilot feels his way up or down, yet without touching anything. Balancing from side to side is even more difficult. Curiously enough, it is when the machine is near the ground that it is hardest of all to bring the aëroplane back to an even keel. Imagine yourself for the first time in your life seated in a biplane with a forty-foot span of wing, sailing along at the rate of thirty-five miles an hour, about ten feet from the ground. If your machine suddenly drops on one side, it will scrape on the ground before you can twist your planes and lift the falling side by increasing the air pressure beneath it. You will come down with a crash. If, on the other hand, you are an old air-dog, you will tilt up your horizontal or elevation rudder and glide up before you attempt to right yourself. So, too, if you see a stone wall or a hedge in your course, you will lift yourself high above it. Why? To avoid the waves of air dashed up against the wall or hedge. For if you did not rise, the waves would catch you and toss you about, and you might lose your aërial balance.

In this connection Prof. G. H. Bryan has pointed out that the distinction between equilibrium and stability should be kept in mind. An aëroplane is in equilibrium when travelling at a uniform rate in a straight line, or, again, when being steered round a horizontal arc of a circle. A badly balanced aëroplane would not be able to travel in a straight line. The mathematics of aëroplane equilibrium are probably very imperfectly understood by many interested in aviation, but they are comparatively simple, while the theory of stability is of necessity much more difficult.

It is necessary for stability that if the aëroplane is not in equilibrium and moving uniformly it shall tend toward a condition of equilibrium. At the same time it may commence to oscillate, describing an undulating path, and if the oscillations increase in amplitude the motion will be unstable. It is necessary for stability that an oscillatory motion shall have a positive modulus of decay or coefficient of subsidence, and the calculation of this is an important feature of the investigation.

At the present time it is certain that aviators rely entirely on their own exertions for controlling machines that are unstable, or at least deficient in stability, and they go so far as to declare that, owing to the danger of sudden gusts of wind, automatic stability is of little importance. Moreover, even in the early experiments of Pilcher, it was found that a glider with too V-shaped wings, or with the centre of gravity too low down, is apt to pitch dangerously in the same way that increasing the metacentric height of a ship while increasing its "statical" stability causes it to pitch dangerously. It thus becomes important to consider what is the effect of a sudden change of wind velocity on an aëroplane. If the aëroplane was previously in equilibrium, it will cease to be so, but will tend to assume a motion which will bring it into the new state of equilibrium consistently with the altered circumstances, provided that this new motion is stable. Thus an aëroplane of which every steady motion is stable within given limits will constantly tend to right itself if those limits are not exceeded. Excessive pitching or rolling results from a short period of oscillation combined with a modulus of decay which is either negative (giving instability) or of insufficient magnitude to produce the necessary damping.

More difficult than the maintenance of stability is the making of a turn. The dangers that



Photograph by courtesy of the U. S. Weather Bureau

Fig. 65.—The kite and balloon-house of the Mt. Weather Observatory

await the unskilled aviator who first tries to sweep a circle have been sufficiently dwelt upon in Chapter VI. The canting of a machine at a considerable angle, which is necessary in order that the weight of the machine may be opposed to the centrifugal force generated in turning, necessarily implies that the aëroplane shall be at a height great enough to clear the ground. Yet many of the early experimenters wrecked their apparatus because they tried to make turns when too near the ground, with the result that one wing would strike the turf and crumple up like paper.

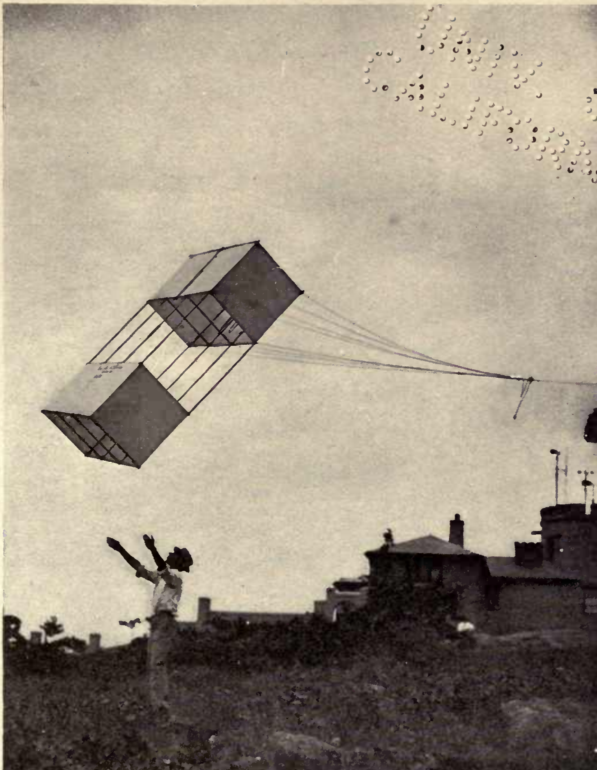
Even at great heights the making of a turn is not unattended with danger, particularly when the machine is brought around suddenly. If a turn is made too abruptly, parts of the structure are sometimes strained to the breaking-point. There is good reason to believe that the Hon. C. S. Rolls was killed because he made too quick a turn.

Flying exhibitions, which tempt the prize-winning airmen to be overbold, are responsible for many of the tragedies that have occurred within the last few years. At the Reims meeting of 1910, as many as eighteen machines were circling around one another, swooping down, hawklike, from great heights, or cutting figure-of-eight curves to the plaudits of an enthusiastic multitude. It was not the possibility of collision that was so perilous, but the disturbance created in the air. The wake that every steamer leaves behind it has its counterpart in the wake that trails behind an aëroplane in the air. A rowboat may ride safely through the steamer's wake with much bobbing; an aëroplane caught in the wake of another pitches alarmingly. That was how the Baroness de la Roche met with such a terrible accident at the Reims meeting in question.

The various accidents which have occurred recently to aëroplanes raise the whole question of whether the construction of the wings is such as to give the requisite margin of safety to insure their not breaking under the loads which are likely to be thrown upon them in use. In all ordinary construction, as in building a steamboat or a house, engineers have what they call a factor of safety. An iron column, for instance, will be made strong enough to hold five or ten times the weight that is ever going to be put upon it, but if we try anything of the kind in flying-machines the resultant structure will be too heavy to fly. Everything in the work must be so light as to be on the edge of disaster. Some of the worst accidents on record are to be attributed to this necessarily flimsy construction. It is, of course, very difficult in the case of aëroplane accidents to ascertain which part broke first, for the fabric is generally so utterly destroyed that no details of the first breakage can be seen. Further, the aviator, who is the only man who can tell accurately what happened, is frequently killed, so that the only information available is what can be seen of the fall while the machine is in the air, and accidents occur so suddenly that different people do not always get the same impression of the sequence of events. There seems, however, little doubt that in several cases the wings collapsed in some way while the machine was flying, and that it fell in consequence.

In the case of a biplane (Fig. 69) the framing of the main wings usually consists of four longitudinals running the whole span of the wings, and these are braced together, both vertically and horizontally, with numerous cross-struts and wire diagonals, so as to give them very great strength, both vertically and horizontally. In fact, if the stresses of the diagonal wires be worked out, they are found to be very much below those usual in ordinary engineering work. Still, the wires are so numerous that, even if one of them breaks from vibration, the extra stress thrown on the adjacent ones will not bring the load up to the ordinary stresses allowed in girder work. The horizontal strength is also practically equal to the vertical, as the trussing is generally of the same character.

In the monoplane the trussing is much simpler. Often there is no horizontal trussing at all. The vertical strength of the main plane is entirely dependent on stays, generally four to each side, which go to the bottom of a strut under the backbone. Should one of these break, the probability is that the wing will collapse with disastrous results. These stays are often single parts of steel wire or ribbon, a material which has not been found sufficiently reliable for use as supports to the masts of small sailing



Photograph by George Brayton

Fig. 66.—Sending up the first of a pair of tandem kites at the Blue Hill Observatory

boats, where wire rope is always preferred, on account of the warning it gives before breakage.

The structure of each wing in a monoplane is, in fact, very much like that of the mast and rigging of a sailing boat, the main spars taking the place of the mast, while the wire stays take that of the shrouds. A very important difference, however, is that the mast of a sailing boat is almost invariably provided with a forestay to take the longitudinal pressure when going head to wind, while the wing of an aëroplane, as we have already noted, often has no such provision, the longitudinal pressure due to the air resistance being taken entirely by the spar.

When a monoplane is flitting through the air at the rate of sixty miles an hour, the wire stays often vibrate so fast that they emit a distinct musical note. The small boy who wants to break a piece of wire simply bends it back and forth many times at a given point. Rapid vibration of wires and ribbons on monoplanes will ultimately produce the same result. For safety's sake either wire rope should be used (heavier and therefore undesirable from the record-breaker's standpoint), or the number of stays must be increased so that the parting of one will not necessarily spell a wreck and possibly death.

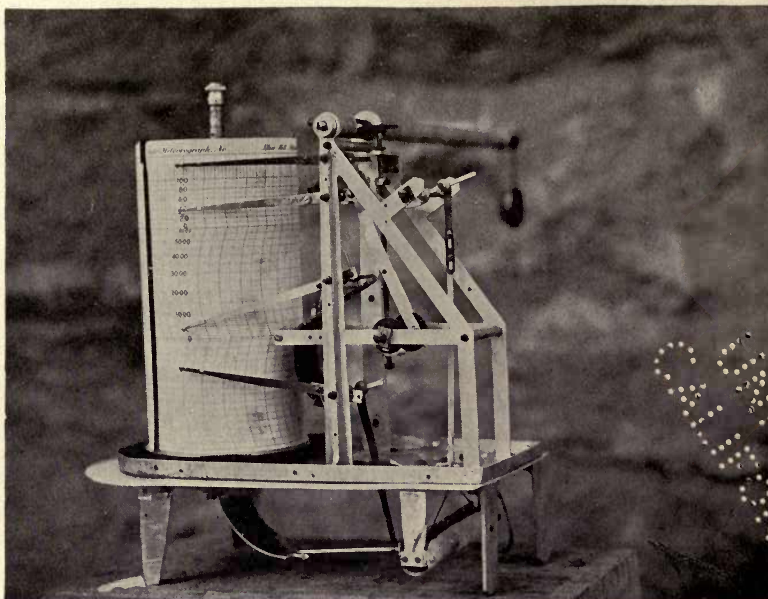
The horizontal stresses thrown on the single supporting surface of an aëroplane are greater than most pilots realise. In one of those breathless downward swoops which almost bring your heart to your throat, or in one of those quick turns in which the machine seems to stand on end, the stresses are enormously increased. It was the breaking of a wing by overstrain that killed Delagrange at Pau on January 4, 1910; it was overstrain that killed Wachter at Reims on July 1, 1910; it was overstrain, due to sharp turning, that killed Rolls on July 12, 1910, at Bournemouth, England; and it was probably overstrain that weakened the wings of Chavez's monoplane in its battle with the Alpine winds and resulted in the fatal accident that occasioned the intrepid Peruvian's death on September 27, 1910.

In commenting upon the lack of horizontal strength in monoplanes, a writer in *Engineering* observes:

"It is, no doubt, assumed that the weight of the machine rests on the wings, and that this is the main stress to be provided for. This is no doubt true, but a careful consideration of the horizontal stresses will show that these are much greater than might at first sight appear. When flying horizontally the horizontal stress cannot, of course, exceed the thrust of the propeller, and must in practice be considerably less than this, as part of that thrust is spent in overcoming the resistance of the body of the machine, the tail, etc. The ratio of lifting power to horizontal stress will vary considerably in different machines with the efficiency of the planes, but even with the machine flying horizontally the horizontal stress will probably be in the neighbourhood of ten per cent of the vertical.

"It appears, however, that there are circumstances in which the horizontal stress may be very much greater than this, for it increases with the speed of the aëroplane through the air, and this may be very much greater when descending than when flying level. The wings contribute the greater part of the air resistance, and therefore, if the aëroplane is descending, it will accelerate till the horizontal stress on the wings balances the acceleration due to gravity. Thus, if the aëroplane descends at a slope of one in five, the horizontal pressure on the planes may be approximately twenty per cent of the weight of the machine. If the engine is kept running, it will be more than this by the amount of the propeller thrust. It is quite clear, therefore, that circumstances might arise in which the horizontal stress would be some twenty-five per cent of the vertical.

"Now, if we examine the framework of many of the monoplanes, we find that the horizontal strength of the wings is nothing like twenty-five per cent of the vertical; in fact, it is often probably under five per cent. The framework of the wing consists of two longitudinals, and numerous cross-battens carrying the fabric. The longitudinals are the only part fixed to the backbone, and therefore take practically the whole stress. These longitudinals are generally made very deep in proportion to their height, and are often channelled on the sides to make them into I-section girders. It is obvious, therefore, that their horizontal strength is very small indeed compared with the vertical. True, the numerous cross-battens stiffen the wing perceptibly, but the extent to which this is the case can hardly be calculated; and as they are often only about ¾ inch by ¼ inch, and fastened with very small nails, they cannot be relied on to any great extent. It seems, therefore, that either the



Photograph by George Brayton

Fig. 67.—Mechanism of a meteorograph which records the velocity of the wind, the temperature, the humidity, and the barometric pressure

wings should have diagonal bracing or should have stays in front corresponding to those down below."

That the question of speed in descent is a matter for which provision should be made is shown by the fatal death of Wachter at Reims in 1910. The speed in descending is higher than when flying level. In some cases the horizontal strength of the wings appears to provide a very small margin for this increased stress, and the accidents seem to have happened exactly as suggested, for in each case, when rapidly descending from a height, the wing collapsed.

It may be said that when descending the engine ought to be stopped and the descent made at a speed not exceeding that which can be maintained on the level. Still, it is hardly practicable to adhere to any such principle; for in alighting it is necessary to travel at top speed to clear the ground eddies. Moreover, if the aëroplane is to be of any practical use, it must be made to stand any reasonable usage to which it is likely to be subjected. Bicycles and motor-cars are often run down hill, or before a wind, at speeds far higher than can be maintained on the flat, and it is quite certain that a machine which is unsafe under these circumstances is not fit for ordinary work. Most men run down a hill as fast as they can without losing control of their cars, and aviators will doubtless do the same. The machine must, therefore, be made to stand the stresses set up under these conditions.

Very little is known of the air's power of breaking aëroplanes travelling at high speeds. Designers work from tables that indicate the breaking strength of wire and wood and the percussive force of the wind at different velocities. But the actual buffeting to which a machine is subjected in the air is still an engineering uncertainty. A storm will tear the roof from a house and toss it a hundred yards; yet aëroplane designers require a machine to travel through the air at hurricane speed and bear up under the sledge-hammer blows of the air, — a machine that is the flimsiest vehicle in which man has risked his life, composed, as it is, of fragile wires, the lightest wood cut as finely as possible, and fabric that is affected by variations in the weather.

In some of the tragedies of the flying-machine the propeller and the motor have each played their part. Lieutenant Selfridge's death at Fort Myer on August 17, 1908, was due to the snapping of a propeller blade, which struck a loose wire, an accident that for months crippled Orville Wright, who was piloting the machine. This, of course, was not due to any inherent defect in the propeller. Indeed, the Wright propellers, because of their low speed (four hundred to five hundred revolutions a minute), are probably the safest in use. The propellers of most monoplanes and biplanes travel at speeds as high as fifteen hundred revolutions a minute, or about as fast as an electric fan. Propellers mean more to an aëroplane than stout axles on an automobile; for if a flying-machine stops it must glide down. Nearly every contestant at a flying-machine meeting is equipped with spare propellers, which are as near alike as brains and hands can make them. Yet the same engine will not be able to turn two propellers seemingly alike at the same speed. Why? Because man can make steel, but he cannot make wood. That is grown by nature. And because woods from different trees are not alike the propellers formed from them are not alike. Untraceable and insurmountable variations create the differences. In aëroplaning science success or failure depends on just such slight differences.

The propeller's mechanical cousin, the motor, is also not what it ought to be. At very great heights it is impossible to obtain adequately high compressions in the motor cylinders. Hence the motor stops, and the aviator must glide down, — *vol plane*, as the French call it. Such glides can be made with comparative safety if the pilot is skilful. Occasionally it happens that motor stoppages have been the cause of death. It was the stopping of his motor that killed Leblon at San Sebastian on April 2, 1910, and Van Maasdysk at Amsterdam on August 22, 1910.

To prevent such accidents, Mr. Edwin Gould in 1910 offered through the *Scientific American* a prize of $15,000 to the designer and demonstrator of a successful machine equipped with more than one motor, the arrangement being either such that should one motor be disabled

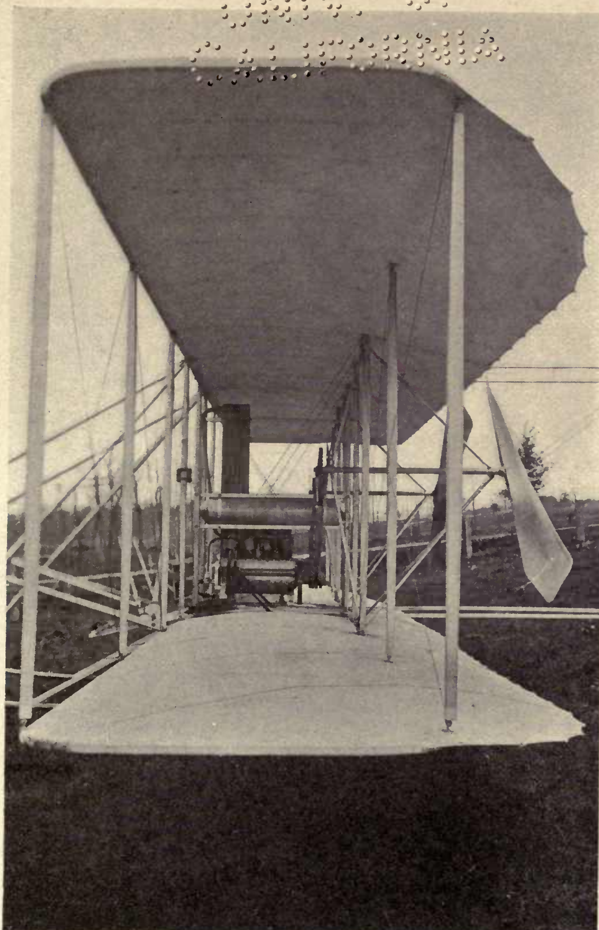


Fig. 69.—A glimpse through a Wright biplane. The two planes are trussed together like the corresponding members of a bridge, so as to obtain great strength

another can be immediately thrown into gear, or that if all the motors should be running simultaneously the stoppage of one will not necessarily leave the apparatus without power.

The progress which has been made since the Wright Brothers gave us the first successful man-carrying motor-driven aëroplane can hardly be called scientific progress. Much of it has been progress of the trial and error variety, very costly and not always productive of valuable results. It may be retorted that, despite the highly scientific experiments of Langley and Maxim, we really owe the successful machine to such men as the Wright Brothers, who are not profound mathematicians but skilful, practical mechanics. If the whole truth were known about the years of patient experimenting which finally led the Wright Brothers to the invention of a successful flying-machine, it would probably be discovered that they were no less scientific in their methods than was Langley himself.

The problem of building a flying-machine is in quite a different position from what it was. If flying-machines are not to be subjected to frequent accidents and are to be made accessible to the million, the sooner aëronauts learn engineering the better. Not until engineers are employed to design and build flying-machines shall we be able to skim the air as safely as we now roll along the ground in motor-cars.

CHAPTER XI

THE FLYING-MACHINE IN WAR

UNLIKE any battle that has ever been fought in the world's history, the battle of the future will be a conflict waged in three dimensions. Long before its artillery will have volleyed and thundered, each great military power will have endeavoured to secure the command of the air by building more dirigible airships and aëroplanes than its rivals. The fighting arm of a nation will henceforth be extended not merely over land and sea, but upward into the hitherto unconquerable air itself. Of all this we had some indication during the remarkable French military manœuvres of 1910. Then for the first time aëroplanes were tested under conditions that approximated those of actual warfare.

To the laymen the aëroplane's chief function in this battle of the future would seem to be the dropping of explosives on a hapless and helpless army below. The military strategist knows better. In the first place he knows that the actual amount of damage which could thus be inflicted would be disappointingly small. A hole may be torn in the ground; the windows of a few buildings may be broken; a battle-ship's superstructure may be blown away; but that wholesale destruction of life and property which would seem obviously to follow from the mere existence of military flying-machines, freighted with bombs and grenades, is not to be looked for. Even were it possible thus to destroy part of a stronghold, the difficulty of hitting the object aimed at is nearly insurmountable. Every small boy has attempted to hit some passer-by in the street with a missile hurled from a third-story window. Usually he failed, because the target was moving and because the wind deflected the projectile. The air-marksman is much worse off. Seated in a craft which is not only skimming at a speed hardly less than thirty-five miles an hour and possibly as great as eighty miles an hour, but skimming at a height of perhaps half a mile, the chance that he will ever be able to hit his target by making the proper allowance for the horizontal momentum which his bomb would receive, as well as for the prevailing wind, seems wofully remote. If bombs are to be dropped on forces below, it must be by means of tubes which will both project and direct the missile and which will be provided with wind gauges and height indicators for the proper guidance of the marksman. We must not allow ourselves to be misled by the skill displayed at flying exhibitions in dropping oranges on miniature battleships. Oranges are not bombs, nor are the heights at which they are dropped the half mile at which a military aëroplane must soar if it is to elude gun-fire.

Nevertheless some such possibility may have been at the bottom of the declaration signed by the delegates of the United States to the Second International Peace Conference held at The Hague in 1907, — a declaration which prohibited the discharge of projectiles and explosives from the air. The declaration reads:

"The contracting powers agree to prohibit, for a period extending to the close of the Third Peace Conference, the discharge of projectiles and explosives from balloons or by other new methods of a similar nature."

The countries which did not sign the declaration forbidding the launching of projectiles and explosives from air-craft were: Germany, Austria-Hungary, China, Denmark, Ecuador, Spain, France, Great Britain, Guatemala, Italy, Japan, Mexico, Montenegro, Nicaragua, Paraguay, Roumania, Russia, Servia, Sweden, Switzerland, Turkey, Venezuela.

To be effective, a bomb must be fairly large. Moreover, a considerable supply of bombs must be available. The aëroplane is a thing of comparative lightness. It cannot carry much ammunition of that sort. Hence, even admitting the possibility of dropping explosives upon any desired spot, the destruction wrought must necessarily be limited in extent. Lastly, there is also considerable danger in unbalancing the machine, by the sudden removal of the load from one side.

During the French manœuvres of 1910 no attempt seems to have been made to drop explosives from either airships or aëroplanes, an omission which implies the ineffectiveness of that mode of attack. In the war of the future the aëroplane will be employed

Photograph by Edwin Levick

Fig. 70.—One of the numerous accidents that happened to Louis Blériot before he devised his present monoplane

primarily for the transmission of orders and despatches; for discovering an enemy in a region in which his presence is suspected, his strength and the disposition of his forces being unknown; for ascertaining the strength of an enemy at points where he is known to be located; and for collecting sufficient information to permit siege guns to plant their shells where they will be most effective. In other words, the future military aëroplane will do the work of a scouting force; for its chief function will be that of reconnaissance. Two men will be seated in its frame, one to pilot the machine, and one to sketch and photograph the terrane below. From the trained eye of the spy in the air nothing will be concealed. He will be like a vulture wheeling in the blue, watching for carrion below. The click of his camera-shutter may be a death-knell, for it will record instantaneously the position of some battery cunningly hidden behind a ridge, an earthwork thrown up across a pass, a stream spanned by military pontoon bridges. His pencil, when it touches the page of a notebook, may spell the death sentence of a regiment; for it will unerringly note those details of position and numbers which the photographic plate may not be able to register. When he has learned all that he can learn, he signals his companion to return. Hardly two hours may have elapsed since he was despatched on his quest. Yet within that time he may be able to give his commanding officer information that a regiment of cavalry could not have gathered with almost unlimited time.

Both Generals Picquart and Meunier, the opposing commanders during the French manœuvres of 1910, expressed their satisfaction with the performance of aërial scouts. The machines were sent up practically whenever they were ordered to do so. What is more, the aviators carried out orders to the letter, and often under very unfavourable weather conditions. It was doubted at first whether they would be able to report with any degree of definiteness upon the position and number of the enemy. At a height of fifteen hundred feet, it seems quite possible, however, for a practised man to discover the character of the troops below him and to ascertain whether they are infantry, cavalry, or artillery. Artillery is easily enough distinguished by the intervals between the horses. By counting the number of gun caissons the strength of the battery can be ascertained. The strength of cavalry and infantry is arrived at by counting the companies or other group formations.

During the manœuvres in question it was sometimes difficult at the first glance to gain definite information of troops in battle formation, and at times it was possible to distinguish friend from foe only by the direction of fire. Lieutenant Sido, a French army officer and aërial scout, in commenting upon the possibility of discovering at a very great height the position of an enemy's forces, stated that a man who goes up in an aëroplane for the first time cannot distinguish anything below him; that many flights are necessary before he can form a judgment of the terrane below; that good eyesight, coupled with experience, are necessary; that field glasses are needed only rarely; and that at a very great height cavalry is somewhat harder to make out than artillery.

Although aëroplanes carrying but a single man did much valuable work during the manœuvres, it is generally agreed that the military aëroplane must carry at least two men, one of whom shall act as a pilot, and the other as an observer. As the field of the military aëroplane is extended, it is very likely that non-commissioned officers, and even ordinary soldiers, will be entrusted with the piloting of the machine. The observer must always be an intelligence officer of experience. Lieutenant (now Captain) Bellenger, who distinguished himself by his effective reconnaissances in a Blériot, maintains that one man will answer for ordinary scouting. When it is considered, however, that the machine is to be controlled, that maps are to be read, that the enemy's strength and disposition are to be discovered, that notes and sketches are to be made, it seems obvious that more than one man will be required.

It may be doubted whether the aëroplane will entirely supplant the usual forces employed for reconnaissance. The mist which usually conceals the ground early in the morning will probably interfere seriously with the activities

Photograph by Edwin Levick

Fig. 71.—A biplane that came to grief because of defective lateral control

of the aërial scout, not to mention ordinary fogs. Night marches and cavalry raids will probably be necessary as they have been in the past, and troops will mask themselves as they always have by natural and artificial concealments.

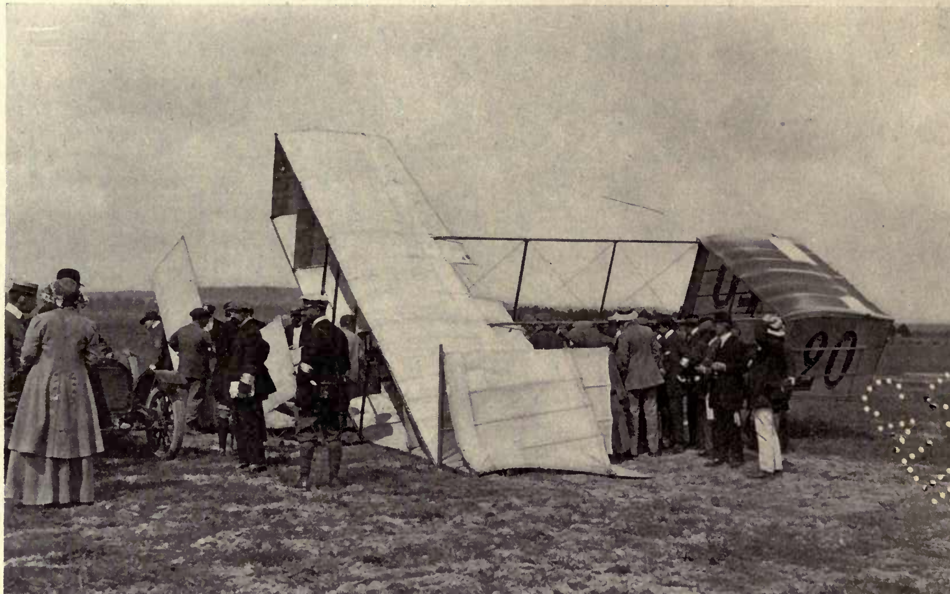
No doubt new stratagems will be devised to deceive the aërial eye. It is conceivable that a regiment may group itself in battalion or even brigade form, so that its strength may be overestimated. Other stratagems suggest themselves, such as the feigned movements which completely misled the observers in dirigible airships during the German army-manœuvres of 1910.

It is highly advisable that the aëroplane be fitted, if possible, with some form of wireless telegraph apparatus, so that the commanding officer may be kept fully informed of each new discovery. The necessity of reporting in person means the return of the aëroplane to headquarters. Up to the present time, no very successful attempt has been made in this direction, although the success of the wireless installation on the dirigible "Clement-Bayard II" would seem to indicate that the problem is not beyond solution.

For ordinary reconnaissance on the battle-field elaborate notes are not essential. The notes that Captain Bellenger took were of the most meagre character, — simply sufficient to refresh his memory. They were mere memoranda which read, for example, "7 h. 47 m. Mortvillers, 3 batteries." Such a note was all that he required when making his oral report to refresh his memory. For siege work, on the other hand, Bellenger insists on much more detailed information. In reconnoitring of that character the chief work to be performed by the man in the air will be the precise indication of the point to be shelled. An error of only one hundred and fifty feet in giving that position may nullify the besieging commander's best efforts. Reconnaissances in force to ascertain the enemy's disposition, a tactical necessity which may require a detachment of several thousand men from the main army for a considerable period of time will probably be of infrequent occurrence in the future warfare. An aëroplane will accomplish the same result in a fraction of the time. One of the bloodiest encounters the world has ever seen was the Japanese attack on "203 Meter Hill." Yet the sole purpose of that great slaughter was the placing of two or three men at the summit of the hill to direct the fire of the Japanese siege guns upon the Russian fleet in the harbour of Port Arthur.

Major G. O. Squier of the United States Signal Corps has pointed out that the realisation of aërial navigation for military purposes brings forward new questions as regards the limitation of frontiers. As long as military operations are confined to the surface of the earth, it has been the custom to protect the geographical limits of a country by ample preparations in time of peace, such as a line of fortresses properly garrisoned. At the outbreak of war these boundaries represent real and definite limits to military operations. Excursions into the enemy's territory usually require the backing of a strong military force. Under the new conditions, however, these geographic boundaries no longer offer the same definite limits to military movements. With a third dimension added to the theatre of operations, it will be possible to pass over this boundary on rapid raids for obtaining information, accomplishing demolitions, etc., returning to safety in a minimum time. Major Squier, therefore, regards the advent of military scouts of the air as, in a measure, obliterating present national frontiers in conducting military operations.

Is the enemy altogether defenceless? Can he offer no resistance? It is inconceivable that he shall lie at the mercy of a great artificial vulture, as helpless as a carcass. Undoubtedly he will have his special artillery, — field pieces so constructed that they can be elevated for high angle fire. Against that military bird of prey which he sees hovering far above him and whose errand he divines only too well, he will train this weapon. If his whistling shrapnel should strike a motor, a propeller blade, or an ignition device, if it should cut a tiller rope or splinter a steering rod, that great bird above him must glide down, wounded at least. It is not necessary to kill the pilot, but merely to strike a vital part of the driving mechanism.



Photograph by Edwin Levick

Fig. 72.—An old style Voisin biplane of cellular construction wrecked because the pilot tried to make too short a turn near the ground

The spy in the air may glide down in safety; but his information is lost to his commanding officer. The question arises, can the aëroplane be struck so easily? Probably not. A moving object is always difficult to hit, but trebly so when it soars half a mile up in the sky.

Such guns are made in Germany by Krupp and by the Rheinische Metallwaaren und Maschinenfabrik, of Düsseldorf. The guns have small bores and use light projectiles, so that they can be fired quickly. The barrels are comparatively long, so that a high initial velocity and a low trajectory are obtained. Telescope sights and a range finder are provided, the latter fitted with an arrangement which gives the necessary elevation as the distance is read off.

The ordinary Krupp field gun has a 6.5 cm. bore (Fig. 73), and is fitted with an hydraulic brake and a spring recoil. A coiled spring is provided to balance the gun as it is pointed above the horizontal. The upper part of the gun-carriage is movable, and the wheels can also be given a half-turn away from the body, which assists in quick aiming. This equipment weighs

875 kilos, 352 kilos of this being in the gun, 523 kilos in the carriage. The projectile weighs 4 kilos — about 81 lbs. 13 oz. The initial velocity is given as 620 m. — roughly 2,034 ft. a second; the extreme range, 8,650 m. — 9,450 yards; and the height of fire obtainable, 5,700 m. — roughly 18,700 ft. The gun can be elevated through an angle of 70 degrees above the horizontal, and depressed 5 degrees below it, and it can be revolved right round through an angle of 360 degrees.

A heavier type of Krupp field gun (Fig. 74) has a bore of 7.5 cm., and weighs when ready for firing 1,065 kilos. The weight of the projectile is 5.5 kilos — about 12 lbs. 2 oz. The initial velocity is stated to be 625 m. per second, and 9,100 m. and 6,300 m. are given as the extreme range and height attained at trials. The motor-car on which the weapon is carried is designed for an average speed of 45 kilometres — 28½ miles an hour, and weighs 3,250 kilos — 7,163 lbs. — without the gun. It carries 62 projectiles under the seats, and is propelled by a 50 horse-power motor. It is steadied during firing by a special arrangement which presses the platform against the axles. The gun can be elevated to an angle of 75 degrees from the horizontal, and can be revolved through a complete circle.

A 10.5 cm. naval gun (Fig. 75) is also made by Krupps. It weighs 3,000 kilos when ready for firing, the projectile 18 kilos, the gun 1,400, the carriage 1,600. Its initial velocity is 700 m. per second, and 13,500 m. and 11,400 m. are given as the extreme range and height attainable. As in the case of the 7.5 cm. gun, it can be elevated through an angle of 75 degrees from the horizontal, and revolved through a complete circle. All these three guns are 35 calibres long.

The guns made by the Düsseldorf firm are of a somewhat different construction. The bore is 5 cm., and the barrel is 30 calibres long. The gun is worked from a centre pivot by a hand-wheel and weighs 140 kilos — 400 kilos with shield. It can be elevated to an angle of 70 degrees above the horizontal, and depressed 5 degrees below it, and can be revolved through a complete circle. The total weight of the gun, ammunition, five men and car comes to 3,200 kilos. The car is built at the factory of Ehrhardt, at Zella, and is driven by a motor of 50 to 60 horse-power, which propels it at a normal speed of 45 kilometres per hour. It is said to be capable of negotiating gradients of 22 per cent even on bad roads. The whole, including the wheels, can be protected by nickel-steel plate shields.

During the French manœuvres of 1910 a special gun was used for the repulsion of airships and aëroplanes, the invention of Captain Houbernat. It was a weapon of 75 millimetres (3 inches) diameter carried on an automobile. The maximum elevation of fire was 66 degrees. The piece was so mounted that it could be swung down for its whole length with the muzzle beside the driver of the car. When elevated, the entire weight of the piece was thrown on the rear of the motor-car. Hence it was necessary to stake down the front wheels. The weapon had a range of 5,000 metres (3 miles). The projectiles fired were Robin shells which explode at a maximum elevation of 2,500 metres (7,200 feet). Besides this piece, a mitrailleuse was used of the usual type employed by French

Fig. 73.—A Krupp 6.5 cm. gun for airship and aëroplane attack. The gun fires a projectile weighing about 8 lbs. 13 oz. to a height of about 18,700 feet

infantry and cavalry, but modified so that it could be elevated at a high angle and fired from an automobile if necessary.

The question of ammunition most suitable for guns is also receiving attention in Germany. The Düsseldorf firm mentioned has introduced a combined shrapnel and ordinary shell for use against both dirigibles and aëroplanes. This new form of shrapnel differs from that which is ordinarily fired in so far as, after the explosion of the shrapnel part, the shell part is carried on to the target, or to the ground, where it detonates, giving off in its flight an observable cloud of smoke. A somewhat similar projectile is also made by the Krupps. The trail of smoke serves the purpose of indicating how close the projectile came to its mark (Figs. 76 and 77).

Not upon such artillery and shells and shrapnel will the enemy rely, but on aëroplanes and airships of his own. He must fight steel with steel. When he sees a black speck in the sky, moving toward him, he gives a quick command. A monoplane or a biplane, perhaps two, start with a whirr from his camp and soar to meet that speck. When machine encounters machine in the sky, what will happen? They dare not ram each other. That would mean the inevitable destruction of both; for the two would surely fall, a mass of twisted and splintered metal and wood. They must fire at each other. But with what? Not with revolvers or rifles, for their range is too small for effective shooting at an aëroplane wheeling around some thousands of yards away; not with a field-piece, for it could not be carried on so light a contrivance; but with a machine-gun of especially light construction, a mitrailleuse which will pour forth so many hundred shots a minute in a steady stream, like a jet of water spouting from a hose. That battle in the sky will be won by the swiftest and most readily controlled flying-machine, — by the aëroplane, in a word, which can run and choose its own position and range.

The question may well be asked: What will be the relation of dirigible to aëroplane? Will the one type displace the other? Both types will probably be necessary. The dirigible and the aëroplane will bear to each other the relation of battleship to torpedo boat. In actual war each combatant will have a fleet of both airships and aëroplanes. When an enemy appears it will be the first duty of the opposing fleet to attack him. The home fleet will have a certain advantage because it will be nearer its base. It is not likely that an attacking fleet will sail over an enemy's country unless it is able to destroy the home fleet.

What chance has the dirigible against the aëroplane in an aërial battle? Because of its greater speed the aëroplane has the advantage of fighting or running. Moreover, the dirigible being a most expensive machine, there are always likely to be more aëroplanes than airships, so that many aëroplanes can be opposed to a single dirigible, just as many torpedo boats are sent against a single battleship on the theory that one at least will deal a fatal blow.

Its great speed gives the aëroplane an immeasurable advantage over the dirigible even in scouting. Suppose that a frontier several miles long is patrolled by a fleet of dirigibles, and suppose that a considerable number of hostile aëroplanes is available to ascertain the position and strength of the enemy beyond that frontier. No reasonable number of dirigibles could alone protect that frontier from invasion. The blockade can always be run. However well the line may be protected, there will be spaces where the aëroplane can cross and recross after having taken all the observations required.

For actual fighting purposes the aëroplane cannot as yet be reckoned with. It can be armed only with the lightest gun and can carry only a very limited amount of ammunition and men. The dirigible, on the other hand, can carry a crew of twenty-six and can be fitted with guns much above rifle-calibre. It can remain in the air thirty or forty hours, and in that time travel several hundred miles. When the aëroplane can carry a couple of fighting men in addition to the pilot, and these can be armed with something in the nature of a machine-gun, the efficiency of aëroplanes will be far increased if they can cruise in fleets against isolated dirigibles. The small target and high speed of the aëroplane will be in its favour, even though its

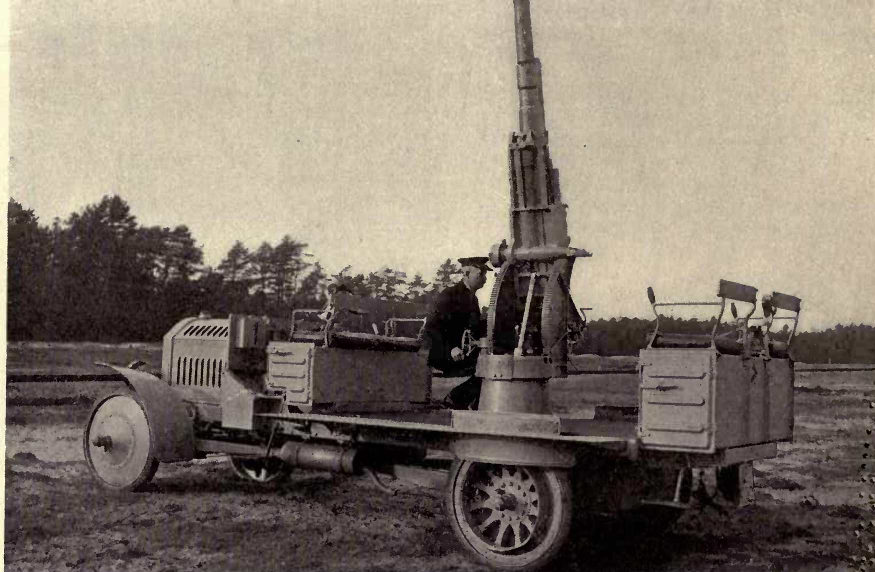


Fig. 74.—A Krupp 7.5 cm. gun mounted on an automobile truck. The gun fires a 12 lb. 2 oz. projectile to a height of about 4 miles. The automobile has a speed of 28½ miles an hour. Under its seats 62 projectiles can be stored

opponent will be more heavily armed. Moreover the inevitable confusion attending a combat waged upwards and downwards and on all sides should offer many a chance to a daring fighter of delivering a telling blow.

It has been urged that if the aëroplane once gets above the dirigible the fate of the latter is sealed; for the gas bag prevents the dirigible from firing at the aëroplane. It may well be that gun-platforms will be arranged on top with a conning-tower projecting from the car below, through the gas bag. Such a construction has been proposed in Germany. At present the dirigible can ascend to heights which the aëroplane has not yet reached. The rarity of air at altitudes of over a mile has an important effect on the operation of the aëroplane engine. Most of the men who have soared to great heights in aëroplanes have found that their motors stopped at a certain elevation, and a motor that stops places the pilot in the position of a balloonist whose gas has leaked away. If the aëroplane can choose its own range because of superior speed, the dirigible can at least choose its own elevation. Yet even here there are limitations to be observed. As a dirigible rises its gas expands. To prevent the bursting of the envelope, gas must be allowed to escape. Hence when the dirigible drops again to a lower level, its ascensional power has been considerably curtailed.

Command of the air, like command of the sea, will depend on men and material. Without men of courage and skill, flying-machines are useless. Without efficient flying-machines, on the other hand, it is obvious that men cannot fly. The situation is much the same in that respect as in naval affairs. England has dominated the sea because she has had the ships and a well-trained industrious body of civilians to fight them. Acquisition of material is merely a matter of spending money. The nation that spends the most money will have the most numerous and best equipped air navy. In the case of war in the air, as at sea, success will depend not only on abundant material, but on the ability to supply wastage of war, which is enormous and increases in enormity as the material becomes more complicated and costly. In matters of armament, however, cost is not the guiding principle. Nothing is so expensive as defeat, and to avoid defeat the most efficient aircraft must be provided in sufficient numbers. Battles, aërial or terrestrial, are won as much by money as by hard fighting.

CHAPTER XII

SOME TYPICAL BIPLANES

All biplanes, no matter by whom designed, have certain features in common. Besides the two superposed supporting surfaces from which they take their name, they all have a horizontal rudder or elevator, by means of which the machine is guided up or down and is prevented from pitching; a vertical rudder, by means of which the machine is kept on an even course and turned to the right or to the left; and some means by which the amount of main surface exposed to the pressure of the air can be varied, so as to keep the machine in balance from side to side. To these essential elements a tail, consisting of a small horizontal surface, is usually added, because it serves to steady the machine in flight.

Just how these elements shall be disposed is a matter of more or less difference of opinion among biplane designers, and this difference of opinion has given us the various biplanes of the

Wrights, Curtiss, Farman, Goupy, Sommer, Bréguet, and others. Biplanes as a class follow the lines of the Wright machine. It is here impossible and unnecessary to describe in detail all the biplanes in use at the present day. For our purpose it will be quite sufficient to confine ourselves to the Wright, Curtiss, Farman, and Sommer machines, inasmuch as they represent the chief systems of control to be found in the two-surface machine.

The Wright Biplane

The two supporting surfaces of the Wright machine consist of canvas stretched over and under ribs of spruce. At a point near the centre these surfaces are three inches thick. The dimensions of the planes vary. In the earlier machines they measured 41 feet in spread, 6.56 feet in depth, and 538 square feet in area. In the later machines the spread has been reduced to 39 feet, the depth to 5.5 feet, and the area to 410 square feet. A smaller model has also been designed in which the spread has been reduced to 26 feet.

In the first Wright machines (Fig. 79) the horizontal or elevation rudder was mounted in front, and was so constructed that it was automatically curved concavely on the under side when elevated, and in the opposite way when depressed. A long wooden rod connected the horizontal rudder with a lever, which was manipulated by the operator's left hand (Fig. 20). By pulling the lever toward him the operator inclined the rudder upward; by pushing the lever away from him the operator depressed the rudder.

The vertical rudder, which not only served to steer the machine in a horizontal plane but also to prevent it from spinning on a vertical axis, was mounted in the rear of the machine as at present. It consisted and still consists of two parallel vertical surfaces, swung by a lever in the operator's right hand. By pushing the lever away from him the operator turns the machine to the left; by pulling it toward him he turns the machine to the right.

Side-to-side balance has always been maintained in the Wright biplane by warping the main planes in the manner explained in Chapter V. The entire front of the two supporting

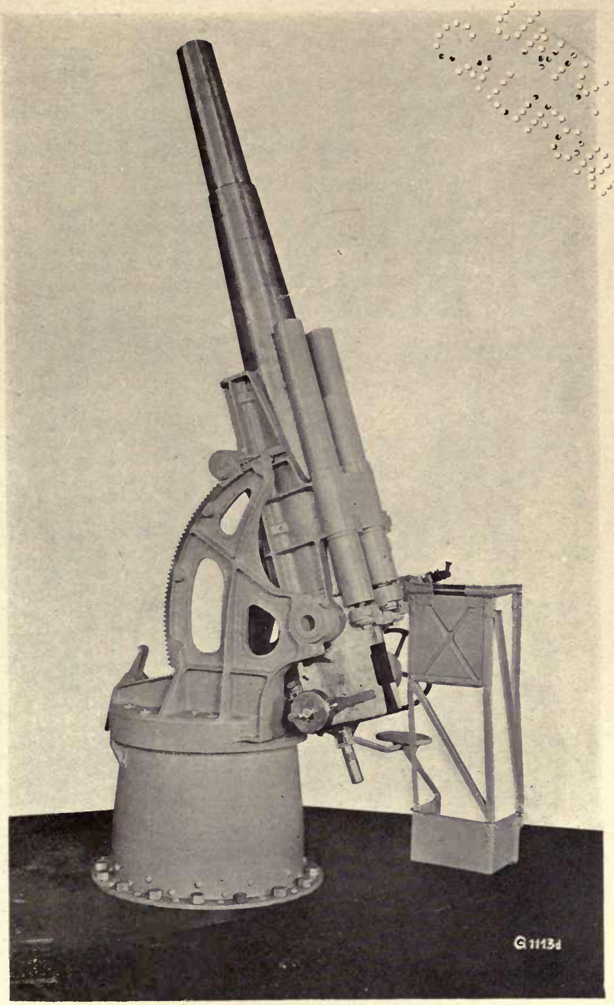


Fig. 75.—A Krupp 10.5 cm. naval gun for repelling aircraft

surfaces is rigid; but the rear corners are movable. The central sections of the two planes are rigid and are never moved in balancing the machine. Only the rear corners of both planes play any part in controlling the apparatus. These flexible rear corners of both planes are connected by means of cables with the lever in the operator's right hand (Fig. 20), in other words, the lever which controls the vertical rudder. By throwing the lever from side to side the rear corners are flexed in opposite directions; in other words, as one corner of one plane is bent down, the other corner of the same plane is bent up, with the result that the entire plane is given what the Wrights call a "helicoidal warp." The same lever controls both the vertical rudder and the warping of the planes, because the Wrights found that as the planes were bent the machine would spin on a vertical axis, as explained in Chapter V. This lever is therefore swung in a circular or elliptical path so that the planes are warped and the vertical rudder swung in the proper direction at the same time.

In the newer Wright biplanes a modified form of lever has been adopted to warp the wings and turn the vertical rudder, the principle, however, remaining substantially the same. The new lever is provided with an auxiliary grip, which can be worked by the fingers to operate the vertical rudder, while the main portion of the lever is pushed forward or backward to warp the wings.

In the European Wright machine a tail was soon added, because it was found that the machine pitched markedly in flight. This pitching was corrected, to be sure, by manipulation of the horizontal rudder, but this required considerable skill on the pilot's part. Hence a horizontal surface was placed in the rear to act as a steadying tail, which surface could be turned up and down to aid the elevation rudder in its action. In the American machines, made by the Wrights themselves, this horizontal tail has also been incorporated (Fig. 80). What is more, the front horizontal rudders have been abandoned altogether and the rear horizontal surface or tail employed both as an elevator and a steadying surface. The result has been that the machine flies far more steadily than formerly.

The earlier Wright machines were mounted on skids. The machines were launched on a starting rail (Fig. 12) in the manner described in Chapter IV. The European manufacturers of Wright machines soon introduced wheels on which the machine ran in the usual manner, the skids serving for alighting as before. This improvement has been adopted by the Wrights (Fig. 14).

The motors which drive the American Wright machines are made by the Wrights themselves. The horse-power, except in small racers, varies from 25 to 30, which is considerably below that of most European biplanes. The motor drives two propellers revolving in opposite directions at the rate of 400 revolutions a minute, which is remarkably slow as propeller speeds go.

The Wright racing aëroplane, which made its first appearance at the Belmont Park International Aviation Meet of 1910, is not essentially different from the regular Wright biplane. In order to attain high speed, the planes have been reduced in spread, and consequently in area, and a V-motor of high power has been installed. The planes are 21 feet in length and 3½ feet wide. The combined area of both planes is 180 square feet. It is stated that the motor develops about 60 horse-power. The machine was used by Johnstone when he made an altitude flight of 9,714 feet. The machine is credited with a speed of 68½ miles an hour.

The Curtiss Biplane

Like the Wrights, Mr. Glenn H. Curtiss has departed somewhat from the type that he originally evolved. In his earlier machines (Fig. 25) the supporting planes consisted of "rubberized" silk stretched over the top of a light spruce frame. The spread of the planes was 26.42 feet, the depth 4.5 feet, the distance between the planes 5 feet, and the area 220 square feet. In the more recent machines the spread is 32 feet, the depth 5 feet, and the area 316 square feet.

The horizontal or elevation rudder of the Curtiss biplane consists of two parallel horizontal surfaces mounted in front of the machine and moved in unison by means of a steer-

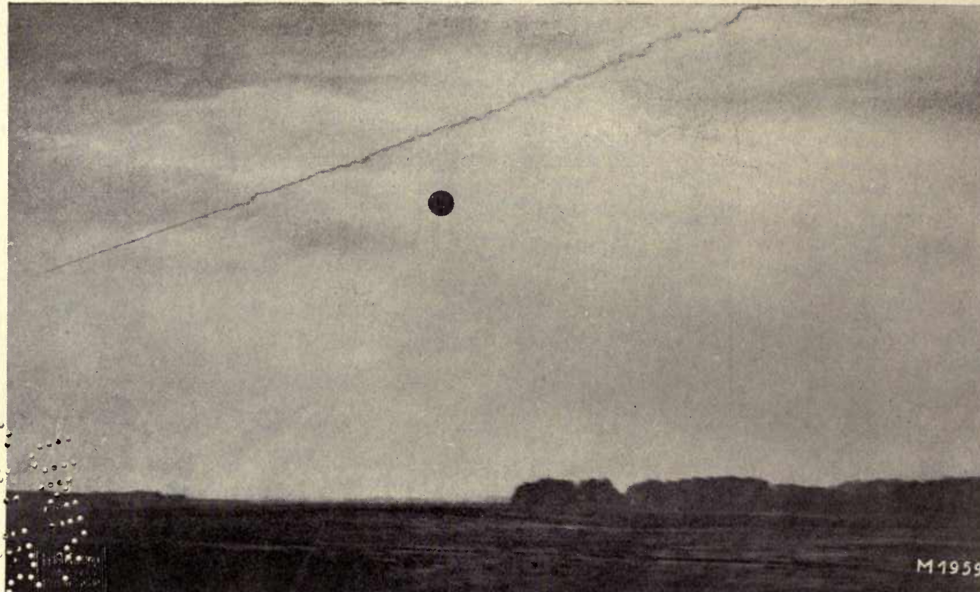


Fig. 76.—The projectiles employed for the repulsion of airships and aëroplanes leave a trail of smoke behind them so that the gun-crew can determine the amount of error in sighting

ing-wheel. A long bamboo rod connects the horizontal rudder with the steering-wheel, the arrangement being such that by pushing or pulling the steering-wheel backward or forward, the rudder is respectively turned down or up.

The vertical rudder of the Curtiss machine is a single surface placed in the rear and also operated by the steering-wheel through the medium of cables. To work the vertical rudder the steering-wheel is rocked like the pilot-wheel of a steamboat. To secure steadiness in flight and to reduce the pitching effect a horizontal surface or tail is mounted in the rear.

Side to side balance was maintained in the Curtiss machine up to 1910 by means of two balancing planes of about 12 square feet in area, mounted between the two main planes. These balancing planes were swung in opposite directions by cables connected with a yoke partially surrounding the aviator's body and mounted to rock. By leaning from side to side the aviator moved the yoke and consequently the balancing-planes. The arrangement was such that the instinctive motion of the body swung the balancing-planes.

In the late Curtiss machines ailerons (Fig. 29) similar to those of the Farman biplane (q. v.) are employed. They are operated in the same manner as the old balancing-planes.

The motors which drive the machine are made by Mr. Curtiss himself. On the larger machines the motors are of the well-known V-type and develop 50 horse-power. On the smaller machines 25 horse-power vertical cylinder motors are used. The engine is controlled by an accelerator pedal on the left of the steering column. There is also a throttle lever close to the pilot's seat. Another pedal under the action of the pilot's right foot is employed to cut off the ignition and to apply a brake to the front wheel of the chassis by which the machine is carried on the ground. Mr. Curtiss himself has driven machines with 100 horse-power motors.

The propellers are made of wood and are two-bladed. Their diameter is 6 feet, the pitch 5 feet, and the speed 1,200 revolutions a minute.

The machine starts and alights on three rubber-tired wheels.

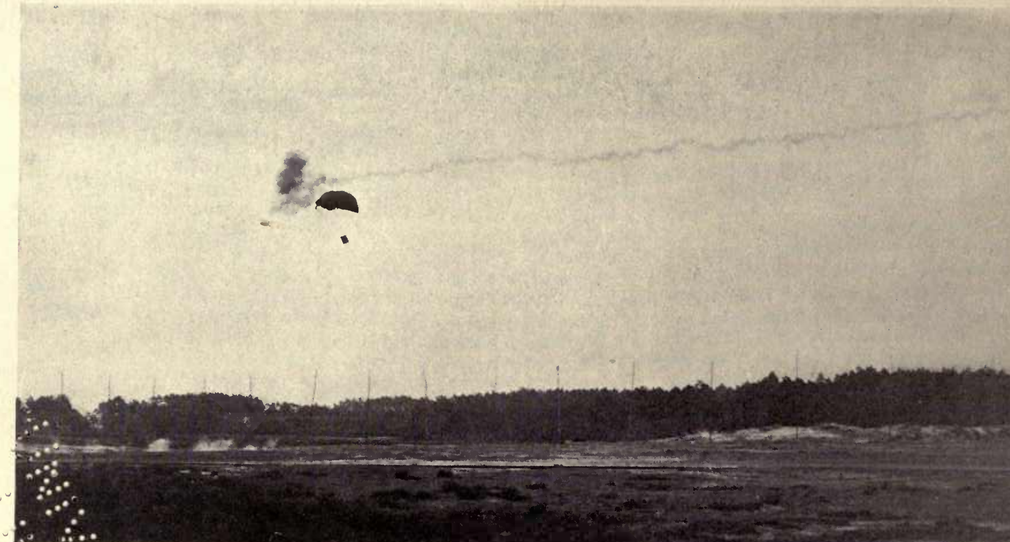


Fig. 77.—A projectile that hit its mark

For the Belmont Park aviation meeting of 1910 Mr. Curtiss made a machine which was practically a monoplane. The upper plane was reduced to a surface of almost negligible area. At the meeting in question the machine was not given a very extensive trial, so that it could not be compared with the Blériot and other machines that were entered.

The Farman Biplane

The Farman biplane is the outcome of Henry Farman's experience with the old, cellular Voisin biplanes (Fig. 34). Like Curtiss, he was manifestly influenced by the Wrights, as, indeed, was every French maker of flying-machines after the memorable flights of Wilbur Wright in France in 1908. As it now stands, the Farman is probably the most widely used biplane in Europe and deservedly so by reason of its ingenious and extraordinarily staunch construction.

The main supporting surfaces of the Farman biplane are made of what is known as "Continental" cloth, a special fabric manufactured for aëronautic purposes. The cloth is stretched over ribs of ash. Although the dimensions vary somewhat, the average Farman biplane has a spread of 33 feet, a depth of 6.6 feet, and a total area of 430 square feet. In the later machine the upper plane has a greater spread than the lower. The planes are separated by a distance of 7 feet.

The elevation or horizontal rudder is carried out in front of the machine, after the early Wright fashion. Wires run from the rudder to a lever held by the pilot's right hand (Fig. 28). By pushing the lever away from him, the pilot depresses the rudder; by pulling the lever toward him, he tilts the rudder up.

The same lever controls the lateral balance of the machine. Four hinged flaps, constituting the rear corners of the main planes, are connected by cables with the lever. By throwing the lever from side to side the flaps (ailerons) on one side are pulled down, and the flaps on the other side are relaxed so that they lie practically flush with the main planes. When the machine is standing still on the ground, the flaps hang down. As soon as the machine is in flight, they stream out behind the main planes.

The vertical rudder consists of two parallel vertical surfaces in the rear of the machine, which surfaces are connected by means of tiller cables with a lever worked by the pilot's feet.

Somewhat in advance of the vertical rudder are two horizontal surfaces which constitute a steadying tail. The top surface of this tail can be swung up and down in conjunction with the front horizontal rudder.

The motors used on the Farman machine are usually Gnôme rotary motors of 50 horse-power, although 100 horse-power motors have been used on occasion. The propeller is a Chauvière wooden propeller of two blades, with a speed of 1,200 revolutions a minute. The pitch of the propeller is 4.62 feet, the diameter 8.5 feet.

The machine is mounted on two skids, each of which is fitted with a pair of wheels. Heavy elastic bands connect the skids with the axles of the two wheels. In alighting the bands yield and allow the skids to take the main shock.

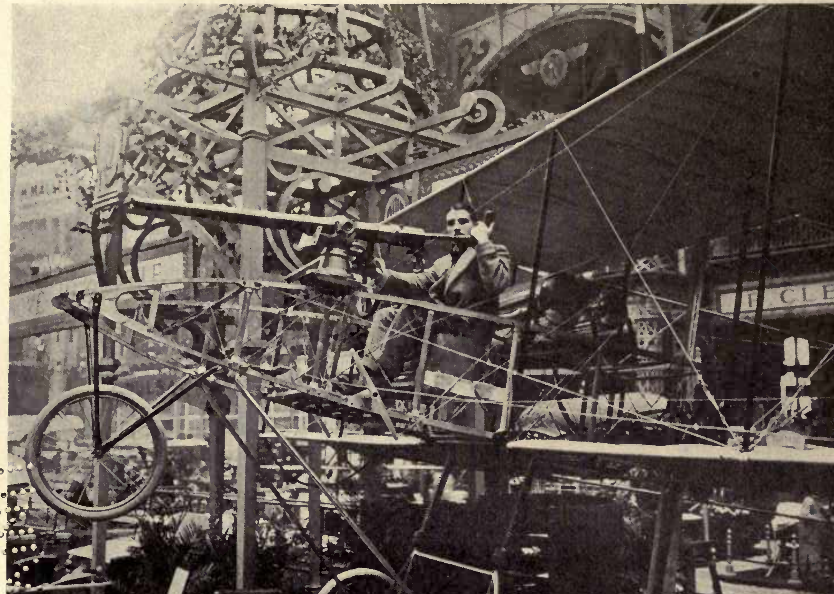
This is a most ingenious, efficient, and simple invention, which has been widely copied.

The Sommer Biplane

The biplane built by Farman's former pupil Roger Sommer (Fig. 83) follows the Farman type rather closely. The supporting surfaces consist of rubber cloth stretched over wooden ribs. The spread is 33 feet, the depth, 5.2 feet, and the total area 326 feet.

The horizontal rudder is carried well out in front of the machine. It consists of a single horizontal surface. As in the Farman machine, it is controlled by a single lever, which, instead of being placed at the right, is mounted at the left. The operation of this lever and the consequent elevation and depression of the rudder are exactly the same as in the Farman machine.

As in the Farman machine, ailerons are employed to maintain side-to-side balance. These ailerons are to be found either on both planes or only on the upper plane. They are not operated, as in the Farman machine, by the lever which controls the horizontal rudder. Instead, the Curtiss principle of using the instinctive



Photograph by Meurisse

Fig. 78.—A Voisin biplane equipped with a Hotchkiss machine gun, exhibited at the 1910 Salon de l'Aéronautique, Paris. This is probably the first attempt to mount a machine gun on an aëroplane, and was a rather poor attempt.

movements of the pilot's body is adopted. Wires leading from the ailerons are attached to a yoke partially surrounding the aviator's body. In obedience to the movements of the body the ailerons are pulled down and up respectively.

The vertical rudder is a single surface at the rear of the machine operated, as in the Farman machine, by a foot lever.

To steady the machine a single horizontal surface is mounted in the rear. This surface is movable, not for the purpose of acting as an elevation rudder, but to increase or decrease the stabilising effect. A lever at the aviator's right controls this tail.

The machine is mounted on skids and wheels, the skids serving for alighting. Rubber springs are employed in connection with the wheels, as in the Farman machine.

As a general rule Sommer machines are driven by 50 horse-power Gnôme motors, which turn a two-bladed Chauvière propeller at the rate of 1,200 revolutions a minute. Some machines have been fitted with 100 horse-power motors.

CHAPTER XIII

SOME TYPICAL MONOPLANES

MONOPLANES differ less from one another than biplanes. Nearly all of them have the same system of lateral control, and the same method of mounting the motor. As a general rule this system of lateral control is the Wright wing-warping method. The motors are usually Gnôme motors mounted in front of the machines.

THE ANTOINETTE MONOPLANE

Antoinette monoplanes (Fig. 84) are designed and built by Levavasseur, a well-known manufacturer of motors.

The single silk surface of an Antoinette monoplane is constructed in two halves which are so mounted that they form a slight dihedral angle. This plane is braced to a central mast or spar, and is carried on a girder-like frame of aluminium, cedar, and ash. The spread of the plane is 49 feet; the area 405 square feet.

The horizontal rudder is a single surface at the extreme rear of the machine and is controlled by a hand-wheel at the aviator's right (Fig. 32).

The vertical rudder comprises two surfaces at the rear of the machine. Tiller cables lead from the surfaces to a lever operated by the aviator's feet.

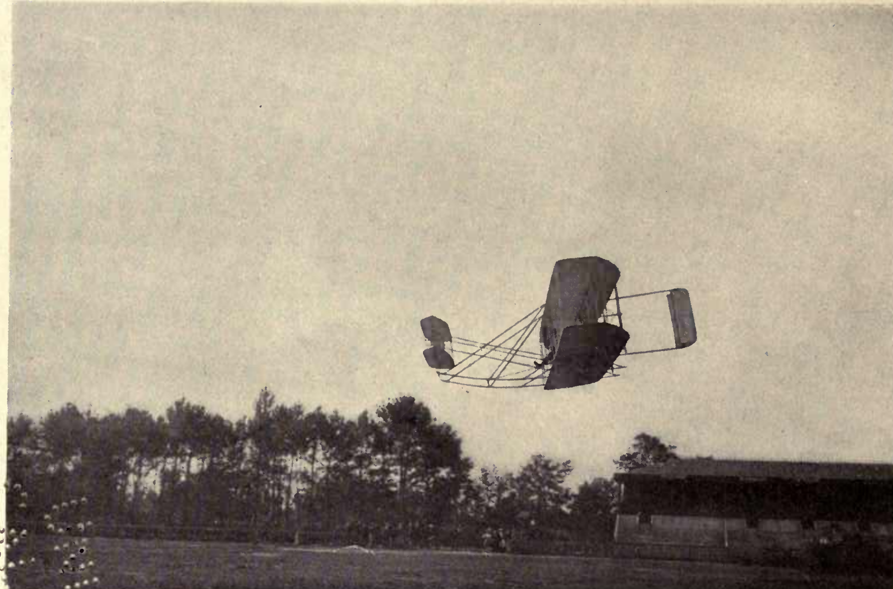
To balance the machine from side to side the plane is warped after the Wright principle. In contradistinction to the Wright machine, however, the front edges are flexible and the rear edges fixed. To warp the plane a hand-wheel is provided at the aviator's left.

The mast, to which the plane-halves are braced, contains a pneumatic shock-absorber in its lower end, besides which there are two wheels with heavy pneumatic tires and a forward plough-like skid. A skid in the rear is used to support the tail.

On each side of the body is a horizontal, fan-shaped keel at the rear to steady the machine longitudinally. A vertical fin above this horizontal fin gives a certain amount of lateral stability.

An 8-cylinder V-type water-cooled Antoinette motor of 50 horse-power is placed in front of the machine and drives a 7-foot propeller. At the International Aviation Meeting held in 1910 at Belmont Park, Latham flew a 100 horse-power Antoinette.

The Antoinette monoplanes which are built in Germany are equipped with 100 horse-power Gnôme motors of fourteen cylinders. The area of the wings can be reduced by about one square metre, the smaller area being employed when the aviator is flying alone. When three passengers are carried besides the aviator, the span can be increased to fifteen metres, so that the area amounts to four square metres. The passengers are placed symmetrically, so that the centre of gravity of the machine is not disturbed. This large Antoinette machine is somewhat longer than the normal Antoinette, built in France. Since the utilisation of the Gnôme motor means the abandonment of the usual Antoinette water-cooling plant, and such auxiliary apparatus as radiators, pumps, etc., it was necessary to redistribute the weight. Accordingly the German machine is longer than the



Photograph by Edwin Levick

Fig. 79.—The Wright biplane that Wilbur Wright flew in France in 1908

French, so that the motor can be placed out further.

The Blériot Monoplanes

Louis Blériot is a well-to-do manufacturer of automobile lamps whose attention was directed to flying-machines in 1906. He has the distinction of having broken more machines and more frequently risked his life than any other man interested in the new sport. What is more, he was the first man who ever flew a monoplane.

Blériot's remarkable experience has resulted in the development of two types of machines known respectively as the Blériot XI (Fig. 81) and the Blériot XII (Fig. 88). The Blériot XI is a fast model patterned after that with which Blériot flew across the English Channel; the Blériot XII is a passenger-carrying machine, which differs somewhat from the XI.

The main plane of the No. XI is built in halves and consists of "Continental rubber" stretched over a wooden frame. In order that the machine may be readily transported the halves of the plane can be detached from a central joint. This detachability, moreover, renders it possible to interchange wings of large and small area. The spread is normally 28.2 feet, the depth 6.5 feet, and the total area 151 square feet.

To steady the machine longitudinally in flight a horizontal surface or tail is employed. The horizontal or elevation rudder consists of two movable surfaces, one at each side of this tail. The horizontal rudder is operated by a central lever in the manner described in Chapter V.

The vertical rudder of the Blériot XI consists of a vertical surface in the rear of the machine. It is operated by tiller wires connected with a foot lever.

Lateral control of the machine is obtained by wing-warping, as in the Wright biplane. For this purpose the central lever or bell-column, described in Chapter V, is employed, the column being thrown from side to side to pull on one wing-warping wire and to slacken the other.

In the machine with which he flew across the English Channel, Blériot used a 25 horse-power Anzani motor. Since then 50 horse-power Gnôme motors have usually been employed, the motor being mounted in front of the machine and driving a two-bladed Chauvière propeller 6.87 feet in diameter at the rate of 1,200 to 1,400 revolutions a minute.

The starting and alighting gear of the Blériot XI consists of rubber-tired wheels and rubber shock-absorbers. For the rear wheel, as shown in Fig. 86, a skid has been substituted.

In the smaller type of Blériot a fuel tank is placed very far below the frame in order to lower the centre of gravity. In the larger type two fuel tanks are placed between the wings in the body of the machine right in front of the pilot's seat. In order that the lowered fuel tank of the small Blériot XI may offer as little resistance to the air as possible, it is given a fish form (Fig. 86) for the reason that Prandtl has proven that such shapes offer the least resistance.

Racing machines are also made on the lines of the Blériot XI, but with a smaller wing-spread and 100 horse-power, fourteen-cylinder Gnôme motors.

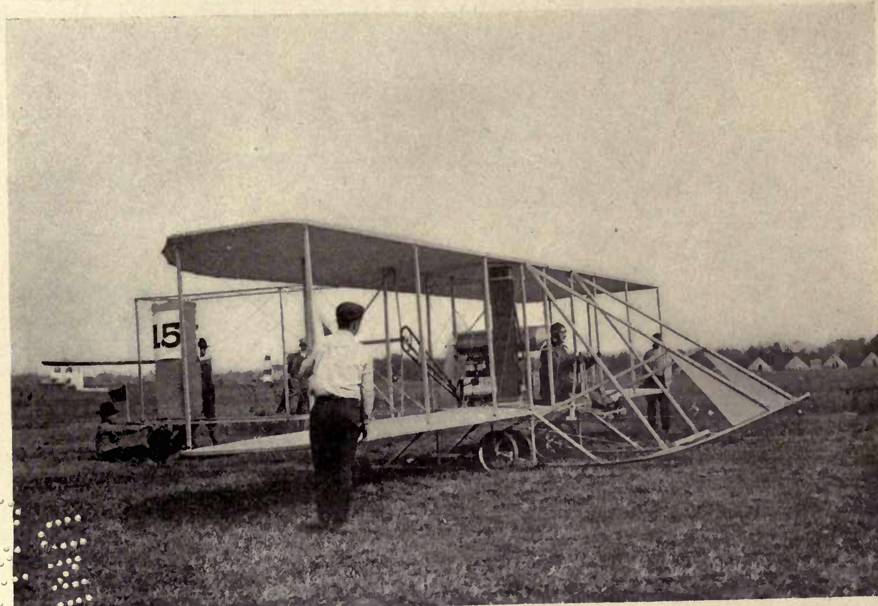
The passenger-carrying Blériot XII is so constructed that the aviator sits with his passengers under the main plane, back of the motor. This type is now practically abandoned. In the Blériot XI he sits with his body above the main plane. A later passenger-carrying model has been evolved in which the two occupants of the machine sit side by side above the plane, as in the regular Blériot XI.

Early in 1911 Blériot brought out a remarkable 10 passenger monoplane, the lateral stability of which was controlled by ailerons and the 100 horse-power motor of which was placed with the propeller directly behind the plane, following Maxim's suggestion. A front horizontal rudder was also provided, similar to that of the Farman biplane.

The Santos-Dumont Monoplane

By far the smallest flying-machine of the day is the monoplane designed by Santos-Dumont. Because of its littleness it is extremely fast.

The supporting surface consists of silk stretched over bamboo ribs. This silken surface is braced by wires to a central frame of bamboo and metal tubing. The spread is 18



Photograph by Edwin Levick

Fig. 80.—The Wright biplane of 1910. The elevating rudder has been placed in the rear of the machine, where it also serves as a tail

feet, the depth 6.56 feet, and the area 113 square feet.

The vertical rudder and the horizontal rudder, usually entirely distinct, in most biplanes and monoplanes, are here combined after the Langley principle. This combined rudder is carried on a universal joint so that it can be turned in any direction. Although they are mounted together, the horizontal and vertical members of the rudder are operated independently. The vertical surface is controlled by a hand-wheel or lever at the pilot's left hand. The horizontal rudder is operated by a lever held in the aviator's right hand.

Following the principle of Curtiss, lateral control is effected by the instinctive movements of the aviator's body; but instead of employing balancing planes or ailerons Santos-Dumont warps the plane. The wires leading from the plane are connected with a steel member sewed on the pilot's coat. Hence the pilot has only to sway his body in order to warp the wings.

The starting and alighting gear consists of two wheels at the front and a skid at the rear.

No tails or other stabilising surfaces are used, although the horizontal member of the rudder undoubtedly acts as a tail, as in the newer Wright biplane.

The motor may be of any type. Darracq, Clément-Bayard, and Panhard motors of 30 horse-power have been used. The propeller is a two-bladed Chauvière.

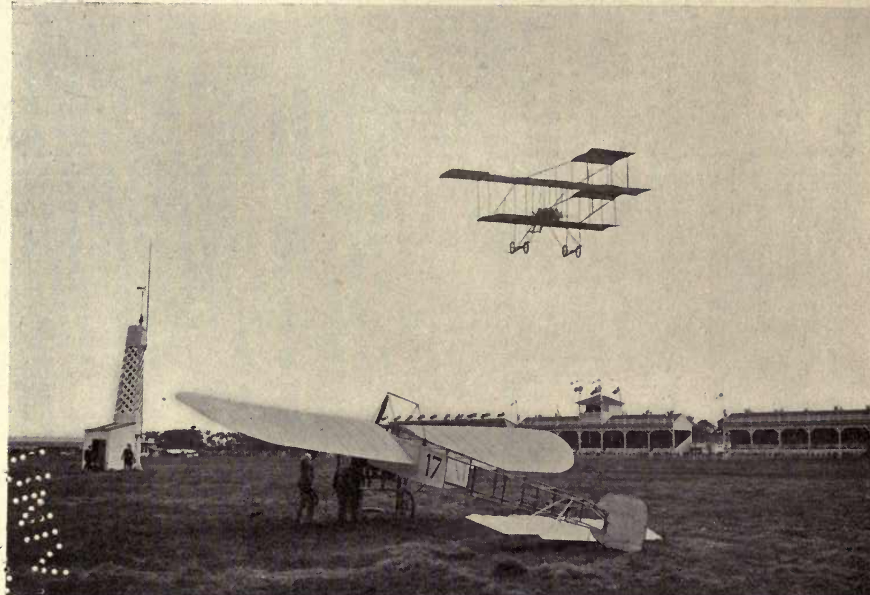
CHAPTER XIV

THE FLYING-MACHINE OF THE FUTURE

WHAT will the flying-machine of the future be like? He would be a wise man indeed who could predict with any degree of accuracy the exact form and dimensions of the coming aëroplane. The dreams of the old-time imaginative novelist seem almost to be realised now. Our more modern Kipling, looking back in his mind's eye at our feeble efforts, talks with scorn in the "Night Mail" of "the days when men flew wooden kites over oil-engines." Yet it is not likely that we shall graduate from that crude type for many years to come. A scientific forecast of the flying-machine's possibilities and its effect on human affairs must therefore be deduced from present aëroplane facts.

The aëroplane of our time is a thing of almost feathery lightness. In its construction the lightest and toughest woods and the smallest possible amount of metal must be used. As a result, it is wellnigh as delicate as a watch, and like a watch it must be handled with some care. Since the motor is the heaviest part of a flying-machine, it offers the most serious obstacle to the attainment of lightness. Because of the motor's necessarily small size its power is none too generous, and because of its delicate construction it breaks down with awkward ease. Hence it is safe to prophesy that the flying-machine of the future will be equipped with motors far higher in power than those at present in use.

It is probable that the future aëroplane will carry two motors, instead of one, each motor independently operative, so that if one fails, the other will still be able to drive the machine safely through the air. For military purposes at least, such a double-motor aëroplane is absolutely necessary. Imagine a spy in the air compelled to glide ignominiously down in an enemy's camp, because his engine failed him! Mere considerations of safety demand the installation of two motors on a flying-machine. In March, 1910, the French aviator Crochon fell to the ground in a cross-country flight from



Photograph by Edwin Levick

Fig. 81.—The machine in the air is a Farman biplane of the latest type. The machine on the ground is a Blériot monoplane

Mourmelon to Châlons, because his motor broke down. Le Blon was killed at San Sebastian on April 2, 1910, as a result of a similar motor trouble. During the Nice meeting in April, 1910, Chavez and Latham mercifully dropped into the Mediterranean, also because of motor trouble. All of these accidents might have been avoided if the aviators could have relied upon a second motor.

The aviator of the present day is somewhat in the position of a bicycle rider on a slack wire, armed with a parasol. He must exercise incessant vigilance, lest he lose his balance. The strain upon nerves and muscles, for the beginner at least, is tremendous. Hence, even now, we hear of automatic devices which will prevent the loss of a flying-machine's equilibrium and which will enable the aviator to soar in the sky more blithely than he can at present.

Balloonists find difficulty in ascertaining their location, particularly after descending from a cloud bank. It is true that the aviator can swoop down to the earth and find out where he is. Nevertheless, it is very likely that in the future he will be provided with charts and instruments which will obviate that necessity, — charts which will indicate landmarks and instruments which will indicate the angle of the flight path and which will include convenient field glasses and day and night signalling devices. Needless to say the aviator will carry a compass, probably a prismatic compass from which directions can be taken with great accuracy so long as fixed objects on the earth are visible. No doubt the compass will have a dial covered with luminous material, visible in the dark. At night a trailing-line will be cast overboard, fitted with some electrical indicator, which will ring a bell if some object should be struck, to warn the pilot that he is flying too low. The German Aërial Navy League has proposed that special beacon lights be erected at certain points. The aviator of the future will certainly need some such guidance if he flies by night, — some light which will send a long beam in the direction in which the wind is blowing.

Two men at least will be carried by the aëroplane of the future, — one to look after the controlling mechanism and the other to navigate. The military aëroplane will surely be so manned; for one man alone cannot perform the duties of mechanician and observer.

Explorations into unknown lands will be robbed of their perils by the flying-machine. The hummocks of the Arctics, the jungles of Africa, the morasses of a country untrodden by the foot of man can hide nothing from the exploring aviator. Tasks which formerly occupied years for their achievement will henceforth be accomplished in as many months, weeks, or even days. If Lieutenant Shackleton found the motor-car of service in Antarctic exploration, what shall be said of the flying-machine which speeds on its journey unimpeded by mountains of snow or grinding pack-ice? The character of the information gathered by the future explorer-aviator will be of greater scientific value than that which is at present so painfully collected. A Livingstone or a Stanley chopping his way through dense tropical vegetation brings back no complete map of the region traversed. All that he can show is his itinerary, — a mere fringe of the new country. Mountains and rivers he indicates rather than charts. Instead of crawling over the face of our planet, the sky-explorer will some day survey it from a height. He will see his Africa or Asia or India spread before him like a map. His eye will sweep an area measuring hundreds of square miles in extent. The camera will record those topographical peculiarities which he came to note, and he will be spared the necessity of imperilling his life to discover the source of a river or the secret of some Tibetan Forbidden Kingdom.

So far as actual appearance goes, the opinions of present-day flying experts differ as to the flying-machine of the future. Mr. R. W. A. Brewer, an English authority, sees a larger and a heavier machine than we have at present, a kind of air yacht, weighing at least three tons, and built with a boat-body. The craft of his fancy will be decked in. It will carry several persons conveniently and will be provided with living and sleeping accommodations. He prophesies that it will fly at speeds of one hundred and fifty to two hundred miles an hour, for the reason that high speeds in flying, according to some authorities, mean less expenditure of power than lower speeds. Mr. F. W. Lanchester, as we

Photograph by Edwin Levick

Fig. 82.—Sommer biplane

have pointed out in a previous chapter, entertains similar views on the necessity of high speed. If it is ever possible for an aëroplane to travel at such terrific velocities, whole continents will become the playgrounds of aviators. Daily trips of one thousand miles would not be extraordinary. It is even conceivable that there will be aëroplane liners which will travel from Europe to America in twenty-four hours.

It seems certain that special starting and alighting grounds will be ultimately provided throughout the world. If tramcars must have their stables and their yards, it is not unreasonable to demand the provision of suitable aëroplane stations. Depots or towers will be erected for the storage of fuel and oil, — garages on stilts, in a word. The aviator in need of supplies will signal his wants, lower a trailing line and pick up gasoline by some such device as we now employ to catch mail sacks on express trains.

It may well be that the advent of the flying-machine will have a marked effect on our architecture. Some day houses will be provided with landing stages, assuming that the aëroplane will be able to alight more easily than at present and without the necessity of running along the ground for some distance before it expends its momentum. Ely's remarkable feat in landing on the deck of a warship in the harbour of San Francisco shows that the thing is not remotely possible. When that day dawns, roofs will disappear in favour of flat terraces suited for launching and landing. A business man instead of travelling in a lift from the ground floor of a building to his office on the twenty-first floor, will start from the roof of the building and proceed downward.

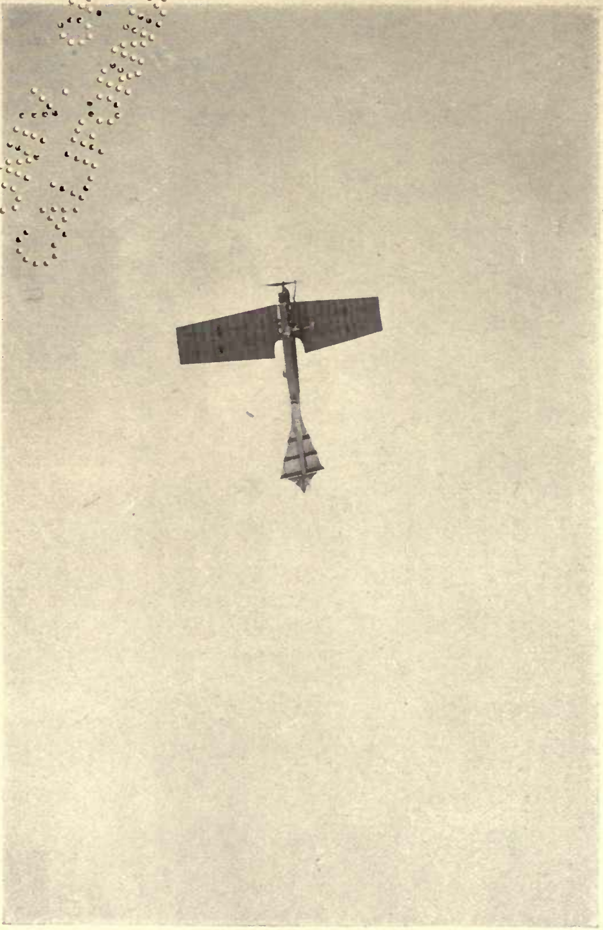
Above all things, flying must be safer than it is now. Although the dangers of a sport will inevitably attract to it adventurous spirits, a really commercial machine must satisfy the requirements of the highly nervous man or woman to whom sailing a yacht seems a suicidal pastime.

The early days of the bicycle and the automobile industries offer a close parallel to the present position of the aëroplane industry. The pioneers having shown the way, the machine immediately became an instrument of sport. Speed was the thing first desired, and the speed of anything that moves can best be demonstrated in a competition. Bicycle and automobile races became and still are, to some extent, the manufacturer's opportunity of testing and demonstrating the quality of his machines. Long before the manufacture of either touring bicycles or touring automobiles assumed their present proportions, the production of the racing machine was all important. The flying-machine is now in this stage. Races and endurance tests will be the battles from which will emerge the flying-machine of the future, — the machine capable of sustained flights, many hours in duration, at speeds of eighty and one hundred miles an hour. The racer will give birth to the touring flyer, just as the touring car of to-day was evolved from the racing car of five years ago.

Incredible as it may seem, in less than a year from the date when Blériot flew over the English Channel, a feat which set France aëroplane-mad, the actual sales of flying-machines outnumbered the actual sales of automobiles in the first year of their commercial development.

A flying Frenchman clamours for his Blériot or Farman as impatiently as an automobiling American millionaire for his high-powered car, ordered months in advance. The one is no more inclined to bide his time than the other. Hence agents have sprung up in Paris, who order machines from the manufacturer on speculation, and receive as much as $500 to $1,000 above the factory price for immediate delivery. In Paris at least such signs as "*Bouvard et Pecuchet, Agents pour Monoplanes Antoinette*" can be seen even now, — the harbinger of a great industry of the future and of flying-machine quarters in our large cities.

Compared with the flying-machine of the future, the motor-car will seem as tame and dull as a cart, drawn by a weary nag on a dusty country road. Confined to no route in particular, unhampered by speed restrictions, the speed maniac can drink his fill in the high-powered monoplane. Even the most leisurely of air-touring machines will travel at speeds that only a racing automobile now attains, while the air racer will flit over us, a mere blur to the eye and a buzz to the ear. In an hour or two a



Photograph by Edwin Levick

Fig. 83.—The 100 horsepower Antoinette monoplane that Hubert Latham flew at Belmont Park during the International Aviation Tournament of 1910

whole province will be traversed; in a day a whole continent. An air tourist, a few years hence, will breakfast in Paris and sup the same evening in Moscow. His air-charts, the equivalent of our present road automobile maps will be an atlas, a book in which the air-routes of all Europe are laid down. Swifter than any storm will be his flight. If the black, whirling maëlstrom of a cyclone looms up before him, he can make a detour or even outspeed it; for the velocity of his machine will be greater than that of the fiercest of howling, wintry blasts. At a gale which now drives every aviator timorously to cover, he snaps a contemptuous finger, plunges through it in a breathless dash and emerges again in the sunshine, as indifferent to his experience as a locomotive engineer after running through a shower.

The aspect of the heavens will be wonderfully changed when the pleasure plane of the air has arrived. Black specks will dot the blue sky, more like birds than machines, specks that the practised will recognise as impetuous and daring high flyers. Lower down the less reckless will perform their evolutions, and the whirr of their motors will be as the droning of bees, so numerous will they be.

All this deals with the sport. Has the aëroplane no mercantile future? Shall we see flocks of gigantic artificial birds, freighted with heavy cargoes, darkening the sky as they wing their way across the Atlantic or the continent? Will travelling by steamship and railway give way to the aëroplane?

The most sanguine aëronautic engineer would not venture to predict the supplanting of the freight train or the steamer by the aëroplane. For many, many years to come the flying-machine will remain what it is now, a vehicle of sport and war only. Perhaps it may never be anything more. Why? Because it cannot be made big enough. The carrying capacity of an aëroplane depends on its spread of plane. To increase the load means so important an increase in spread that an unmanageable area of supporting surface would be necessary. In order to secure the necessary strength to uphold this increased area an increased weight per square yard is entailed. Hence it is unlikely that aëroplanes carrying many passengers will be built in our time. Not so very long ago Mr. Orville Wright expressed the opinion that aëroplanes "will never take the place of trains or steamships for the carrying of passengers. My brother and I have never figured on building large passenger-carrying machines. Our idea has been to get one that would carry two, three, or five passengers, but this will be the limit of our endeavours."

The late Prof. Samuel P. Langley discovered in the course of his classic experiments that the higher the speed at which a plane travels through the air the less is the supporting surface required. Hence there is a chance that a machine may be constructed in the future which, taking advantage of this law, will be provided with a supporting surface adjustable in area, so that it can start with a large surface, and fold up its planes at full speed. In such a machine the supporting surface would be ultimately reduced until it is a thin edge. We would have an aëroplane propelled by great power, supported largely by the pressure against its body, its wings reduced to mere fins, serving to guide its motion.

As a future commercial possibility, the airship is far more promising than the aëroplane. To the size of the airship there is no limit. Indeed, the larger it can be built the more economically can it be driven, when we measure economy by ratio of carrying power to cost of operation. Just how large an airship can be constructed is a question of constructive engineering. In considering that question the late Prof. Simon Newcomb pointed out that economy is gained only when the dimensions of an airship are so increased that it will carry more than an ocean steamer or a railroad train. To attain that end he estimated that it would be necessary to build an airship at least half a mile in length and six hundred feet in diameter. Such an airship might carry a cargo of ten thousand tons or fifteen thousand passengers. The construction of so huge a craft is not an utter engineering absurdity, remote as it may seem to us now. We recently witnessed something like this when Count von Zeppelin's passenger-carrying airship made a voyage that excited the admiration of the world, even though the vessel was wrecked in a storm. Some fourteen passengers were transported on that remarkable trip, for whom adequate seating and dining accommodations were provided. But the cost of operating such a giant of the air is enormous.

After all is said, money will decide the question of the commercial possibilities of flying-machines and airships. How much does it cost to build? How much does it cost to maintain? How much does it cost to operate? Not until these questions are answered satisfactorily can we tell whether or not the aëroplane will ever be anything more than a racing machine for gilded youth and the dirigible an air-yacht for bankers too old for the more perilous aëroplane.

CHAPTER XV

THE LAW OF THE AIR

It is one of the most difficult tasks of government to adapt existing laws to those incessant changes in the relationships of nations and individuals which are brought about by the invention of new arts and industries. The railroad, the telegraph, the telephone, and wireless signalling have each given the legislatures of the world no little concern in developing codes which would enable the new inventions to take their place in our daily lives without too greatly disturbing vested rights.

Englishmen and Americans are fortunate in having a common law, which, although based upon custom and precedent, is nevertheless so flexible that it is able to adapt itself to the new conditions which the flying-machine will create. To supplement whatever shortcomings the common law may have, there can be no doubt that special statutes will be passed in this country and England to define the relations of the airmen to people on the earth below. European nations develop their laws more consciously. They even anticipate conditions that may arise by the introduction of a new invention. Thus we find that continental jurists have given consideration to questions of such detail as the nationality to be ascribed to persons born on board voyaging air-craft, rights in respect of salvage, and other doctrines drawn from maritime law. Twenty years hence it will be interesting to compare Anglo-Saxon air-laws evolved from custom and actual experience, with the air-laws of the continent, many of them enacted before aërial navigation was really established. The mere fact that aëroplanes and airships plough the air above us is in itself a circumstance that gives rise to a new legal situation. As Professor Meli of Zürich has put it, a careful man must now look not simply in front of him and on either side, but above him as well.

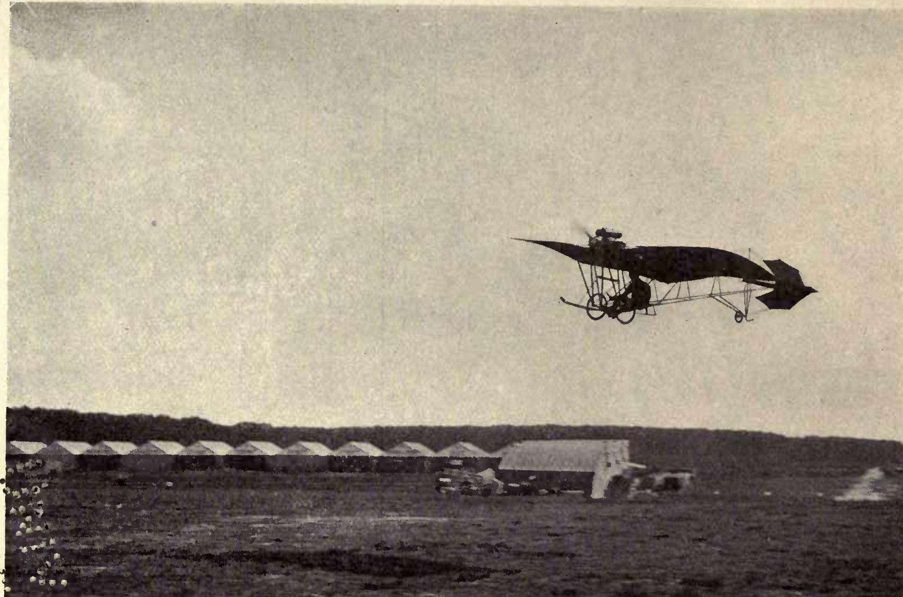
Has the airman any inherent right to navigate the air at all? That is the first question that must be decided by civilised countries, whether they be Anglo-Saxon, European, or Asiatic. The question of an inherent right must be considered both from the standpoint of the private property owner and from the standpoint of international law.

Even among lawyers the old saying that to the owner of a piece of land belongs not only the earth beneath his feet to the very centre of the globe, but the air above his property to an infinite height, is regarded as a basic principle of the English common law. Yet, to use the words of Brett, Master of the Rolls, in the case of Wandsworth Board of Works *v.* United Telephone Company, (1884) 13 Q. B. D. 904, this old maxim is at best a "fanciful phrase." The maxim can be traced to Coke upon Littleton and to Blackstone. In all the vast body of decisions on which the English common law is based, there can be found none in which the ownership of the air to a height above that at which a property owner could make reasonable use of it, is the point at issue. It is true that Coke's old saw and its reiteration by Blackstone have been approved in many a dictum; but dicta are not decisions. If the doctrine were really good common law, every man who sailed over the land of another would be a trespasser. Suppose that an action were brought to collect damages for trespass. It is hardly likely that even nominal damages could be recovered, for the simple reason that no injury has been worked to the landowner's estate and no nuisance has been created. Decisions enough can be found to justify the action of trespass in all cases of encroaching signs, buildings, trees, overhanging telegraph and telephone wires; but in all these cases the defendant's possession and the use of the land have been interfered with. It may well be concluded that rights in the air must be strictly appurtenant to the soil beneath, and that unless a reasonable use of the land is interfered with, no action for trespass will lie.

The actual interference with the enjoyment of the land as the sole justification for legal action is fully recognised in Europe. Even before the advent of the flying-machine and the airship the code of the Canton of Grisons provided that "property in land extends to the air space (above) and the earth beneath, so far as these may be of productive value to the owner." In the German Civil Code the rights of the airman are recognised in a clause in which the property holder "cannot prohibit such interferences undertaken at such a height or depth that he has no interest in the prevention."

It is probable that one of the first of the future laws of the air will fix the height at which air-craft must travel. In all likelihood the aëronaut will be compelled to sail at a height not less than fifteen hundred feet over inhabited districts and navigable inland waters, leaving him free to fly at any height he pleases over wildernesses and the high seas. A man who sails over a city not only takes his own life into his hands, but also endangers the lives of others, because he cannot readily alight should his motor fail him. The French advocate, Fauchille, has therefore proposed a law which will forbid flying over communities without the permission of the authorities.

That an action can be brought against an aviator who alights upon a piece of land without the owner's permission, even though he be compelled to do so against his will, is even now well established. In a New York case (Guille *v.* Swann, 19 Johns. 381; 10 Amer. Dec. 234) decided in 1822, an aëronaut was held respon-



Photograph by Edwin Levick

Fig. 84.—The Santos-Dumont "Demoiselle" in flight

sible not only for the direct damage caused by the descent of his balloon into a garden, but even for the remote damage caused by the crowding of strangers upon the property to satisfy their curiosity. Such unpremeditated descents will be frequent in coming years. The obvious necessity of sometimes alighting against one's will demands some law which will enable the airman to land without necessarily incurring a suit for damages or imprisonment. Judge Simeon Baldwin questions whether it will not be advisable to prescribe a mode of indicating where a landing is prohibited and where it is permitted. If, for instance, a red flag were made the sign of prohibition, it may fairly be provided, in his opinion, that to land in the face of such a warning the aviator subjects himself to an action for double damages, enforcible by his arrest. The Berlin Conference relating to wireless telegraphy imposed on all coast and shipping stations the duty of exchanging wireless messages, regardless of the system employed. A similar arrangement would probably apply to the right of air-craft to use local areas set apart for alighting, mooring, and embarkation. It would seem that a distinction should be made between an accidental landing, which is due to negligence and which causes damage, and a landing which is made with all due care in order to save the airman from death. In the one case a penalty of some kind should be imposed, but in the other the airman should be allowed to escape by simply paying the amount of the actual damage which he has inflicted. Judge Baldwin has even raised the question whether the law of self-preservation cannot be invoked by an airman who is compelled to make an immediate landing to save his own life and by so doing accidentally causes the death of another.

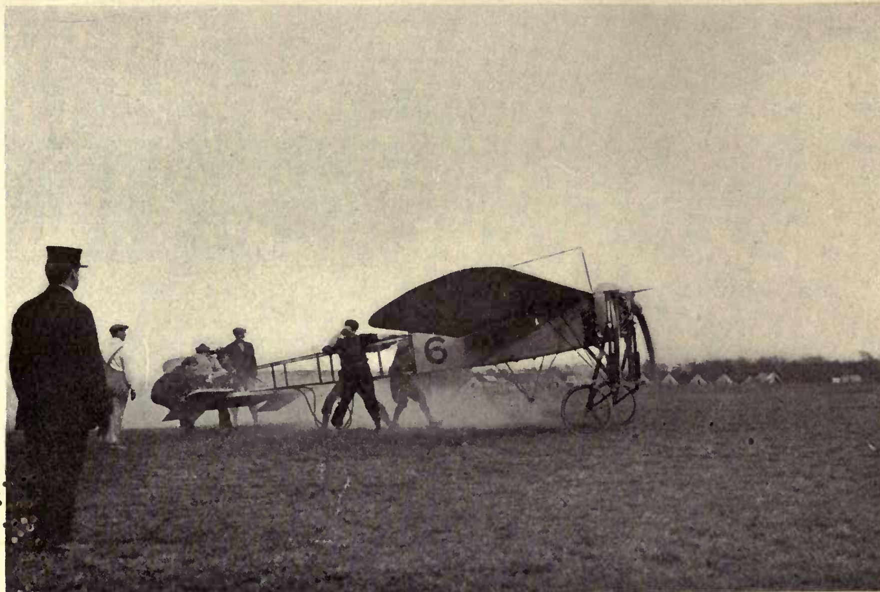
It is certain that in order to reduce the possibility of accidents to a minimum only a licensed pilot will be permitted to navigate the air in the future. Judge Baldwin advises that the government issue such licenses only on the filing of a proper indemnity bond for the benefit of those who may suffer such accidents. He has pointed out that the same result could be obtained by compelling the owners of aircraft to take out blanket policies of accident insurance, covering all injuries occasioned by the use of the ship and authorising the injured to bring suit upon it in the name of the insured, but for their own benefit.

In European countries a tendency is shown to subject air navigation to the monopolistic control of the state. In the United States and in England private enterprises will have a freer hand, subject, of course, to strict governmental supervision by registration, license, and inspection. But shall such a government license issued in one state or country be respected in another? There seems to be no good reason why it should not. Automobile licenses are so respected for a limited number of hours. Treaties and agreements will undoubtedly be drawn which will secure the recognition of air licenses by foreign governments. But to harmonise the aëronaut's rights with those of other men and those of foreign lands over which he may take his course, demands not only adequate local legislation but adequate international agreements. Professor Meli of Zürich, in a recent address before the International Vereinigung für vergleichende Rechtswissenschaft of Berlin, strongly advocated the convening of an international conference for this purpose. Such a conference was held at Paris in 1910, but accomplished very little in the way of practical results. The British Government demanded more time for consideration before approving the measures of the Conference.

Although every reasonable concession will be made to the man who builds and flies air-craft, it must not be supposed that those below are altogether at the mercy of the man in the air. Every moment of an atmospheric voyage is fraught to some extent with danger to those below. If actual physical injury is sustained by a man on the ground, the civil or criminal courts may be appealed to for justice. The man who is wounded by an object dropped from an air-craft certainly has a right of action for damages, whether or not he be the owner of the land upon which he happens to be standing at the time. The master and servant rule would apply here as well as in other cases. An action for damages would lie against the pilot of the flying-machine, whether he be the owner of the craft or not, or the master by whom he is employed. It is even conceivable that an injunction could be obtained to abate a nuisance caused by a fleet of air-craft travelling in a defined roadway day after day and week after week, so as to annoy a tenant or a property holder by their noise, odours, exhaust, and the like.

Besides these rights of the man below, whether he be a landowner or not, there are broader national questions to be considered. In a sense the state is the ultimate owner of the soil, and as such it has the right to regulate the air above its territory, and to state the conditions under which it will permit the navigation of the air. That air-craft will sooner or later become the subject of governmental regulation and authorisation seems almost self-evident when we consider the history of the railroad, the telegraph, the telephone and wireless telegraphy. In the United States the individual states will regulate the air-craft that ply the air wholly within the state; the federal government those vessels that travel from state to state.

The international aspects of the question are somewhat more difficult to dispose of. Before the American Political Science Association, Mr. Arthur K. Kuhn suggested that the right of the craft of one nation freely to traverse the air-space of another might be compared with that of the vessel of one state freely to navigate the river of a coriparian state, especially when the river becomes navigable within its own territory. Dr. Hazeltine, reader in English law at Cambridge, believes, however, that the analogies of the high seas and the maritime belt of coastal waters as applied by advocates of limited sovereignty are far from being sound and applicable. Still it is not unlikely that, in settling the international problems that must inevitably arise in the future, some of the principles of maritime law will be applied to the navigation of the air. Because the airship, and to a lesser degree the aëroplane, may be an instrument of commerce as well as a ship sailing the high seas, Judge Baldwin has suggested that provision must be made for ship's papers; that the number of passengers to be carried on an air vessel must be fixed; that the qualifica-



Photograph by Edwin Levick

Fig. 85.—A Blériot racing monoplane. Six men are exerting every muscle to hold back the machine

tions of those in charge must be determined; that machinery must be inspected; and that pilotage must be provided for.

Freedom of the seas is based on the impossibility of an effective control by any one state. It has been urged by one school of German advocates, among them Meurer, Holtzendorff, and Grünwald, that the air-space over a state is an appurtenance of it, and as such the right to navigate it is not as free as the right to navigate the high seas. By another school the relation of the state to its overlying air-space is compared with that of its coastal waters. The abortive Convention drafted by the International Conference on Aërial Navigation of 1910 was based entirely upon the provisions of international maritime law. There are the same requirements as to registration and nationality of air-vessels, certificates of fitness of the craft and the competence of its navigators and navigation in territorial waters — using the maritime phrase for the sake of convenience — and the same regulations applying to the sojourn of alien craft in distress. It is laid down that aërial navigators must keep a very detailed log, giving the names, nationality and domicile of all persons on board, and embodying a record of the course, altitude and all the events of the voyage. This log must be preserved for at least two years from the date of the last entry, and must be produced on the demand of the authorities. Each state would have to exercise the right of police and customs supervision in the atmosphere over its territory. It would have power to regulate passenger and goods traffic between points in its own territories, and it could prohibit navigation in certain zones of reasonable extent, indicated with sufficient precision to permit of their being shown on aëronautical charts. There is such a thing as a three-mile limit in maritime law, a limit originally set by the range of a cannon. Why then, we are asked, should there not be sovereignty within a certain zone, the height of which is determined by gun fire? The analogy and the rule resulting from it were strongly supported by Westlake before the Institute of International Law; but they were rejected in favour of a negative sovereignty, saving the right of self-protection. The range of Krupp ordnance, which has been especially designed for airship repulsion, would no doubt aid in determining the height of such a zone. Holtzendorff, Fauchille, and Rolland would restrict absolute sovereignty within a zone of isolation varying from three hundred and thirty metres (the altitude of the Eiffel Tower as the highest artificial object) to fifteen hundred metres. The topography of the earth is in itself a sufficient objection to that proposal. Dr. Hazeltine has expressed the view that any theory of sovereignty limited in height is open to the same objection as the theory of a zone of protection in which free passage is allowed to non-military craft. In his opinion the state should have full, sovereign dominion in the entire air space above its territory. Furthermore, he maintains that the recognition of each territorial state's full right of sovereignty in the air space above it would constitute a basis for the future development of national and international aërial law, leaving, as it would, to aërial navigators as well as states and their inhabitants the full legal enjoyment of their proper interests.

A nation's sovereignty can hardly extend to a domain that it cannot defend from invasion. When Balboa stood upon a peak in the Andes and, surveying the Pacific, claimed in the name of Spain all the land that its waters might wash, he was as ridiculous as he was grandiloquent. Even in that age of limited geographical knowledge he must have felt that his country could never uphold the claim by force of arms. To be sure, it would be easier for a nation to defend all the air-space above its territory than to restrain encroachments upon land washed by the waters of a vast ocean. The maximum height at which air-craft can sail may be placed at about five miles, with the probability that the average height will be about one mile. It would not be a task of extraordinary difficulty for any nation equipped with a formidable aërial navy to police its air-space more or less effectively. Whatever zone is adopted, self-interest alone will impel each state to grant access to and passage through its air-space in time of peace, subject only to such rules as its reasonable interests may require. As to the liberty to navigate the air, the following rule was accepted at the International Conference of 1910:

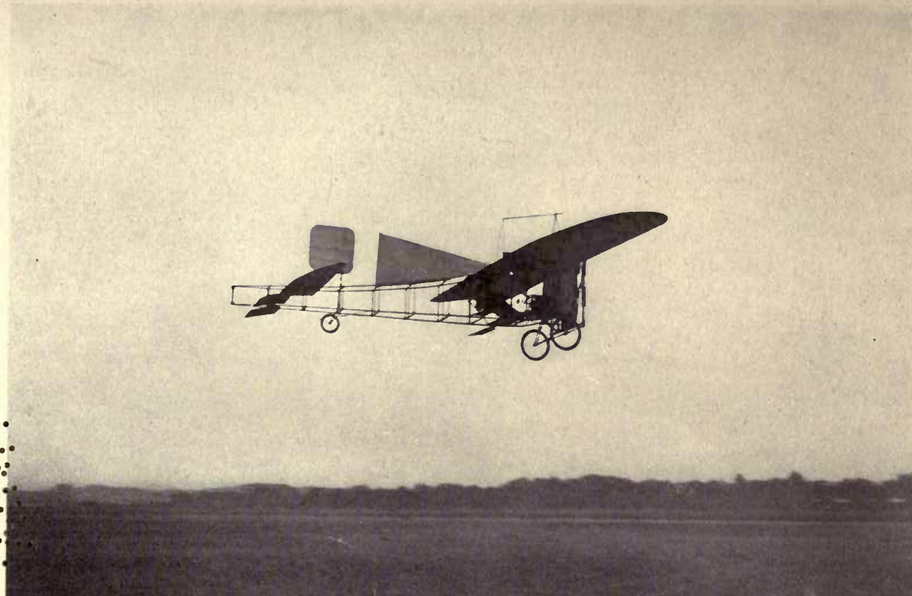
"Each of the contracting States shall permit the navigation of the airships of the other contracting States within and above its territory, reserving the restrictions necessary to guarantee its own safety and that of the persons and property of its inhabitants."

The restrictions referred to relate chiefly to the question of certain zones, over which, if they are properly indicated in advance, no airship may fly unless compelled to by necessity. If an aëroplane is carried by accident or by adverse air conditions over an interdicted zone, it must descend at once and indicate its disability. It must also descend if signalled to from the earth.

The matter of jurisdiction over crimes committed by airmen or their passengers is likewise a matter of international concern. Fauchille has proposed that crimes committed on air-craft "fall under the competence of the tribunals of the nation to which the air-craft belongs." American and English lawyers will object to any such principle because Anglo-Saxon law has always been territorially administered. Probably concurrent jurisdiction will be agreed upon, as in the case of crimes committed on foreign vessels in territorial waters.

Besides crimes committed on air-craft, there are also crimes committed on the ground which involve the rights of airmen. Balloons have been shot at in pure wantonness. Jurisdiction in such cases obviously belongs to the country in which the firearms were discharged. If a man is killed in a flying-machine in the United States by a bullet discharged over the border-line in Canada, there is no reason why murder has not been done in the United States and why the murderer should not be extradited and tried in a United States court.

Lastly, there remains to be considered the legal status of the airship and the aëroplane in time of war. Balloons were used in war long before the dirigible airship or the aëroplane were brought to a state of practical perfection, but they never played so conspicuous a part in military operations that it was necessary to define their status according to the principles of international law. It is true that Bismarck said that an Englishman who manned a French balloon would be subject to arrest and trial



Photograph by Edwin Levick

Fig. 86.—The Blériot monoplane XII. This is a passenger-carrying type. The pilot and his companion sit side by side below the wings

"because he had spied out and crossed our outposts in a manner which was beyond the control of the outposts, possibly with a view to making use of the information thus gained to our prejudice." That dictum of blood and iron seems much too drastic even to German commentators. A spy is supposed to act clandestinely. An air-craft is so conspicuous an object that even though bent on ascertaining the enemy's strength and the disposition of its forces, its errand can hardly be secret. On the other hand, Mr. Kuhn has pointed out that the impossibility of flying secretly by day, at least, is in itself no reason why the use of the air-craft may not be clandestine. The Hague Peace Conference in 1907 left the matter in a very unsatisfactory condition. It provided that aëronauts were not to be regarded as spies if they carried despatches or maintained communication between different parts of an army or territory, but it failed to fix the status of the reconnoitring airman. In the war of the future the aëroplane and the airship will perform much the same function as a cavalry reconnaissance in force; yet even Bismarck would not have shot as a spy a trooper captured on a scouting raid. The international complications which may arise even at the present time will undoubtedly be considered when the next Hague International Conference takes place. The possibility that an alert military spy, floating serenely over a fortress which has cost a nation millions, may photograph or sketch every battery, manifestly necessitates the adoption of some restrictive measures. So jealously are many of the fortifications of Europe guarded from the watchful eyes of spies, that entry within their portals is granted only on certain conditions. No cameras may be taken within the lines; nor is admission granted without credentials. What a spy on land might be unable to discover in months by cunning, cajolery, and bribery, will be exposed to an aëronaut in half an hour. Some check must therefore be placed upon the scout in the air. At the International Conference on Aërial Navigation of 1910 it was proposed that a state should have the privilege of developing photographic negatives found on board an airship coming to earth in its territory, and if necessary to seize them and the photographic apparatus. Wireless telegraphic instruments, too, could not be used, according to another provision, without special permission, for any other purpose than to secure the vessel's safety. Perhaps, although no International Conference has thus far suggested it, the pilots of the future will be constrained to avoid fortifications entirely, or run the risk of arrest by air sentry, — military lookouts gliding along in aëroplanes ready to act if a too closely approaching atmospheric tourist appears. Arrests will undoubtedly be made by these sentinels in the air; the captured aëronaut will be asked for his credentials and will be searched for sketches that may implicate him. If he is caught red-handed, he will be punished — how, must be determined by international agreement.

The war of the future will be a conflict of aircraft as well as of infantry and artillery. How shall the aëroplane of any warring country be distinguished from those of any other? Every ship on the high seas, whether it be merchantman or battleship, flies the flag of its country, — a challenge to its foes in time of war, a badge of peace to its friends. The question of nationality brought up some interesting points during the International Conference of 1910. It was decided that it should be determined by the nationality of the owner or by his domicile. It was also voted that:

"A State may require its subject to be at the same time domiciled on its territory, or it may admit domiciled foreigners as well as its subjects. Airships belonging to companies must take the nationality of the State in which their head office is situated. In the case of an airship belonging to several owners, at least two-thirds must be owned by subjects of, or foreigners domiciled in, the State conferring nationality."

The Swiss delegates protested that this article would permit the establishment of many foreign airships in one nation without the supervision of their own, and then drew attention to a suggestion already made by them that no nationality be attributed to airships, but that each airship be compelled to acknowledge a "certain port of register or domicile." This system, the Swiss believe, "offers, from the point of view of the safety of States, guarantees very superior to those secured by the system of owner's nationality." But the Swiss proposal was rejected.

Fully as important as these considerations are the rights of neutral air-craft in time of war. If France and Russia are at war, has Germany the right to prevent the vessels of either nation from crossing her boundaries because her neutrality is violated? The right of exclusion is absolute, if no neutral zone be agreed upon internationally. But if a free zone be agreed upon, the aërial equivalent of the maritime three-mile limit, have belligerents the right to engage in battle over neutral territory with a possibility of injuring those below? There is such a force as gravitation and with that force airships and aëroplanes must constantly reckon.

Will the air-craft that seeks refuge on neutral ground or in neutral air be compelled to leave within a stipulated time, as in the case of a warship that seeks refuge in a neutral harbor? Will an air-craft so badly injured that it cannot leave, even when ordered to do so, be disarmed?

The military reports of the question were discussed at the International Conference of

1910, but more with regard to the status of air-craft in time of peace than in time of war. The departing or landing of military airships of one state in the territory of another was prohibited, unless with the authorization of the state whose territory is involved; while each contracting state was at liberty to prohibit or regulate in accordance with its interests the passage over its territories of military airships belonging to other contracting states. A clause in the Convention relating to the extra-territoriality of military airships and their crews while within the limits of jurisdiction of a foreign state, appears not to have met with the full approval of the delegates of several Powers, Great Britain and Austria being among those who reserved their adhesion. The Convention stipulated that nothing it contained should interfere with the liberty of action of belligerents or with the rights and duties of neutrals. As bearing on this point, it is of interest that all the participating nations agreed that the aërial transport of explosives, firearms, ammunition, and carrier-birds must be forbidden.

GLOSSARY

Adjusting Plane or Adjusting Surface: A surface of small area for regulating lateral stability; usually located at the side edge or rear edge of a supporting plane. It is to be distinguished from an *aileron* (q. v.) in that it is capable of adjustment but not of independent movement by special operating devices.

Advancing Edge: See *Entering Edge.*

Advancing Surface: The forward supporting surface of a machine provided with supporting planes in tandem, as in the Langley aërodrome, or with superposed surfaces arranged in step formation.

Aërocurve: Any arched supporting surface. The term has been proposed because few supporting surfaces are true aëroplanes. See also *Aërofoil.*

Aërodrome: A term invented by the late Prof. Samuel P. Langley and used by him to designate an aëroplane flying-machine. Etymologically the term signifies "air-runner." It is more commonly used to designate a flying-course by analogy with "hippodrome." Mr. F. W. Lanchester and Dr. Alexander Graham Bell have sought to restrict the term to the use which Langley intended.

Aërodromics: Langley's term for the science and art of flying with an aëroplane flying-machine.

Aërofoil: The supporting surface of a flying-machine, coined, like *Aërocurve,* because the supporting surfaces of a flying-machine are not, strictly speaking, flat planes.

Aëronaut: One who navigates the air.

Aëronautics: The science of aërial navigation.

Aëronef: A term invented in France and introduced into English-speaking countries to designate any heavier-than-air flying-machine. The term is not much employed either in French or in English.

Aëroplane: Any plane surface propelled through the air. The term was invented before it was discovered that curved surfaces are better than flat surfaces. Hence it is not strictly applicable to modern supporting surfaces.

Aileron: A French word meaning "winglet," introduced into English to designate any freely swinging surface controlled by the aviator and designed to maintain lateral stability. Ailerons may be either tips hinged to the side edges or rear edges of the main supporting surface, or they may be small independent planes. See also *Adjusting Surface, Balancing Plane or Surface, Stabiliser,* and *Wing-Tip.*

Airship: A term originally employed to designate any aërial craft, whether heavier or lighter than air, but now restricted by the best writers to dirigible balloons.

Air Speed: The velocity of a machine in the air as distinguished from its velocity on the ground.

Airman: An aëronaut; one who navigates the air.

Alighting Gear: The wheels or skids or combinations of both on which a machine alights. See *Skids.*

Angle of Attitude: See *Angle of Incidence.*

Angle of Entry: The angle formed by a tangent to the entering edge with the line of motion.

Angle of Incidence: The angle made by the main planes with the line of travel. Sometimes called " angle of attitude " and " angle of attack." The angle may be positive or negative, depending on the direction in which the plane is turned to the line of flight.

Angle of Trail: The angle formed by a tangent to the rear edge with the line of travel in curved supporting surfaces.

Apteroid: Lanchester's term for a short, broad form of wing.

Arch: The downward curve or droop to the ends of supporting surfaces.

Aspect: The top plan view of an aëroplane flying-machine.

Aspect Ratio: The ratio of the length to the width of a plane or curved supporting surface.

Aspiration: The suction produced by a current of air which strikes a curved supporting surface.

Attitude: See *Angle of Incidence.*

Automatic Stability: See *Stability.*

Auxiliary Surface: See *Supplementary Surface.*

Aviation: Flight with heavier-than-air machines as distinguished from ballooning.

Aviator: The pilot of a heavier-than-air machine.

Balance: The maintenance of equilibrium by means of balancing surfaces. A distinction is sometimes made between *Balancing* and *Stabilising* (q. v.).

Balancing Plane or Balancing Surface: A surface for establishing and maintaining equilibrium as well as to assist in turning. Such surfaces may be operated either automatically or by hand; they maintain both longitudinal and lateral balance.

Beat: A periodically recurring movement in a propeller blade or in a wing of a flapping-wing machine.

Biplane: A flying-machine with two superposed supporting surfaces.

Body: See *Fuselage.*

Box-Kite: A kite invented by Hargrave and provided with two parallel vertical and two parallel horizontal surfaces in the form of an open box.

Brace: A compression member.

Camber: The curve of a supporting surface measured from port to starboard.

Caster-Wheel: A small wheel of the alighting gear, so pivoted that, like the caster of a chair, it automatically suits itself to the direction of the flying-machine's motion on the ground.

Carburetter: An apparatus by which air is charged with a hydrocarbon so that it will either burn or explode. In the gasoline flying-machine motor it serves the purpose of mixing the gasoline vapor with air in the right proportion to form an explosive when ignited.

Chassis: The under framework of a flying-machine.

Cell: An open box-like unit. Its parallel vertical and parallel horizontal surfaces serve to maintain stability.

Centre of Effort: The point in which the effect of an axially exerted force is theoretically concentrated, as, for example, the thrust of a propeller.

Centre of Gravity: A point in which the weight of a flying-machine is theoretically concentrated.

Centre of Lift: See *Centre of Pressure.*

Centre of Pressure: An imaginary centre in which the air pressure on a supporting surface is theoretically concentrated.

Centre of Thrust: See *Centre of Effort.*

Chord: The line connecting the ends of the segment of a circle.

Compound Control: A system of hand-levers and ropes or hand-wheels and ropes by which two controlling operations are simultaneously carried out with but a single operating device, as, for example, the single lever in a Wright machine, which serves not only to warp the main planes, but also to swing the vertical rudder at the same time.

Compression Side: The side of a surface, such as an aëroplane or air-propeller, which faces the flow of air current.

Curtain: A vertical plane, as in the Voisin cellular biplane, between the main planes, serving to insure a certain amount of lateral stability.

Diagonal: A diagonal brace in a framework.

Derrick: A pyramidal structure from the top of which a weight can be mechanically dropped in order to start a flying-machine in motion on a rail. Sometimes called a "pylon."

Dihedral Angle: The angle formed by two planes placed at opposite sides of a median line, so as to form a very wide "V."

Double-Decker: A synonym of biplane (q. v.).

Double Monoplane: A machine having two sets of supporting surfaces arranged in a single tier. Such a machine is also called a "following-surface" machine.

Double Rudder: A rudder having two surfaces of more or less similar surface and outline, which surfaces may or may not act simultaneously.

Doubled-Surfaced: Covering both sides of the framework of a supporting surface.

Drift: The resistance offered to forward motion of a plane or curved surface in the air by the horizontal component of the air pressure against the plane. It is to be carefully distinguished from mere head resistance (q. v.).

Elevator: The horizontal rudder of a flying-machine, used for steering in a vertical plane.

Entering Edge: The front or leading edge of an aëroplane.

Equilibrator: The tail of a flying-machine.

Equilibrium: In flying-machine parlance the term is used in the same sense as "stability." Properly speaking, an aëroplane is in equilibrium when travelling at a uniform rate in a straight line, or, again, when it is steered around a horizontal arc or circle. It is necessary for stability that if the aëroplane be not in equilibrium and moving uniformly it shall tend toward a condition of equilibrium.

Equivalent Head Area: The area which would offer head resistance equal to that of the supporting surfaces of a flying-machine plus the struts, stays, wires, chassis, etc.

Feathering: Said of surfaces which are manœuvred in a manner to pass edgewise and flatwise in alternate directions while in motion.

Fin: A rigid vertical surface which acts somewhat like the keel of a sailing yacht.

Fish Section: A section resembling in shape the body of a fish. Such sections are commonly found in flying-machine struts.

Fixed Wheel: In contradistinction to a caster-wheel (q. v.), a wheel that always preserves its relative position in the alighting-gear.

Flapping-Wing Flight: Flight by means of beating wings as distinguished from flight obtained by means of rigid aëroplanes. See *Ornithopter.*

Flexible Propeller: A fabric propeller, capable of adjusting itself in flight.

Flying Angle: Flying attitude. See *Angle of Incidence.*

Following Edge: The rear edge of an aëroplane surface.

Following Surface: The rear surfaces of two similar surfaces arranged in tandem.

Fore-and-Aft: Longitudinally.

Front Control: Front Rudder: The framework and planes situated at the extreme front of the aëroplane, in advance of the operator.

Fusiform: Spindle-shaped.

Fuselage: The framework or body of an aëroplane.

Gap: The distance between two planes in a multiplane machine.

Glide: To travel without power.

Glider: An aëroplane without a motor.

Gliding Angle: The angle at which a machine glides down without power.

Ground Attitude or Incidence: The difference in the angle formed by the aëroplane surface when on the ground and when in flight.

Guy-Wire: A wire connecting two members of an aëroplane, usually parts of the controlling system.

Gyroplane: A flying-machine with rotating planes. See *Heliocopter.*

Gyroscope: A freely-hung, rapidly-rotating fly-wheel, which resists forces that tend to throw it from its plane of rotation.

Hangar: A term said to be of Hungarian origin, now also used in English, to designate a shed for housing aëroplanes or airships.

Head Area: The total head resistance offered by the entire framework of an aëroplane.

Head Resistance: The resistance a surface offers to movement through the air.

Heavier-than-Air: A term applied to all air-craft not sustained by a buoyant gas.

Helicopter or Helicoptère: A heavier-than-air machine in which flight is secured by lifting screw propellers revolving in more or less horizontal planes.

Helix: The path of a point moving uniformly around a cylinder and uniformly along the cylinder.

Horizontal Rudder: See *Elevator.*

Keel: The under framing of an aëroplane to stiffen it both laterally and vertically. Sometimes used as a synonym of fin (q. v.).

Land Speed: The rate of travel of an aëroplane on the ground before ascension.

Landing Area: A special allotment of ground on which a machine can land safely.

Landing Skid: See *Skid.*

Lateral: A strut for sidewise bracing in the framework of an aëroplane.

Lateral Stability: Lateral equilibrium in the side-to-side direction.

Lattice Girder: A girder with many crossed members, resembling in appearance a lattice window.

Leeway: Lateral drift in the direction in which the air current is flowing due to the air current.

Lift: The ascensional force of an aëroplane surface.

Longitudinal Stability: Lengthwise stability.

Magneto: An apparatus for generating electric current to produce a spark wherewith to ignite the explosive mixture in the cylinder of an internal-combustion motor.

Main Plane: The largest supporting wing in a multiplane.

Mast: A spar or strut for fastening trussing wires or stays to stiffen the planes.

Monoplane: An aëroplane with one or more supporting surfaces, all in the same plane.

Monorail: A rail used as a track in starting some machines.

Multiplane: An aëroplane with more than one main supporting surface.

Nacelle: See *Fuselage.* In some monoplanes the enclosed, boat-like part of the body, containing the seat for the pilot and his passenger.

Negative Angle of Incidence: The angle formed by a plane inclined downwardly to the direction of travel.

Ornithopter, Ornithoptère, Orthopter, or Orthoptère: A machine which attains flight by bird-like flapping of wings.

Orthogonal Action: The vertical reaction of the air in affording equilibrium by means of wing motion.

Panel: The vertical planes in a box-like or cellular structure.

Pendular Movement: To-and-fro movement like that of a pendulum.

Phugoid: Lanchester's designation for the undulating course naturally adopted by plane surfaces when moving in the air.

Pitch: The forward movement that would be produced by one turn of a propeller in a solid.

Plane: Literally a flat surface; in aëroplanes a flat or curved surface.

Polyplane: See *Multiplane.*

Pylon: The tower required by some types of aëroplanes to start. Also, the pillars that mark a definite course to be taken by a flying-machine at a flying-machine meeting.

Radiator: A coil of piping or any circuitous conduit in which water is cooled by radiation after having circulated around the hot cylinder of an internal combustion engine.

Rarefaction Side: The side opposite the compression side, as, for example, the top of an aëroplane in motion.

Reactive Stratum: The compressed or rarefied layer of free air flowing along an aëroplane surface.

Rear Control: A stabilising tail surface which may also be a rear horizontal rudder.

Rising Angle: The maximum angle of ascension.

Rudder: A horizontal or vertical plane used for steering.

Runner: See *Skids.*

Screw: A propeller.

Single-Decker: A monoplane.

Single-Surfaced: Aëroplane surfaces covered only on one side. Compare with *Double-Surfaced.*

Skids: Runners underneath some types of machines, used for landing.

Skin Friction: The friction of the air against surfaces.

Slip: The difference between the pitch of a propeller and its actual forward travel.

Soaring Flight: Flight with rigid wings.

Spar: A strut, a brace, etc.

Stability: Maintenance of balance in flight by automatic devices such as a shifting weight or a gyroscope (q. v.); or hand-operated devices such as ailerons, wing-tips, and plane-warping devices.

Stabilise: To maintain equilibrium by means of surfaces and not by mechanism.

Stabiliser: The tail of a flying-machine.

Stabilising Plane: A surface for the maintenance of equilibrium; small horizontal planes hinged to the main planes, and suiting the angle of the wind.

Starting Frame: See *Chassis.*

Starting Rail: See *Monorail.*

Stay: A brace or wire in an aëroplane framework.

Steadying Vane: Small vertical planes, usually placed in the front control of the old Wright machine.

Straight Pitch: In propellers, a flat instead of a helical blade surface.

Strainer: A turnbuckle.

Strut: A compression member in a structure. In biplanes the posts separating the main planes.

Supplementary Surface or Auxiliary Surface: A small surface such as an aileron or wing-tip, which acts in unison with a larger one for a specific purpose.

Supporting Surfaces: The main planes.

Tail: A collective term for the framework and planes in the rear of the main plane.

Tail Planes: The rear planes supported by the tail framework.

Tail Wheel: A small wheel under the tail of some machines to support the tail on the ground.

Tie: A tension member in a framework; used also for wire stays.

Tractor Screw: A propeller set in front of the supporting surface instead of in the rear, so that the machine is drawn through the air and not pushed.

Triplane: An aëroplane with three superposed supporting surfaces.

Turnbuckle: A combined right and left-hand screw for taking up the slack in a loose wire stay.

Up-Wind: Moving against the wind.

Variable Pitch: In propellers, a varying angle of blade width in contradistinction to uniform pitch.

Vol-Plane: See *Glide.*

Wake: The wash of an aëroplane in flight.

Warping: The act of twisting a plane for the maintenance of equilibrium.

Wash: See *Wake.*

Wing Arc: The arc described by a moving wing.

Wing-Bar: A longitudinal strip so placed as to strengthen an aëroplane surface.

Wing Section: The longitudinal curvature with relation to the arc of travel.

Wing-Skid: A runner under a wing-tip.

Wing-Tip: The hinged outer side of a plane.

Wing-Wheel: A wheel under a wing-tip to support the wing when the machine strikes on the ground.

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