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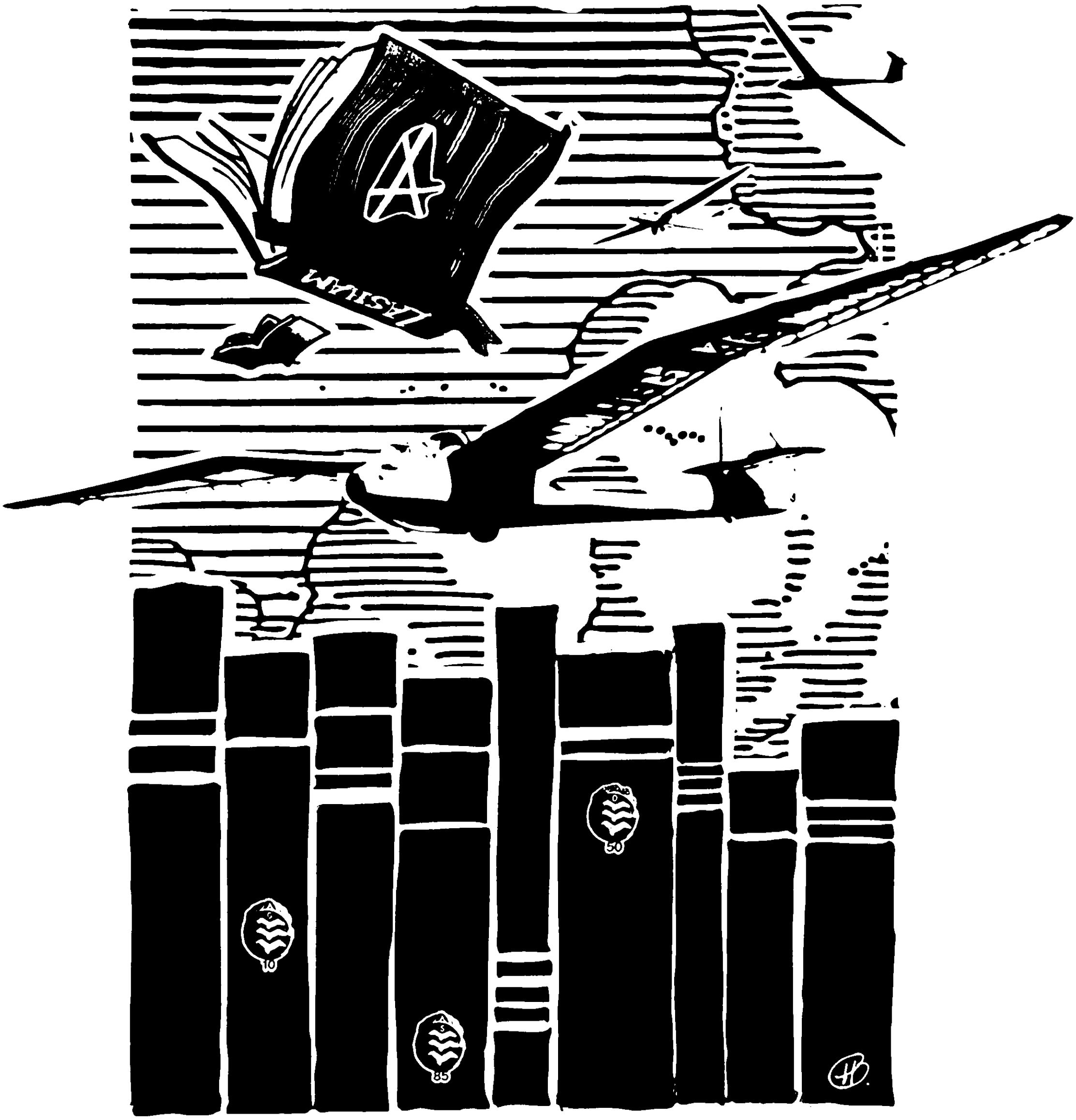

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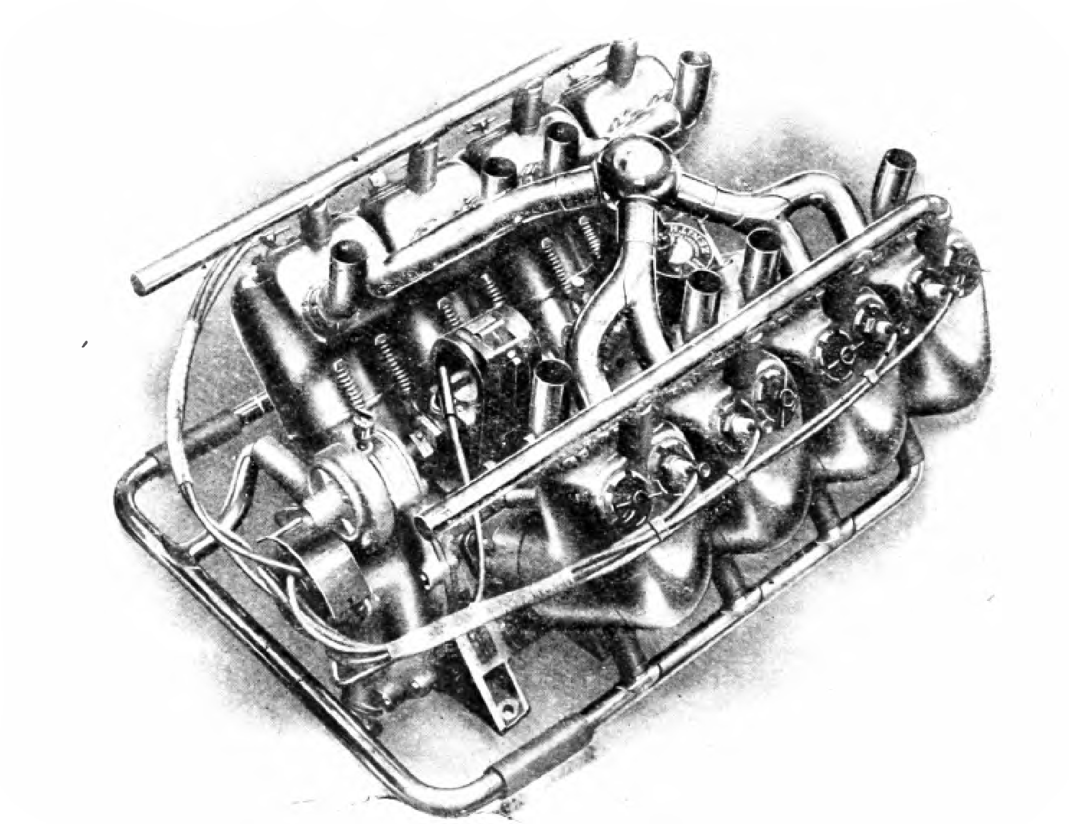


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AERO MANUAL

A MANUAL OF MECHANICALLY-PROPELLED HUMAN FLIGHT, COVERING THE HISTORY OF THE WORK OF EARLY INVESTIGATORS, AND OF THE PIONEER WORK OF THE LAST CENTURY. RECENT SUCCESSES, AND THE REASONS THEREFOR, ARE DEALT WITH, TOGETHER WITH MANY CONSTRUCTIVE DETAILS CONCERNING AIRSHIPS, AEROPLANES, GLIDERS, Etc.

Compiled by the Staff of "The Motor."

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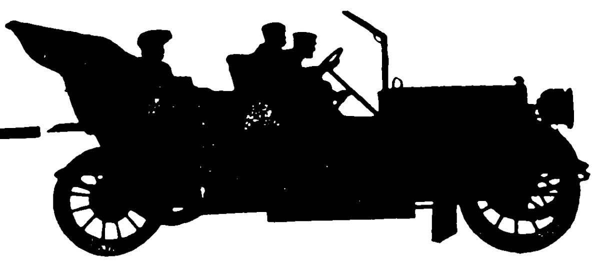

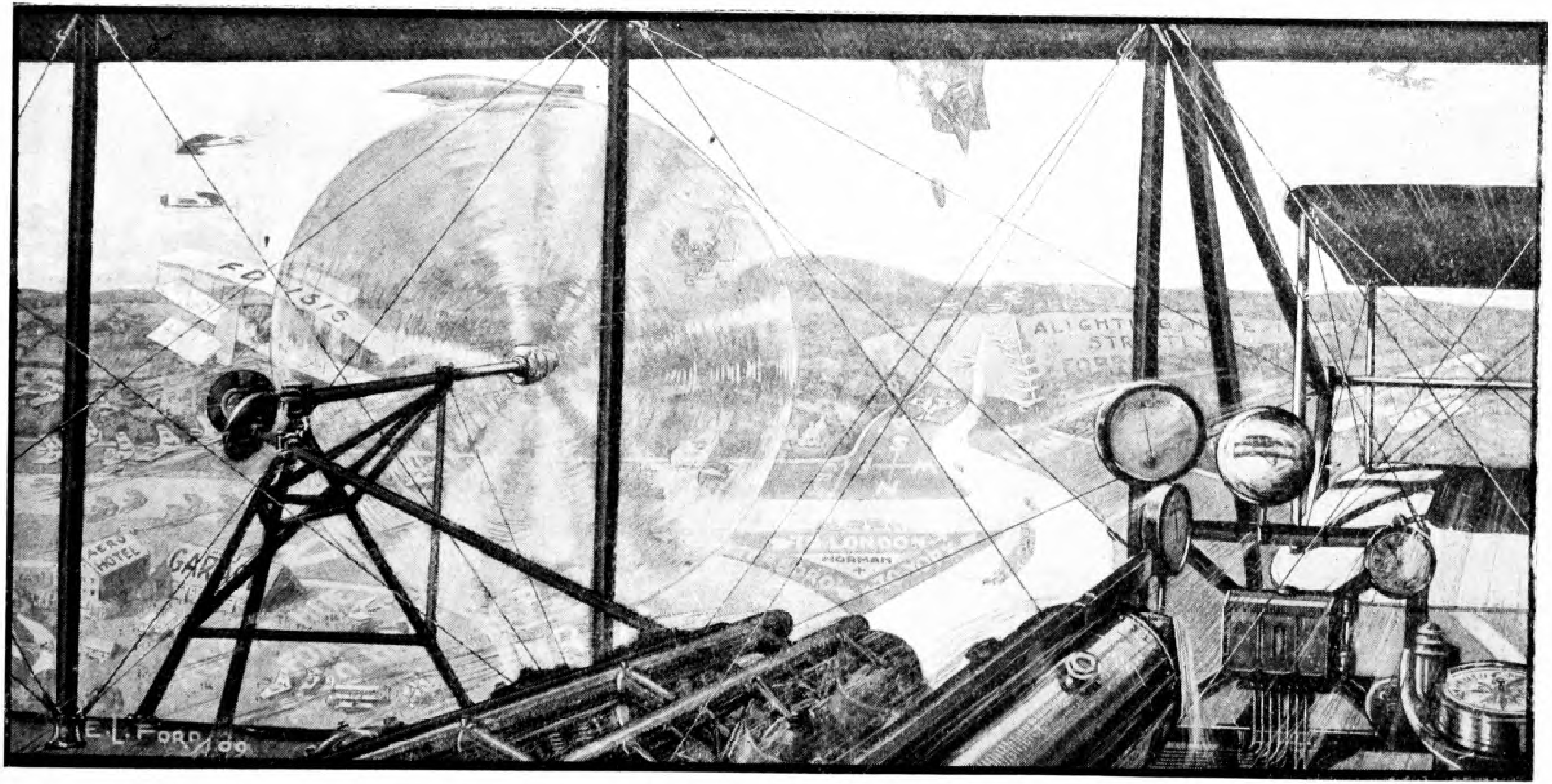

FIFTY YEARS HENCE.

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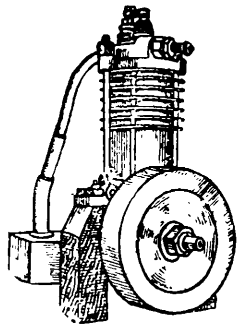

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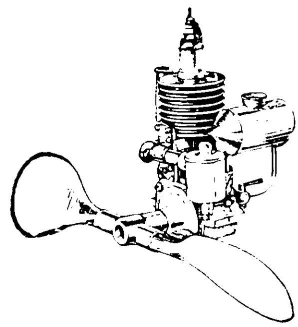

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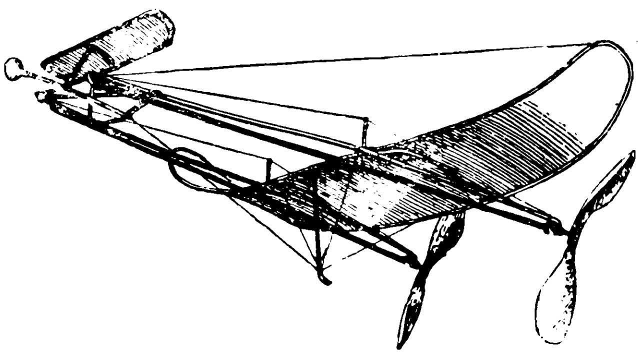

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INTRODUCTION TO FIRST EDITION.

AT first thought, the man in the street would probably be inclined to assert that, in connection with the art of human flight, very little indeed had been written. And, although he would be in error, he would, paradoxically, be justified in his assertion. As a matter of fact, an immense amount has been written concerning aviation: from the earliest times the subject has appealed to the imagination and has inflamed the desires of man. Condemned to inhabit the lowest depths of an ocean of air, man has never ceased to envy the ability of the birds to rise off the solid bottom and float in the elastic medium that encloses them, and he has never ceased to study the means employed by them, or to investigate the possibilities of imitating them. And, although the advanced thinker along this line of thought has ever had to bear the sneers of his contemporaries, not a little of his work has been placed on record to serve some purpose—more or less useful—in the elucidation of the problem.

Thus a complete library of all that has been written on the subject of aviation would equal in bulk the contents of many an average bookcase. But—and it is a very big but—the literature of aviation is in many languages and considerably scattered, and much of it, in the light of latter-day knowledge, is mere chaff, the only difficulty about the sifting of the wheat from it being that we are only just learning to distinguish between the grain and the husk. The work of experimenters in the very first decade of the twentieth century has already provided us with some power of differentiation, and it is in the exercise of this power—admittedly imperfect—that "THE AERO MANUAL" has been prepared.

The scheme underlying its compilation has been first a very severe winnowing of the wheat from the chaff and the presentment of the work of those investigators of the past whose work would now appear to count. And it has been found that much of the work that, had this Manual been prepared ten years ago, would have been dealt with therein, can now be disregarded. No previous decade has ever permitted of such extensive and useful weeding out. The importance of this lies in the fact that by our mistakes we learn and by our ability to recognise and disregard that which is useless so do we progress. This vein of thought has dominated the preparation of the historical section of "THE AERO MANUAL" in order that it may usefully contribute to further investigation of the subject.

The work of the Brothers Wilbur and Orville Wright is dealt with fully and in their own words, because of its immense value. Their achievements have set the seal on the work of the school which, starting with Lilienthal, has attained the success that man has sought through many centuries. The Wrights have told us personally that gliding is the basis of aviation and that to first gain perfection in gliding will materially quicken the attainment of the art of flying. For this reason, we have devoted space to the subject of gliding and have prepared designs for a suitable machine, based upon practical experience of men who have actually glided with them.

INTRODUCTION TO SECOND EDITION.

THE demand for the first edition of THE AERO MANUAL (5,000, published in July, 1909) and for the revised first edition (7,000, published in October, 1909) has been unprecedented, we should imagine, so far as books on flying are concerned. And, added to this, orders are in hand which will completely absorb this second edition, of 10,000 copies. We had intended to discard, in the second edition, certain features of the first which we imagined were by now common knowledge, but we have been surprised to find that those very features have been greatly appreciated and, therefore, we have decided to retain them in this edition. The matter has been carefully revised throughout, stale information has been taken out, descriptions of more recent aeroplanes and dirigibles added, as well as descriptions of new engines, new fabrics, and new constructional methods.

The plan adopted in the first edition of getting the various chapters written by acknowledged authorities has been continued, and thus we have gone to Mr. Moore-Brabazon for the article on piloting a Short aeroplane, to Mr. Maurice Farman for the article dealing with the management of his machine, and to M. Edouard Chateau for an account of his methods in teaching aviation. A careful study of these three articles will be of great assistance to every prospective aviator.

M. Edouard Chateau has also written the article on the differences between monoplanes and biplanes, and although he to an extent is unable to conceal his bias in favour of the biplane, that bias is only natural in the circumstances of his past work with the Voisin biplane.

We make no apologies for including the ten drawings of the accomplished artist, M. A. Tyberghein. They give a clearer idea of details of aeroplanes than many photographs, and traceable in his work is the touch of caricature so beloved of the Frenchmen, although likely to be misunderstood in this country.

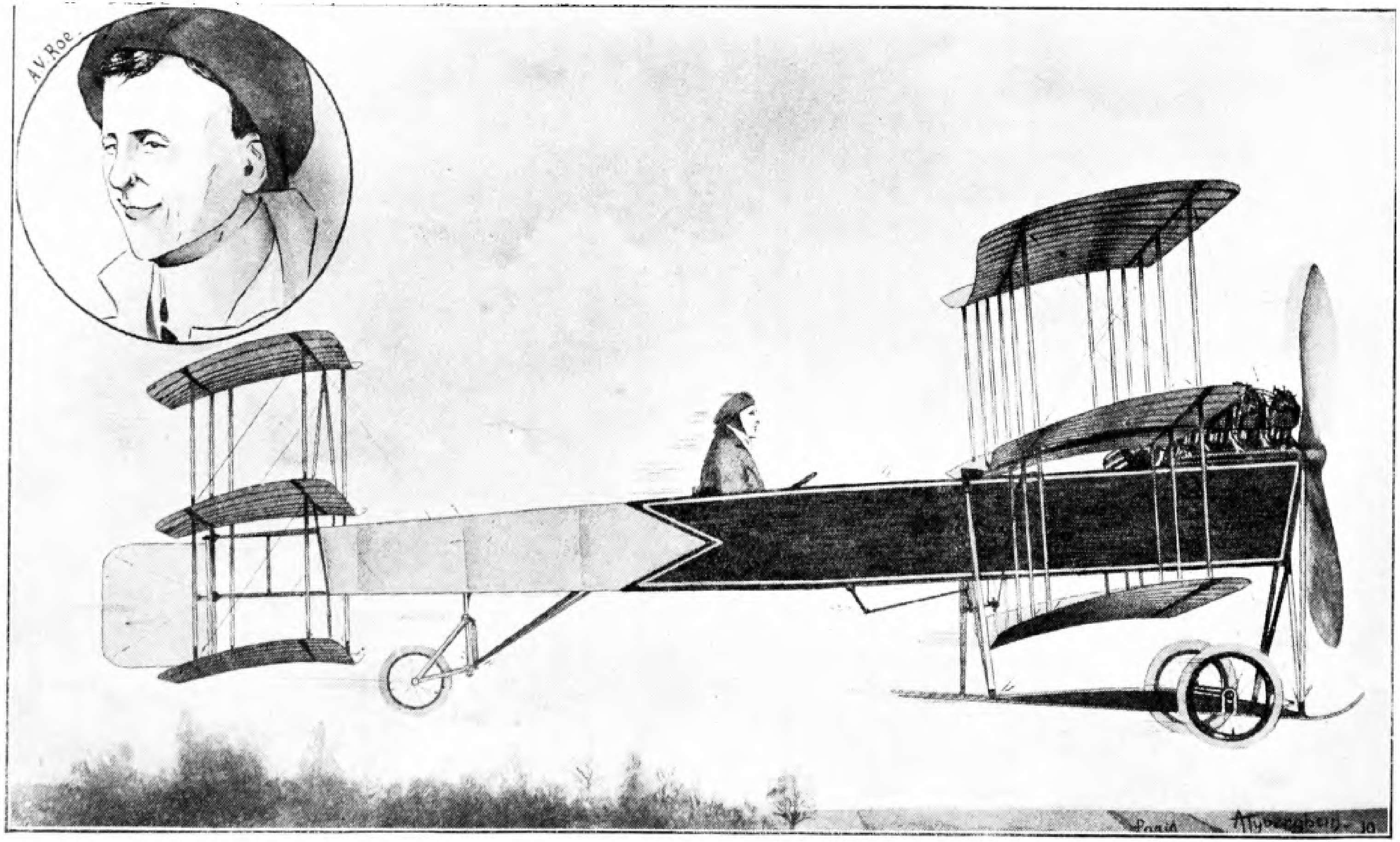
With other informative articles the second edition is really a new book with the favourite features of its predecessor retained, and we hope that it will be as greatly appreciated as the first edition.

THE FRONTISPIECE.

The scene, as observed from the pilot's seat of an aeroplane, 50 years hence, will show great departures from present-day methods of locomotion. The difficulty of the aeronaut in ascertaining his whereabouts has been overcome by the artist. To meet the many difficulties the highways have been considerably widened, the broad road for motor traffic being bordered on either side by great green swards, which serve as landing places for flying machines. Over these great trackways flying machines may travel, and, to facilitate night travelling, each trackway is bordered with a broad band of white chalk so that the searchlights of the flying machines may pick out the road boundaries. Each road is given a distinguishing symbol, the great national roads being lettered N R and numbered. Thus the aeroplane in the picture is travelling over N R—71, the great north road between London and York, whilst branching to the left is C R—3, the county road to Peterborough. The names and the signs are all laid in white chalk set into the green grass, and the name of each place is similarly shown as clearly as possible. The artist has assumed that navigation in the air will be governed by the same rules that control the navigation of ships at sea. A new regulation is needed only for the variation of altitude. It can be defined by a parody on the verse that refers to ships crossing:

If, beneath you, planes appear,
It is your duty to keep clear;
To act as judgment says is proper,
To port or starboard—rise, or drop her!

Flying clubs can be seen in the picture at a couple of points, and the Aero Hotel at Norman Cross has made ample provision in the way of landing space and machine storage.



AVIATORS AND THEIR MACHINES.

Mr. A. V. Roe and the Avroplane.

PREFACE.

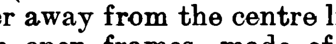
Aeroplane Design and Construction.

By Professor Herbert Chatley, B.Sc., A.M.I.C.E., Imperial Engineering College, North China.

THERE are quite a number of books on the subject of aviation which profess to tell the reader how to construct a machine, and, doubtless, by the exercise of considerable mental effort, useful information can be obtained from them, but the average man who has a bent for mechanical invention and is drawn into the glamour of this subject, wants to know a few particular things and not much more. He is, probably, aware that very few people know much about the subject, and thinks that, by breaking out in a new direction, he may do something fresh. Within limits, this is probably true. What, then, are the points he wants to get hold of?

He hears a lot about gliding angles, skin friction, etc., but the features that interest him most are sizes, shapes and weights. To start with, what size must a man-carrying machine be? Well, for every pound weight (including that of itself and the load) there must be nearly a square foot of supporting surface, so that, when the machine is being designed, the inventor must figure out whether there is enough surface to support the weight. This means that there is a considerable width and length. As may be recognized from the numerous photographs of machines now accessible, the surfaces may be superposed, i.e., subdivided and placed in sheets one over another. The only precaution necessary is that the vertical distance between the planes must be equal to the smaller dimension thereof. Thus, two surfaces 4 ft. wide must be 4 ft., at least, apart. Furthermore, the surfaces must be narrow in the direction of motion, the span being from six to twelve times the width of the surface. Next, how shall we arrange these surfaces? Well, as far as present information is concerned, they may be arranged just as one pleases, provided that two rules are observed. The first is that the centre of gravity (i.e., the place where the whole weight can be supported without turning) should lie between the surfaces so that the lift on those surfaces shall balance about the centre of gravity.

The second is similar to the first, and is that the surfaces must be symmetrically placed about the centre line.

What shape should the surfaces be? In section they should be curved if possible in this way:  The curvature should be quite small (about 1-12th or less of the width). In plan, they should taper away from the centre line.

The surfaces should be fixed in open frames, made of some tough timber with metal joints and good piano-wire stays. Coupling nuts should be used for tightening the latter. The frame should be arranged to rest on an under frame supported by springs on light wheels. The springs should have a total stiffness equal to at least twice the weight.

Steering is performed by surfaces which can be rotated about axes parallel to the length of the machine, perpendicular to the length of the machine and parallel to the breadth of the machine. These surfaces should also be balanced about the centre of gravity. As an alternative, the main surfaces may be warped, the joints of the frames being able to turn in suitable directions, and the planes pulled to the required shape with controlling wires.

Before the inventor thinks of a motor, he should try the machine down a slight slope against the wind and see if it will glide stably. A tail or balancer will probably be necessary at the rear of the machine. If he finds the machine will glide a certain number of feet from a given height, then the gliding angle for his machine is measured by the $\frac{\text{height of glide}}{\text{length of glide}}$. Multiply this fraction into the weight, and the result is the head resistance of the machine. This should be cut down as much as possible by carefully shaping all the exposed parts with easily curved sections so that the wind gets no grip on them.

Now as to the motor. If the propeller is properly designed, the motor should carry about 50 lb. per brake-horse-power, so that a machine weighing 1,000 lb. requires 20 b.h.p. This assumes, however, that the propeller is a good one, and that both it and the motor are running at the best speeds. It will be wisest for an amateur to purchase his propeller, since there is considerable knowledge required in the correct formation, and to ascertain what torque is required to drive it at the specified speed of advance and revolutions. He should then see that the motor is working with high efficiency, and, when direct coupled to the propeller, at the same number of revolutions and with the same torque. If the propeller is driven through gearing, then the torque and revolutions at the driving shaft should be the same as that of the propeller. This matter is most important. No good results can be expected unless the motor, propeller and aeroplane are in harmony. This involves a further equality between the propeller thrust and the aeroplane resistance at the specified speed of advance. The resistance will be rather higher than that mentioned above as the "head resistance" on account of the surface of the motor and accessories, and, perhaps, a rather higher speed, but in any case the thrust should be upwards of one-quarter the total weight.

The propellers should run at a level between the superposed surfaces, so that the head resistance on these is balanced. Well-designed, moderate-speed propellers are preferable to high-speed small ones. Unless one has thoroughly studied the subject, the making of a propeller should not even be attempted.

For those whose knowledge of mechanics is fairly advanced, there is plenty of scope for acquiring a fund of preliminary information. It must, however, be realized that no book-knowledge is comparable with experiment, but the books may help one to avoid unnecessary repetition of work and also to concentrate research on to the lines of known error and doubt.

HUMAN FLIGHT: THE SOLVED PROBLEM.

Man, the great adventurer, has sought to penetrate into every domain, to pry into the habits and methods of all other living creatures, and to imitate and adopt such of their methods as should prove interesting and useful to him. And, at last, after many centuries, he has evolved a machine which shall give him the mastery of the air as his machines have already given him the mastery of the land and the sea. He has always envied the bird and its freedom and sense of easy, perfect motion, and he has wondered and thought and experimented and tried, never daunted by failure a thousand times repeated, until the first decade of the twentieth century sees him rise a victor in the struggle. He has compared the human skeleton with that of the bird and marked the likeness, and he has seen in the bones of a bird's wing a resemblance to those of the human arm, all of which has made him think that he need only discover the secret of flight to be the equal of the bird at least in some measure. But, with all his study, the goal of winged flight is not yet within man's reach. He knows better than he did, thanks to modern high-speed recording photographic apparatus, what the bird does when it flaps its wings, but, to devise a mechanical appliance or to develop the power to lift himself by means of his own arms, seems far beyond his present skill.

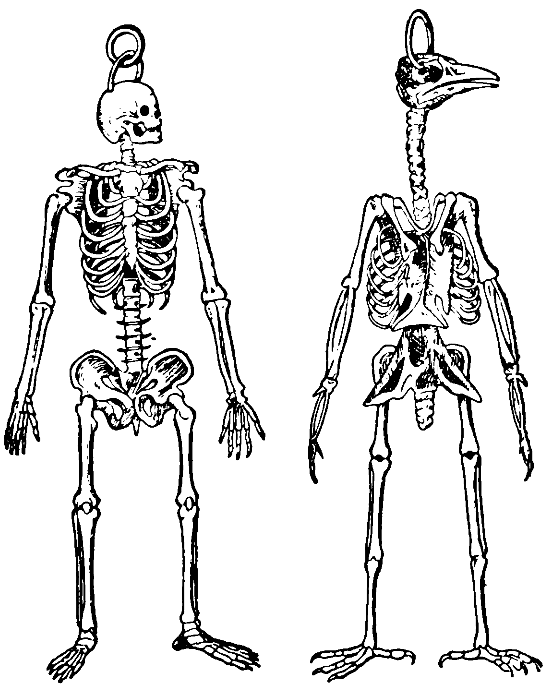


Fig. 1.—The human skeleton and the skeleton of a bird, the latter drawn to an enlarged scale.

The flapping mode of flight may, therefore, be said to have few, if any, advocates, for man has gained his successes — the small preliminary successes and the greater achievements of the past year or two— solely in his efforts to soar. He has watched the albatross, the buzzard, the gull and the kite, and, as a result, his toys, his models, and his man-lifting gliders have all been soaring machines and, when he finally found the forms that more nearly complied with

A

the conditions laid down by nature, enterprise in another direction had prepared for him a source of power light enough for his purpose, and so, with the petrol engine, he used his adaptation of the reciprocating action of the tail and fins of the fish and the wings of the bird — the rotary propeller — and his flying apparatus was complete. And, almost as marvellous as this achievement is the fact that, whereas, six years ago, man had not a single flying machine, to-day he possesses a little handful of types—quite different—each of which is capable of successful free flight.

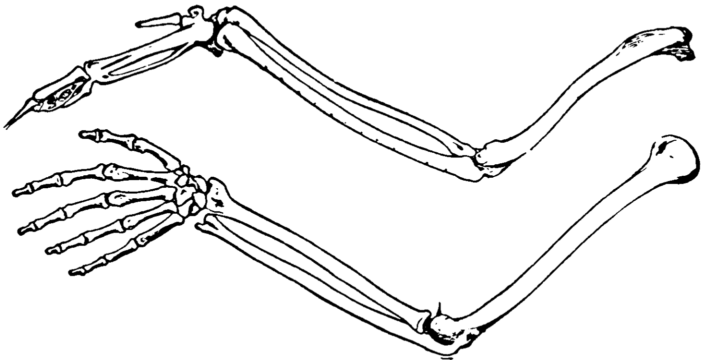


Fig. 2.— Acomparison of the arm bones of a man and the wing bones of a bird, the latter drawn to an enlarged scale.

Success first began to come to man when he definitely ceased to attempt to hit off the flying machine by chance and, instead, devoted himself to the study of the principles underlying and governing the art. Then vanished his theories of some mysterious power that permitted a bird, like the albatross, for instance, to sweep for hundreds of miles across the ocean apparently effortless, gliding without wing motion and steering with delightful ease. There can be no doubt that the soaring bird (and also the wing-flapping bird) has developed extraordinary skill in the discovery of rising air currents. One has only to watch the movements of a number of seagulls in windy and gusty weather to secure innumerable proofs of the existence of this sense and also of the skill with which the birds counteract the influence of some new air current that is suddenly entered.

The air does not flow along sedately in currents parallel with the earth's surface, except in rare instances. Could we observe the movements of a body of air we should see that, whilst as a whole it moved forward, in itself it was a maze of whirling eddies, currents of warm air flowing upward and currents of

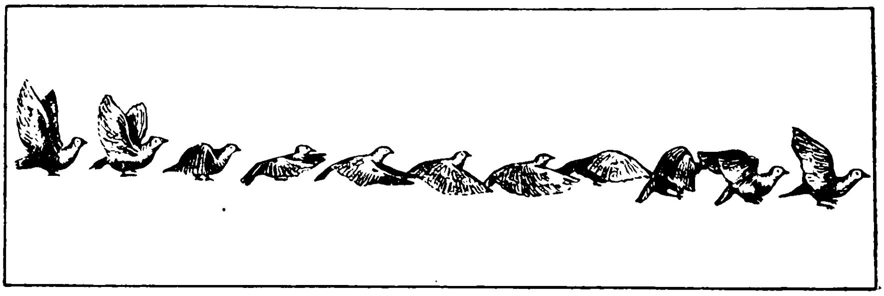


Fig. 3.—The successive positions of the wings of a pigeon in flight, photographed in 1890 by Professor Marey.

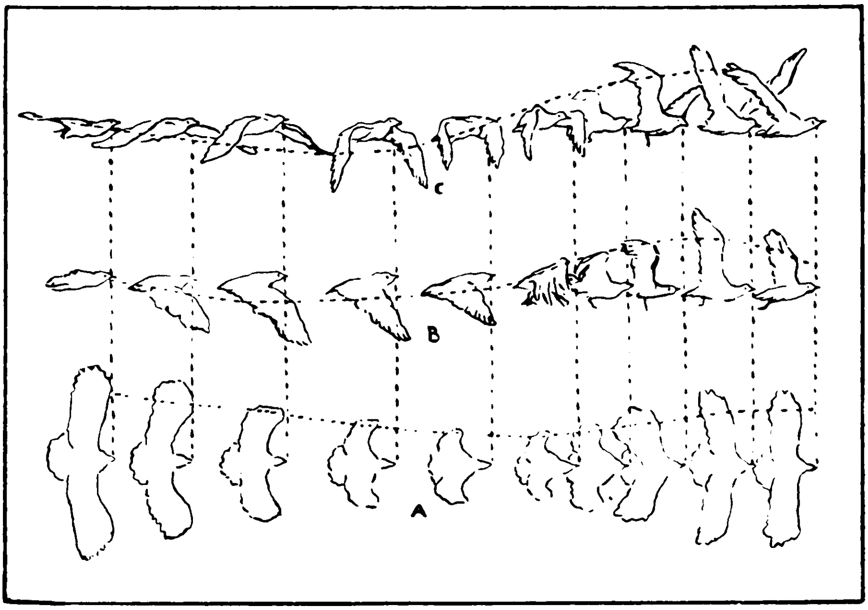


Fig. 4.—The successive positions of the wings of a seagull flying, with the trajectory of a fixed point on its wing, at A on a horizontal plane, at B on a vertical plane parallel to the line of flight, and at C on a vertical plane obliquely to the line of flight.

cooled air flowing downward to fill the space. Obstructions, such as a cliff face, will deflect the current upward, leaving a partial void at the summit, into which air will enter in a whirling mass of eddies. By taking advantage of all rising currents the soaring bird is able to lift itself at such intervals as will allow it to maintain the elevation desired by it. If we regard the bird as being in a constant state of falling by gravity towards the ground, of utilizing this tendency to secure forward motion, and of opposing it by taking advantage of each rising current of air to maintain or increase its elevation, we get a much clearer idea of the work which the bird has to do, and we see that its soaring flights are not so effortless as they appear. In fact, there is the same deceptiveness about the walk of a man, for his efforts to maintain a balance are not noticeable, although they are constantly at work. That man will never approach the birds in skill is as obvious as is already the fact that he cannot emulate the feats of fish in their own element. He has equipped himself to move at moderate speeds on the surface of the waters and is content therewith, and he will equip himself with mechanism that in the air will enable him to attain a certain level of proficiency and be equally content.

That the problem of human flight has been solved is now beyond need of argument. The feats and performances of the past period from 1907 to 1910 amply support the contention that man has at last planted his foot firmly upon the ladder of human flight, and from this time forward advancement in design and methods of construction will be rapid.

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THE WRIGHT BROTHERS' FIRST GLIDING EXPERIMENTS.

As related by Mr. Wilbur Wright before the Society of Western Engineers of Chicago, on 18th September, 1901.

The difficulties which obstruct the pathway to success in flying-machine construction are of three general classes: (1) Those which relate to the construction of the sustaining wings; (2) those which relate to the generation and application of the power required to drive the machine through the air; (3) those relating to the balancing and steering of the machine after it is actually in flight. Of these difficulties, two are already to a certain extent solved. Men already know how to construct wings or aeroplanes, which, when driven through the air at sufficient speed, will not only sustain the weight of the wings themselves, but also that of the engine and of the engineer as well. Men also know how to build engines and screws of sufficient lightness and power to drive these planes at sustaining speed. As long ago as 1893 a machine weighing 8,000 lb.* demonstrated its power both to lift itself from the ground and to maintain a speed of from 30 to 40 miles per hour; but it came to grief in an accidental free flight, owing to the inability of the operators to balance and steer it properly. This inability to balance and steer still confronts students of the flying problem, although nearly ten years have passed. When this one feature has been worked out, the age of flying machines will have arrived, for all other difficulties are of minor importance.

The person who merely watches the flight of a bird gathers the impression that the bird has nothing to think of but the flapping of its wings. As a matter of fact, this is a very small part of its mental labour. To even mention all the things the bird must constantly keep in mind, in order to fly securely through the air, would take a considerable time. If I take a piece of paper, and after placing it parallel with the ground, quickly let it fall, it will not settle steadily down as a staid, sensible piece of paper ought to do, but insists on contravening every recognized rule of decorum, turning over and darting hither and thither in the most erratic manner, much after the style of an untrained horse. Yet this is the style of steed that men must learn to manage before flying can become an every-day sport. The bird has learned this art of equilibrium, and learnt it so thoroughly that its skill is not apparent to our sight. We only learn to appreciate it when we try to imitate it.

Now, there are only two ways of learning how to ride a fractious horse: one is to get on him and learn by actual practice how each motion and trick may be best met; the other is

* *Made by Maxim.*

to sit on a fence and watch the beast a while, and then retire to the house and at leisure figure out the best way of overcoming his jumps and kicks. The latter system is the safer; but the former, on the whole, turns out the larger proportion of good riders. It is very much the same in learning to ride a flying machine; if you are looking for perfect safety, you will do well to sit on a fence and watch the birds; but if you really wish to learn you must mount a machine and become acquainted with its tricks by actual trial.

Lilienthal and Balancing.

Herr Otto Lilienthal seems to have been the first man who really comprehended that balancing was the *first,* instead of the *last*, of the great problems in connection with human flight. He began where others left off, and thus saved the many thousands of dollars that it had theretofore been customary to spend in building and fitting expensive engines to machines which were uncontrollable when tried. He built a pair of wings suitable to sustain his own weight, and made use of gravity as his motor. This motor not only cost him nothing to begin with, but it required no expensive fuel while in operation, and never had to be sent to the shop for repairs. It had one serious drawback, however, in that it always insisted on fixing the conditions under which it would work. These were, that the man should first betake himself and machine to the top of a hill and fly with a downward as well as a forward motion. Unless the conditions were complied with, gravity served no better than a balky horse—it would not work at all. Although Lilienthal must have thought the conditions were rather hard, he nevertheless accepted them till something better should turn up, and, in this manner, he made some two thousand flights, in a few cases landing at a point more than a thousand feet distant from his place of starting.

Other men, no doubt, long before had thought of trying such a plan. Lilienthal not only thought, but acted; and, in so doing, probably, made the greatest contribution to the solution of the flying problem that has ever been made by any one man. He demonstrated the feasibility of actual practice in the air, without which success is impossible. Herr Lilienthal was followed by Mr. Pilcher, a young English engineer, and by Mr. Chanute, a distinguished member of the Society of Western Engineers of Chicago. A few others have built machines, but nearly all that is of real value is due to the experiments conducted under the direction of the three men just mentioned.

The Difficulty of Balancing.

The balancing of a gliding, or flying, machine is very simple in theory. It merely consists in causing the centre of pressure to coincide with the centre of gravity. But, in actual practice, there seems to be an almost boundless incompatibility of temper, which prevents their remaining peaceably together for a single instant, so that the operator, who in this case acts as peacemaker, often suffers injury to himself while attempting to bring them together. If a wind strikes a vertical plane, the pressure on that part to one side of the centre will exactly balance that on the other side, and the part above the centre will balance that below. This point we call the centre of pressure. But if the plane be slightly inclined, the pressure on the part nearest the wind is increased, and the pressure on the other part decreased, so that the centre of pressure is now located, not in the centre of the surface, but a little towards the side which is in advance. If the plane be still further inclined, the centre of pressure will move still farther forward. And, if the wind blow a little to one side, it will also move over as if to meet it. Now, since neither the wind nor the machine, for even an instant, maintains exactly the same direction and velocity, it is evident that the man who would trace the course of the centre of pressure must be very quick of mind; and he who would attempt to move his body to that spot at every change must be very active indeed.

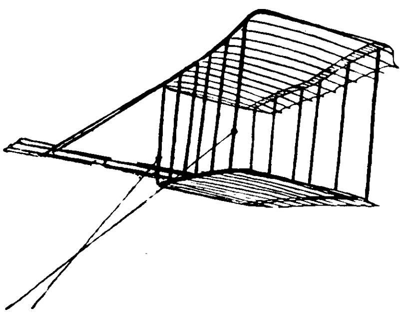

Fig. 5.—Wright Brothers' first glider of 1900.

Yet, that is what Herr Lilienthal attempted to do, and did with most remarkable skill, as his two thousand glides sufficiently attest. However, he did not escape being overturned by wind gusts several times, and, finally, lost his life through a breakage of his machine, due to defective construction. The Pilcher machine was similar to that of Lilienthal, and, like it, seems to have been structurally weak, for, on one occasion, while exhibiting the flight of his machine to several members of the Aeronautical Society of Great Britain, it suddenly collapsed and fell to the ground, causing injuries to the operator which proved sadly fatal. The method of management of this machine differed in no important respect from that of Lilienthal, the operator shifting his body to make the centres of pressure and gravity coincide. Although the fatalities which befell the designers of these machines were due to the lack of structural strength, rather than to lack of control, nevertheless, it had become clear to the students of the problem that a more perfect method of control must be evolved.

The Chanute machines marked a great advance in both respects. In the multiple-wing machine, the tips folded slightly backward under the pressure of wind gusts, so that the travel of the centre of pressure was thus largely counterbalanced. The guiding of the machine was done by a slight movement of the operator's body toward the direction in which it was desired that the machine should go. The double-deck machine, built and tried at the same time, marked a very great structural advance, as it was the first in which the principles of the modern truss bridges were fully applied to flying-machine construction. This machine, in addition to its greatly-improved construction and general design of parts, also differed from the machine of

Lilienthal in the operation of its tail. In the Lilienthal machine, the tail, instead of being fixed in one position, was prevented by a stop from folding downward beyond a certain point, but was free to fold upward without any hindrance. In the Chanute machine, the tail was at first rigid, but afterward, at the suggestion of Mr. Herring, it was held in place by a spring that allowed it to move slightly either upward or downward with reference to its normal position, thus modifying the action of the wind gusts upon it, very much to its advantage. The guiding of the machine was effected by slight movements of the operator's body, as in the multiple-wing machines. Both these machines were much more manageable than the Lilienthal type, and their structural strength, notwithstanding their extreme lightness, was such that no fatalities, or even accidents, marked the glides made with them, although winds were successfully encountered much greater in violence than any which previous experimenters had dared to attempt.

The Wrights' First Interest in Flight.

My own active interest in aeronautical problems dates back to the death of Lilienthal in 1896. The brief notice of his death which appeared in the telegraphic news at that time aroused a passive interest which had existed from my childhood, and led me to take down from the shelves of our home library a book on "Animal Mechanism," by Prof. Marey, which I had already read several times. From this, I was led to read more modern works, and, as my brother soon became equally interested with myself, we passed from the reading to the thinking, and, finally, to the working stage. It seemed to us that the main reason why the problem had remained so long unsolved was that no one had been able to obtain any adequate practice. We figured that Lilienthal in five years of time had spent only about five hours in actual gliding through the air. The wonder was not that he had done so little, but that he had accomplished so much. It would not be considered at all safe for a bicycle rider to attempt to ride through a crowded city street after only five hours' practice, spread out in bits of ten seconds each over a period of five years; yet Lilienthal, with this brief practice, was remarkably successful in meeting the fluctuations and eddies of wind gusts. We thought that if some method could be found by which it would be possible to practise by the hour instead of by the second, there would be a hope of advancing the solution of a very difficult problem. It seemed feasible to do this by building a machine which would be sustained at a speed of 18 miles per hour, and then finding a locality where winds of this velocity were common. With these conditions, a rope attached to keep it from floating backward would answer very nearly the same purpose as a propeller driven by a motor, and it would be possible to practise by the hour, and without any serious danger, as it would not be necessary to rise far from the ground, and the machine would not have any forward motion at all. We found, according to the accepted tables of air pressures on curved surfaces, that a machine spreading 200 square feet of wing surface would be sufficient for our purpose, and that places could easily be found along the Atlantic coast where winds of 16 to 25 miles were not at all uncommon. When the winds were low, it was our plan to glide from the tops of sand hills, and when they were sufficiently strong, to use a rope for our motor and fly over one spot.

Our next work was to draw up the plans for a suitable machine. After much study, we finally concluded that tails were a source of trouble rather than of assistance; and, therefore, we decided to dispense with them altogether. It seemed reasonable that, if the body of the operator could be placed in a horizontal position instead of the upright, as in the machines of Lilienthal, Pilcher, and Chanute, the wind resistance could be very materially reduced, since only one square foot instead of five would be exposed. As a full half-horse-power could be saved by this change, we arranged to try at least the horizontal position. Then, the method of control used by Lilienthal, which consisted in shifting the body, did not seem quite as quick or effective as the case required; so, after long study, we contrived a system consisting of two large surfaces on the Chanute double-deck plan, and a smaller surface placed a short distance in front of the main surfaces in such a position that the action of the wind upon it would counterbalance the effect of the travel of the centre of pressure on the main surfaces. Thus, changes in the direction and velocity of the wind would have little disturbing effect, and the operator would be required to attend only to the steering of the machine, which was to be effected by curving the forward surface up or down. The lateral equilibrium and the steering to right or left were to be attained by a peculiar torsion of the main surfaces, which was equivalent to presenting one end of the wings at a greater angle than the other. In the main frame, a few changes were also made in the details of construction and trussing employed by Mr. Chanute. The most important of these were: (1) the moving of the forward main cross-piece of the frame to the extreme front edge; (2) the encasing in the cloth of all cross-pieces and ribs of the surfaces; (3) a rearrangement of the wires used in trussing the two surfaces together, which rendered it possible to tighten all the wires by simply shortening two of them.

With these plans we proceeded, in the summer of 1900, to Kitty Hawk, North Carolina, a little settlement located on the strip of land that separates Albemarle Sound from the Atlantic Ocean. Owing to the impossibility of obtaining suitable material for a 200-square-foot machine, we were compelled to make it only 165 sq. ft. in area, which, according to the Lilienthal tables, would be supported at an angle of three degrees in a wind of about 21 miles per hour. On the very day that the machine was completed, the wind blew from 25 to 30 miles per hour, and we took it out for trial as a kite. We found that, while it was supported with a man on it in a wind of about 25 miles, its angle was much nearer 20 degrees than 3 degrees. Even in gusts of 30 miles the angle of incidence did not get as low as 3 degrees, although the wind at this speed has more than twice the lifting power of a 21-mile wind. As winds of 30 miles per hour are not plentiful on clear days, it was at once evident that our plan of practising by the hour, day after day, would have to be postponed. Our system of twisting the surfaces to regulate the lateral balance was tried and found to be much more effective than shifting the operator's body. On subsequent days, when the wind was too light to support the machine with a man on it, we tested it as a kite, working the rudders by cords reaching to the ground. The results were very satisfactory, yet we were well aware that this method of testing is never wholly convincing until the results are confirmed by actual gliding experience.

Lift and Drift Experiments.

We then turned our attention to making a series of actual measurements of the lift and drift of the machine under various loads. So far as we were aware, this had never previously been done with any full-size machine. The results obtained were most astonishing, for it appeared that the total horizontal pull of the machine, while sustaining a weight of 52 lb., was only 8.5 lb., which was less than had previously been estimated for head resistance of the framing alone. Making allowance for the weight carried, it appeared that the head resistance of the framing was little more than 50 per cent. of the amount which Mr. Chanute had estimated as the head resistance of the framing of his machine. On the other hand, it appeared sadly deficient in lifting power as compared with the calculated lift of curved surfaces of its size. This deficiency we supposed might be due to one or more of the following causes: (1) That the depth of the curvature of our surfaces was insufficient, being only about 1 in 22, instead of 1 in 12; (2) that the cloth used in our wings was not sufficiently airtight; (3) that the Lilienthal tables might themselves be somewhat in error. We decided to arrange our machine for the following year so that the depth of curvature of its surfaces could be varied at will, and its covering air-proofed.

Our attention was next turned to gliding, but no hill suitable for the purpose could be found near our camp at Kitty Hawk. This compelled us to take the machine to a point four miles south, where the Kill Devil sandhill rises from the flat sand to a height of more than 100 ft. Its main slope is toward the north-east and has an inclination of 10 degrees. On the day of our arrival the wind blew about 25 miles an hour, and, as we had had no experience at all in gliding, we deemed it unsafe to attempt to leave the ground. But, on the day following, the wind having subsided to 14 miles per hour, we made about a dozen glides. It had been the original intention that the operator should run with the machine to obtain initial velocity, and assume the horizontal position only after the machine was in free flight. When it came time to land he was to resume the upright position and alight on his feet, after the style of previous gliding experimenters. But, on actual trial, we found it much better to employ the help of two assistants in starting, which the peculiar form of our machine enabled us readily to do; and, in landing, we found that it was entirely practicable to land while still reclining in a horizontal position upon the machine. Although the landings were made while moving at speeds of more than 20 miles an hour, neither machine nor operator suffered any injury.

The slope of the hill was 9.5 degrees, or a drop of 1 ft. in 6 ft. We found that, after attaining a speed of about 25 or 30 miles with reference to the wind, or 10 to 15 miles over the ground, the machine not only glided parallel to the slope of the hill, but greatly increased its speed, thus indicating its ability to glide on a somewhat less angle than 9.5 degrees, when we should feel it safe to rise higher from the surface. The control of the machine proved even better than we had dared to expect, responding quickly to the slightest motion of the rudder.

The Conclusions of 1900.

With these glides our experiments for the year 1900 closed. Although the hours and hours of practice we had hoped to obtain finally dwindled down to about two minutes, we were very much pleased with the general results of the trip, for, setting out as we did, with almost revolutionary theories on many points and an entirely untried form of machine, we considered it quite a point to be able to return without having our pet theories completely knocked on the head by the hard logic of experience, and our own brains dashed out in the bargain. Everything seemed to us to confirm the correctness of our original opinions: (1) that practice is the key to the secret of flying; (2) that it is practicable to assume the horizontal position; (3) that a smaller surface set at a negative angle in front of the main bearing surfaces or wings will largely counteract the effect of the fore and aft travel of the centre of pressure; (4) that steering up and down can be attained with a rudder, without moving the position of the operator's body; (5) that twisting the wings so as to present their ends to the wind at different angles is a more prompt and efficient way of maintaining lateral equilibrium than shifting the body of the operator.

1901—A Memorable Year.

When the time came to design our new machine for 1901 we decided to make it exactly like the previous machine in theory and method of operation. But, as the former machine was not able to support the weight of the operator when flown as a kite, except in very high winds and at very large angles of incidence, we decided to increase its lifting power. Accordingly, the curvature of the surfaces was increased to 1 in 12 to conform to the shape on which Lilienthal's table was based, and, to be on the safe side, we decided also to increase the area of the machine from 165 sq. ft. to 308 sq. ft., although so large a machine had never before been deemed controllable. The Lilienthal machine had an area of 151 sq. ft.; that of Pilcher 165 sq. ft.; and the Chanute double-decker 134 sq. ft. As our system of control consisted in a manipulation of the surfaces themselves, instead of shifting the operator's body, we hoped that the new machine would be controllable, notwithstanding its great size. According to our calculations, it would obtain support in a wind of 17 miles per hour with an angle of incidence of only 3 degrees.

Our experience of the previous year having shown the necessity of a suitable building for housing the machine, we erected a cheap frame building 16 ft. wide, 25 ft. long, and 7 ft. high at the eaves. As our machine was 22 ft. wide, 14 ft. long (including the rudder) and about 6 ft. high, it was not necessary to take the machine apart in any way in order to house it. Both ends of the building, except the gable parts, were made into doors, which hinged above, so that when opened they formed an awning at each end, and left an entrance the full width of the building. We went into camp about the middle of July, and were soon joined by Mr. E. C. Huffaker, of Tennessee, an experienced aeronautical investigator in the employ of Mr. Chanute, by whom his services were kindly loaned, and by Dr. G. A. Spratt, of Pennsylvania, a young man who has made some valuable investigations of the properties of variously-curved surfaces and the travel of the centre of pressure thereon. Early in August Mr. Chanute came down from Chicago to witness our experiments, and spent a week in camp with us.

The machine was completed and tried for the first time on 27th July in a wind blowing about 13 miles an hour. The operator having taken a position where the centre of pressure was supposed to be, an attempt at gliding was made; but the machine turned downward and landed after going only a few yards. This indicated that the centre of gravity was too far in front of the centre of pressure. In the second attempt the operator took a position several inches further back, but the result was much the same. He kept moving further and further back with each trial, till finally he occupied a position nearly a foot back of that at which we had expected to find the centre of pressure. The machine then sailed off, and made an undulating flight of a little more than 300 ft. To the onlookers this flight seemed very successful, but, to the operator, it was known that the full power of the rudder had been required to keep the machine from either running into the ground or rising so high as to lose all headway. In the 1900 machine one-fourth as much rudder action had been sufficient to give much better control. It was apparent that something was radically wrong, though we were for some time unable to locate the trouble. In one glide the machine rose higher and higher till it lost all headway. This was the position from which Lilienthal had always found difficulty in extricating himself, as his machine then, in spite of his greatest exertions, manifested a tendency to dive downward almost vertically and strike the ground head on with frightful velocity. In this case a warning cry from the ground caused the operator to turn the rudder to its full extent and also to move his body slightly forward. The machine then settled slowly to the ground, maintaining its horizontal position almost perfectly, and landed without any injury at all.

This was very encouraging, as it showed that one of the very greatest dangers in machines with horizontal tails had been overcome by the use of a front rudder. Several glides later, the same experience was repeated with the same result. In the

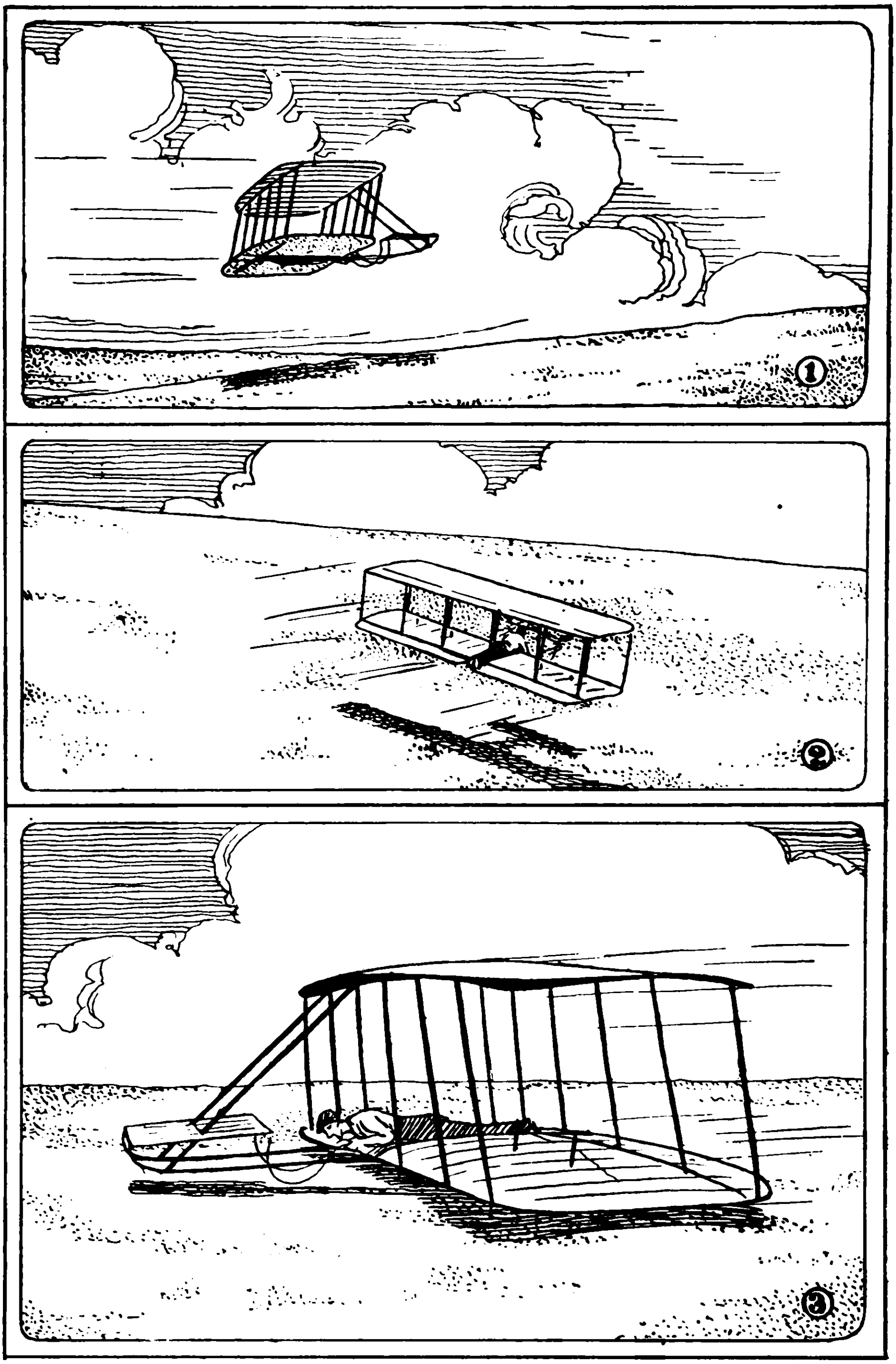

Fig. 6.—Wright Brothers' experiments of 1900.
1, a high glide; 2, a low glide; 3, landing.

latter case, the machine had even commenced to move backward, but was, nevertheless, brought safely to the ground in a horizontal position. On the whole, this day's experiments were encouraging, for, while the action of the rudder did not seem at all like that of our 1900 machine, yet we had escaped without difficulty from positions which had proved very dangerous to preceding experimenters, and, after less than one minute's actual practice, had made a glide of more than 300 ft., at an angle of descent of 10 degrees, and with a machine nearly twice as large as had previously been considered safe.

The trouble with its control, which has been mentioned, we believed could be corrected when we should have located its cause. Several possible explanations occurred to us, but we finally concluded that the trouble was due to a reversal of the direction of the travel of the centre of pressure at small angles. In deeply-curved surfaces, the centre of pressure at 90 degrees is near the centre of the surface, but moves forward as the angle becomes less, till a certain point is reached, varying with the depth of curvature. After this point is passed, the centre of pressure, instead of continuing to move forward, with the decreasing angle, turns and moves rapidly towards the rear. The phenomena are due to the fact that, at small angles, the wind strikes the forward part of the surface on the *upper* side instead of the lower, and, thus, this part altogether ceases to lift, instead of being the most effective part of all, as in the case of the plane. Lilienthal had called attention to the danger of using surfaces with a curvature as great as one in eight, on account of this action on the upper side; but he seems never to have investigated the curvature and angle at which the phenomena entirely cease.

My brother and I had never made any original investigation of the matter, but assumed that a curvature of 1 in 12 would be safe, as this was the curvature on which Lilienthal based his tables. However, to be on the safe side, instead of using the arc of a circle, we had made the curve of our machine very abrupt at the front, so as to expose the least possible area to this downward pressure. While the machine was building, Messrs. Huffaker and Spratt had suggested that we would find this reversal of the centre of pressure, but we believed it sufficiently guarded against. Accordingly, we were not at first disposed to believe that this reversal actually existed in our machine, although it offered a perfect explanation of the action we had noticed in gliding. Our peculiar plan of control by forward surfaces, instead of tails, was based on the assumption that the

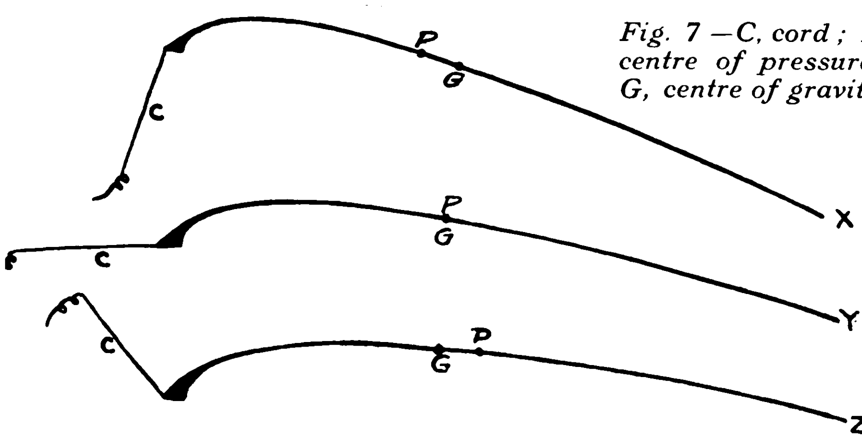

Fig. 7 —C, cord ; P, centre of pressure ; G, centre of gravity.

centre of pressure would continue to move farther and farther forward, as the angle of incidence became less, and it will be readily perceived that it would make quite a difference if the front surface, instead of counteracting this assumed forward travel, should in reality be expediting an actual backward movement. For several days we were in a state of indecision, but were finally convinced, by observing the following phenomena (Fig. 7). We had removed the upper surface from the machine and were flying it in a wind, to see at what angles it would be supported in winds of different strengths. We noticed that, in light winds, it flew in the upper position (X) shown in the figure, with a strong upward pull on the cord (C). As the wind became stronger, the angle of incidence became less, and the surface flew in the position shown in the middle of the figure, with a slight horizontal pull. But when the wind became still stronger, it took the lower position shown in the figure, with a strong downward pull. It at once occurred to me that here was the answer to our problem, for it is evident that, in the first case, the centre of pressure was in front of the centre of gravity and then pushed up the front edge; in the second case, they were in coincidence, and the surface in equilibrium, while, in the third case, the centre of pressure had reached a point even behind the centre of gravity, and there was therefore a downward pull on the cord. This point having been definitely settled, we proceeded to truss down the ribs of the whole machine, so as to

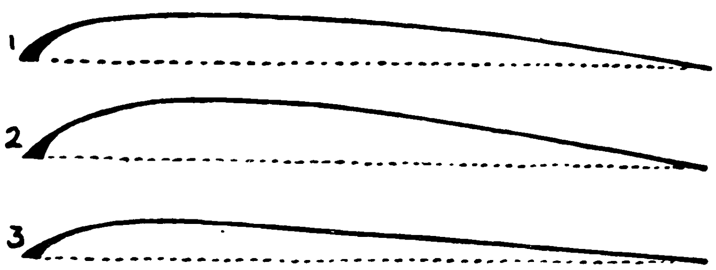

Fig. 8.—The changes effected in the curvature of the plane as the result of experience.

reduce the depth of curvature. In Fig. 8, line 1 shows the original curvature; line 2 the curvature when supporting the operator's weight; and line 3 the curvature after trussing.

Complete Success Obtained.

On resuming our gliding, we found that the old conditions of the preceding year had returned, and, after a few trials, made a glide of 366 ft., and, soon after, one of 389 ft. The machine, with its new curvature, never failed to respond promptly to even small movements of the rudder. The operator could cause it to almost skim the ground, following the undulations of its surface, or he could cause it to sail out almost on a level with the starting point, and, passing high above the foot of the hill, gradually settle down to the ground. The wind on this day was blowing 11 to 14 miles per hour. The next day, the conditions being favourable, the machine was again taken out for trial. This time the velocity of the wind was 18 to 22 miles per hour. At first we felt some doubt as to the safety of attempting free flight in so strong a wind, with a machine of over 300 sq. ft., and a practice of less than five minutes spent in actual flight. But, after several preliminary experiments, we decided to try a glide. The control of the machine seemed so good that we then felt no apprehension in sailing boldly forth. And, thereafter, we made glide after glide, sometimes following the ground closely, and sometimes sailing high in the air. Mr. Chanute had his camera with him, and took pictures of some of these glides.

We made glides on subsequent days, whenever the conditions were favourable. The highest wind thus experimented in was a little over 12 metres per second—nearly 27 miles per hour.

It had been our intention, when building the machine, to do the larger part of the experimenting in the following manner: When the wind blew 17 miles an hour, or more, we would attach a rope to the machine and let it rise as a kite with the operator upon it. When it should reach a proper height, the operator would cast off the rope and glide down to the ground just as from the top of a hill. In this way, we would be saved the trouble of carrying the machine up hill after each glide, and could make at least 10 glides in the time required for one in the other way. But when we came to try it we found that a wind of 17 miles, as measured by Richard's anemometer, instead of sustaining the machine with its operator, a total weight of 240 lb., at an angle of incidence of three degrees, in reality would not sustain the machine alone—100 lb.—at this angle. Its lifting capacity seemed scarcely one-third of the calculated amount. In order to make sure that this was not due to the porosity of the cloth, we constructed two small experimental surfaces of equal size, one of which was air-proofed and the other left in its natural state; but we could detect no difference in their lifting powers. For a time, we were led to suspect that the lift of curved surfaces little exceeded that of planes of the same size, but further investigation and experiment led to the opinion that (1) the anemometer used by us over-recorded the true velocity of the wind by nearly 15 per cent.; (2) that the well-known Smeaton coefficient of .005 V^2 for the wind pressure at 90 degrees is probably too great by at least 20 per cent.; (3) that Lilienthal's estimate that the pressure on a curved surface having an angle of incidence of 3 degrees equals .545 of the pressure of 90 degrees is too large, being nearly 50 per cent. greater than very recent experiments of our own with a special pressure-testing machine indicator; (4) that the superposition of the surfaces somewhat reduced the lift per square foot, as compared with a single surface of equal area.

The Importance of the Ratio of Lift to Drift.

In gliding experiments, however, the amount of lift is of less relative importance than the ratio of lift to drift, as this alone decides the angle of gliding descent. In a plane, the pressure is always perpendicular to the surface and the ratio of lift to drift is therefore the same as that of the cosine to the sine of the angle of incidence. But, in curved surfaces, a very remarkable situation is found. The pressure, instead of being uniformly normal to the chord of the arc, is usually inclined considerably in front of the perpendicular. The result is that the lift is greater and the drift less than if the pressure were normal. Lilienthal was the first to discover this exceedingly important fact, which is fully set forth in his book, "Bird Flight the Basis of the Flying Art," but, owing to some errors in the methods he used in making measurements, question was raised by other investigators not only as to the accuracy of his figures, but even as to the existence of any tangential force at all. Our experiments confirm the existence of this force, though our measurements differ considerably from those of Lilienthal. While at Kitty Hawk, we spent much time in measuring the horizontal pressure on our unloaded machine at various angles of incidence. We found that at 13 degrees the horizontal pressure was about 23 lb. This included not only the drift proper, or horizontal component of the pressure on the side of the surface, but also the head resistance of the framing as well. The weight of the machine at the time of this test was about 108 lb. Now, if the pressure had been normal to the chord of the surface, the drift proper would have been to the lift (108 lb.), as the sine of 13 degrees is to the cosine of 13 degrees or $\frac{.22 \times 108}{.97} = 24\frac{1}{2}$ lb.; but this slightly exceeds the total pull of 23 lb. on our scales. Therefore, it is evident that the average pressure on the surface, instead of being normal to the chord, was so far inclined toward the front that all the head resistance of framing and wires used in the construction was more than overcome. In a wind of 14 miles per hour resistance is by no means a negligible factor, so that tangential force is evidently a force of considerable value. In a higher wind, which sustained the machine at an angle of 10 degrees, the pull on the scales was 18 lb. With the pressure normal to the chord, the drift proper would have been $\frac{.17 \times 98}{.98} = 17$ lb., so that although the higher wind velocity must have caused an increase in the head resistance, the tangential force still came within 1 lb. of overcoming it.

Pressures on Curved Surfaces.

After our return from Kitty Hawk, we began a series of experiments to accurately determine the amount and direction of the pressure produced on curved surfaces when acted upon by winds at the various angles from zero to 90 degrees. These experiments are not yet concluded, but, in general, they support Lilienthal in the claim that the curves give pressures more favourable in amount and direction than planes; but we find marked differences in the exact values, especially at angles below 10 degrees.

We were unable to obtain direct measurements of the

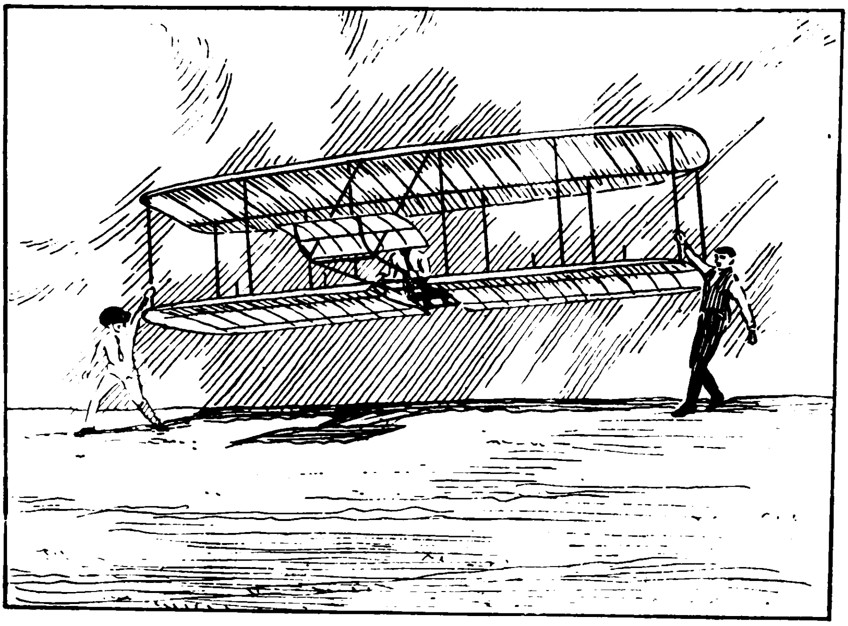

Fig. 9.—The machine of 1900, showing forward elevation plane.

horizontal pressures of the machine with the operator on board, but, by comparing the distance travelled in gliding with the vertical fall, it was easily calculated that, at a speed of 24 miles per hour, the total horizontal resistances of our machine, when bearing the operator, amounted to 40 lb., which is equivalent to about $2\frac{1}{3}$ h.p. It must not be supposed, however, that a motor developing this power would be sufficient to drive a man-bearing machine. The extra weight of the motor would require either a larger machine, higher speed, or a greater angle of incidence, in order to support it, and, therefore, more power. It is probable, however, that an engine of 6 h.p., weighing 100 lb., would answer the purpose. Such an engine is entirely practicable. Indeed, working motors of one-half this weight per horse-power (9 lb. per horse-power) have been constructed by several different builders. Increasing the speed of our machine from 24 to about 33 miles per hour reduced the total horizontal pressure from 40 to about 35 lb. This was quite an advantage in gliding, as it made it possible to sail about 15 per cent. further with a given drop. However, it would be of little or no advantage in reducing the size of the motor in a power-driven machine, because the lessened thrust would be counterbalanced by the increased speed per minute. Some years ago, Prof. Langley called attention to the great economy of thrust which might be obtained by using very high speeds, and from this many were led to suppose that high speed was essential to success in a motor-driven machine. But the economy to which Prof. Langley called attention was in foot-pounds per mile of travel, not in foot-pounds per minute. It is the foot-pounds per minute that fixes the size of the motor. The probability is that the first flying machines will have a relatively low speed, perhaps not much exceeding 20 miles per hour, but the problem of increasing the speed will be much simpler in some respects than that of increasing the speed of a steamboat, for, whereas in the latter case the size of the engine must increase as the cube of the speed, in the flying machine, until extremely high speeds are reached, the capacity of the motor increases in less than simple ratio; and there is even a decrease in the fuel consumption per mile of travel. In other words, to double the speed of a steamship (and the same is true of the balloon type of airship) eight times the engine and boiler capacity would be required, and four times the fuel consumption per mile of travel; while a flying machine would require engines of less than double the size, and there would be an actual decrease in the fuel consumption per mile of travel.

The Efficiency of the Flying Machine.

But, looking at the matter conversely, the great disadvantage of the flying machine is apparent; for, in the latter, no flight at all is possible unless the proportion of horse-power to flying capacity is very high; but, on the other hand, a steamship is a

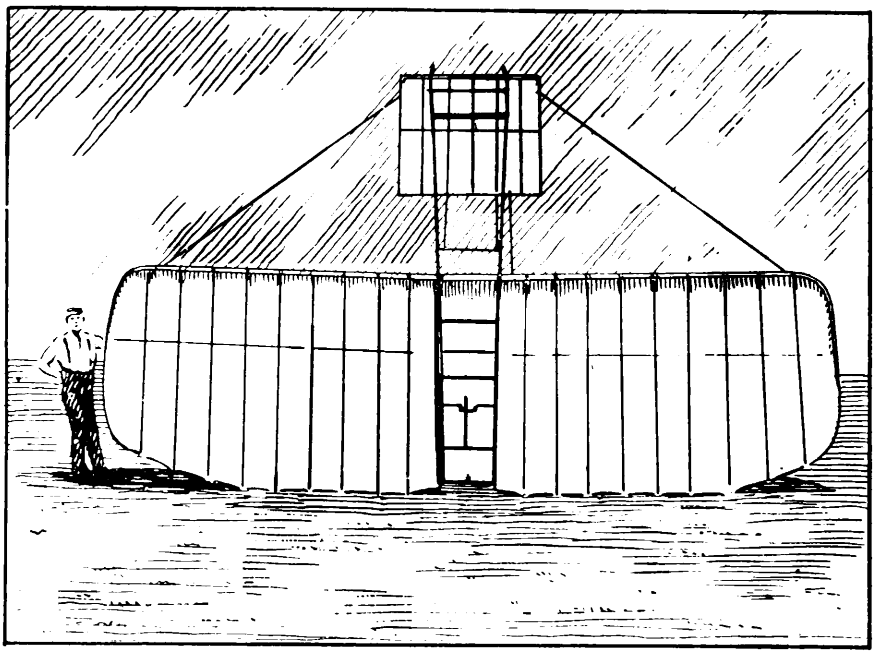

Fig. 10.—The 1900 machine: Under-view.

mechanical success if its ratio of horse-power to tonnage is insignificant. A flying machine that would fly at a speed of 50 miles an hour with engines of 1,000 h.p., would not be upheld by its wings at all at a speed of less than 25 miles an hour, and nothing less than 500 h.p. could drive it at this speed. But a boat which could make 40 miles per hour with engines of 1,000 h.p. would still move four miles per hour even if the engines were reduced to 1 h.p. The problems of land and water travel were solved in the 19th century, because it was possible to begin with small achievements and gradually work up to our present success. The flying problem was left over to the 20th century, because, in this case, the art must be highly developed before any flight of any considerable duration at all can be obtained.

However, there is another way of flying which requires no artificial motor, and many workers believe that success will first come by this road. I refer to the soaring flight, by which the machine is permanently sustained in the air by the same means that are employed by soaring birds. They spread their wings to the wind, and sail by the hour, with no perceptible exertion beyond that required to balance and steer themselves. What sustains them is not definitely known, though it is almost cer-

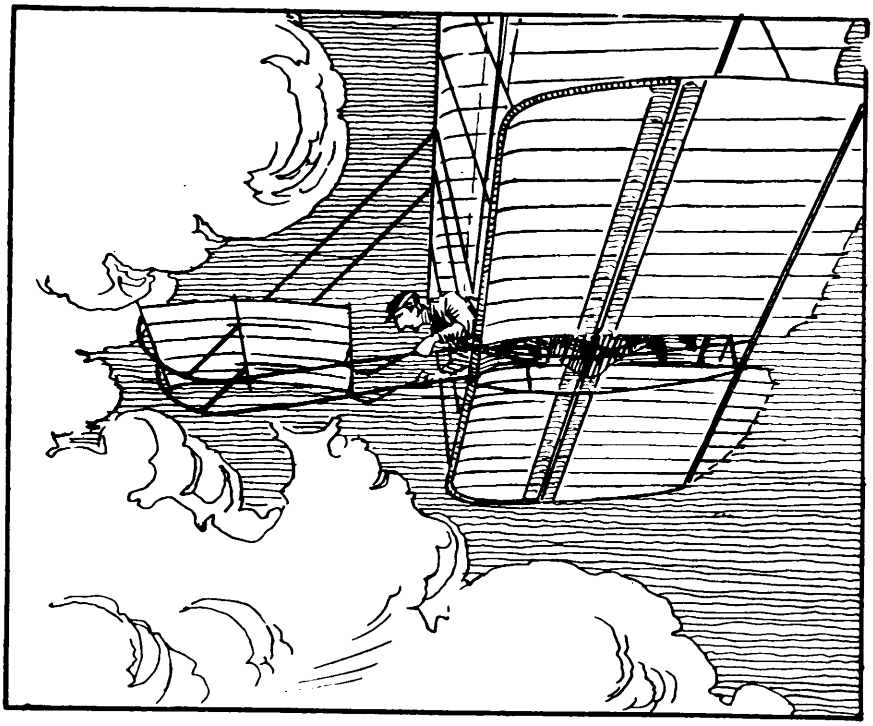

Fig. 11.—A soaring flight, the machine being practically at a standstill.

tain that it is a rising current of air. But, whether it be a rising current or something else, it is as well able to support a flying machine as a bird, if man once learns the art of utilizing it. In gliding experiments it has long been known that the rate of vertical descent is very much retarded and the duration of the flight greatly prolonged if a strong wind blows *up* the face of the hill parallel to its surface. Our machine, when gliding in still air, has a rate of vertical descent of nearly 6 ft. per second, while in a wind blowing 26 miles per hour up a steep hill we made glides in which the rate of descent was less than 2 ft. per second; and, during the larger part of this time,

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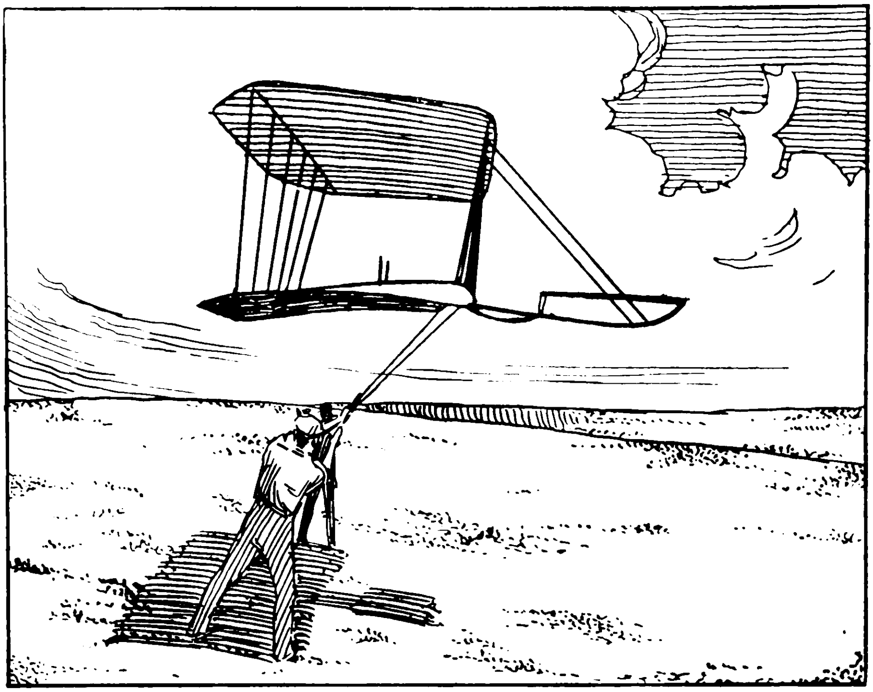


Fig. 12.—The 1900 machine soaring in a wind of 35 m.p.h.

while the machine remained exactly in the rising current, *there was no descent at all, but even a slight rise.* If the operator had had sufficient skill to keep himself from passing beyond the rising current he would have been sustained indefinitely at a higher point than that from which he started. Fig. 11 shows one of these very slow glides at a time when the machine was practically at a standstill. These slow glides in rising currents probably hold out greater hope of extensive practice than any other method within man's reach, but they have the disadvantage of requiring rather strong winds or very large supporting surfaces. However, when gliding operators have attained greater skill, they can, with comparative safety, maintain themselves in the air for hours at a time in this way, and thus by constant practice so increase their knowledge and skill that they can rise into the higher air and search out the currents which enable the soaring birds to transport themselves to any desired point by first rising in a circle and then sailing off at a descending angle. The illustration (Fig. 12) shows the machine, alone, flying in a wind of 35 miles per hour on the face of a steep hill 100 ft. high. It will be seen that the machine not only pulls upward, but also pulls forward in the direction from which the wind blows, thus overcoming both gravity and the speed of the wind. We tried the same experiment with a man on it, but found danger that the forward pull would become so strong that the men holding the ropes would be dragged from their insecure foothold on the slope of the hill. So this form of experimenting was discontinued after four or five minutes' trial.

In looking over our experiments of the past two years, with models and full-size machines, the following points stand out with clearness:—

1. That the lifting power of a large machine, held stationary in a wind at a small distance from the earth, is much less than the Lilienthal table and our own laboratory experiments would lead us to expect. When the machine is moved through the air, as in gliding, the discrepancy seems much less marked.

2. That the ratio of drift to lift in well-shaped surfaces is less at angles of incidence of 5 degrees to 12 degrees than at an angle of 3 degrees.

3. That, in arched surfaces, the centre of pressure at 90 degrees is near the centre of the surface, but moves slowly forward as the angle becomes less, till a critical angle varying with the shape and depth of the curve is reached, after which it moves rapidly toward the rear till the angle of no lift is found.

4. That, with similar conditions, large surfaces may be controlled with not much greater difficulty than small ones, if the control is effected by manipulation of the surfaces themselves, rather than by a movement of the body of the operator.

5. That the head resistances of the framing can be brought to a point much below that usually estimated as necessary.

6. That tails, both vertical and horizontal, may with safety be eliminated in gliding and other flying experiments.

7. That a horizontal position of the operator's body may be assumed without excessive danger, and thus the head resistance reduced to about one-fifth that of the upright position.

8. That a pair of superposed or tandem surfaces has less lift in proportion to drift than either surface separately, even after making allowance for weight and head resistance of the connections.

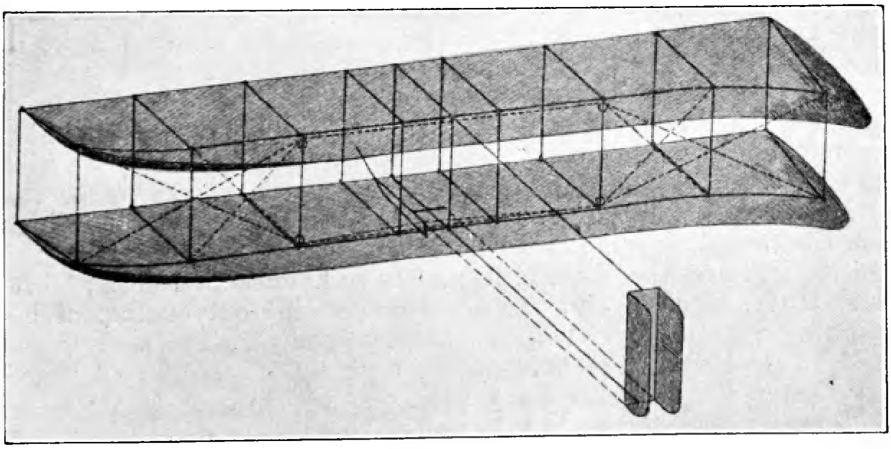


Fig. 13.—The manner in which the wings of a Wright aeroplane are warped. The left ends of the wings are raised and the right ends depressed for the purpose of causing the right hand side of the machine to lift.

THE LATER EXPERIMENTS OF THE WRIGHT BROTHERS IN SOARING FLIGHT.

Related by Wilbur Wright before the Society of Western Engineers of Chicago, 1st June, 1903.

In the address which I delivered before the Society of Western Engineers in September, 1901, some account was given of the gliding experiments made by my brother Orville Wright and myself in the years 1900 and 1901. Afterwards, laboratory experiments were undertaken for the purpose of determining for ourselves the amount and direction of the pressures produced by the wind upon plane and arched surfaces exposed at various angles of incidence. The results having indicated the possibility of a gliding machine capable of much better performance than any previously built by us, we set about designing a new one for the 1902 season, and, in August, repaired to our old camp at the Kill Devil hills.

The 1902 pattern was a double-deck machine having two surfaces, each 32 ft. from tip to tip and 5 ft. from front to rear. The total area of the main surfaces was about 305 sq. ft. The front rudder spread 15 sq. ft. additional, and the vertical tail about 12 sq. ft., which was subsequently reduced to 6 sq. ft. The weight was 116½ lb. Including the operator, the total weight was from 250 lb. to 260 lb. It was built to withstand hard usage, and, in nearly a thousand glides, was injured but once. It repeatedly withstood without damage the immense strains arising from landing at full speed in a slight hollow where only the tip of the wings touched the earth, the entire weight of machine and operator being suspended between.

The practice ground at the Kill Devil hills consists of a level plain of bare sand, from which rises a group of detached hills or mounds formed of sand heaped up by the winds. These hills are constantly changing in height and slope, according to the direction and force of the prevailing winds. The three which we use for gliding experiments are known as the Big Hill, the Little Hill and the West Hill, and have heights of 100 ft., 30 ft. and 60 ft. respectively. In accordance with our custom of beginning operations with the greatest possible caution, we selected the Little Hill as the field of our first experiments, and began by flying the machine as a kite. The object of this was to determine whether or not it would be capable of soaring in a wind having an upward trend of a trifle over 7 degrees, which was the slope of the hill up which the current was flowing.

When I speak of soaring I mean not only that the weight of the machine is fully sustained, but also that the direction of the pressure upon the wings is such that the propelling and the retarding forces are exactly in balance; in other words, the resultant of all the pressures is exactly vertical, and, therefore, without any unbalanced horizontal component. A kite is soaring when the string stands exactly vertical, this showing that there is no backward pull. The phenomenon is exhibited only when the kite is flown in a rising current of air. In principle, soaring is exactly equivalent to gliding, the practical difference being that in one case the wind moves with an upward trend against a motionless surface, while in the other the surface moves with a downward trend against motionless air. The reactions are identical. The soaring of birds consists in gliding downwards through a rising current of air, which has a rate of ascent equal to the bird's relative rate of descent.

Testing a gliding machine as a kite on a suitable slope, with just enough wind to sustain the machine at its most favourable angle of incidence, is one of the most satisfactory methods of determining its efficiency. In soaring, the kite must fly steadily with the string vertical or a little to the front. Merely darting up to this position for an instant is not soaring. On trial, we found that the machine would soar on the side of a hill having a slope of about 7 degrees, whenever the wind was of proper force to keep the angle of incidence between 4 and 8 degrees. If the wind became too strong or too weak the ropes would incline to leeward. The accompanying illustration (Fig. 14) was taken when the wind was too weak for real soaring. The surfaces are inclined 4 degrees above the horizon, which is marked by the ocean level in the distance. Since the wind had an upward trend of 7 degrees, the total angle of incidence was 11 degrees, which is outside the limits specified. On steeper slopes the ropes inclined to windward quite strongly. In experimenting on this plan it is essential that a uniform slope be found which will give the air current a rising trend just sufficient to cause the kite string to stand vertical.

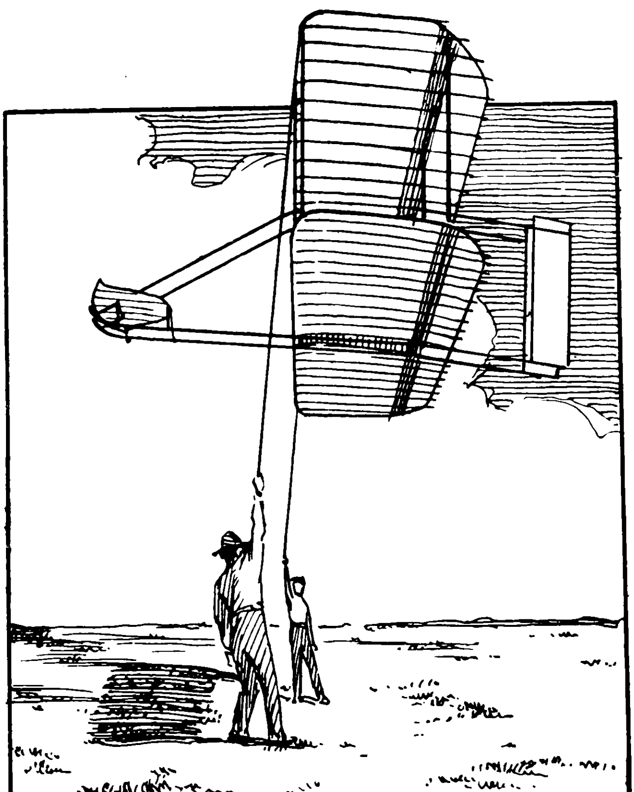


Fig. 14.—The 1902 machine flown as a kite in a light wind.

Then, both gravity and the pull on the string, which together provide the force counteracting the wind pressure on the surfaces, are applied in a single direction. It is, therefore, not material what proportion of the total counteracting force is due to each of the several components, nor even what is their total amount, because the experiment is exclusively for the purpose of determining the direction of the pressure on the surfaces by observing the direction of the reaction. When the kite string inclines to windward the slope is too steep; if to leeward, not steep enough. But it is not advisable to attempt to determine how much the slope varies from the proper amount by observing the angle of the string from the vertical, for, when the pull of the string differs in direction from that of gravity, it becomes necessary to know not only the angle, but also the exact amount of the pull and the proportion which it bears to the weight of the kite. It is, therefore, advisable to find a better slope rather than attempt to make so many observations.

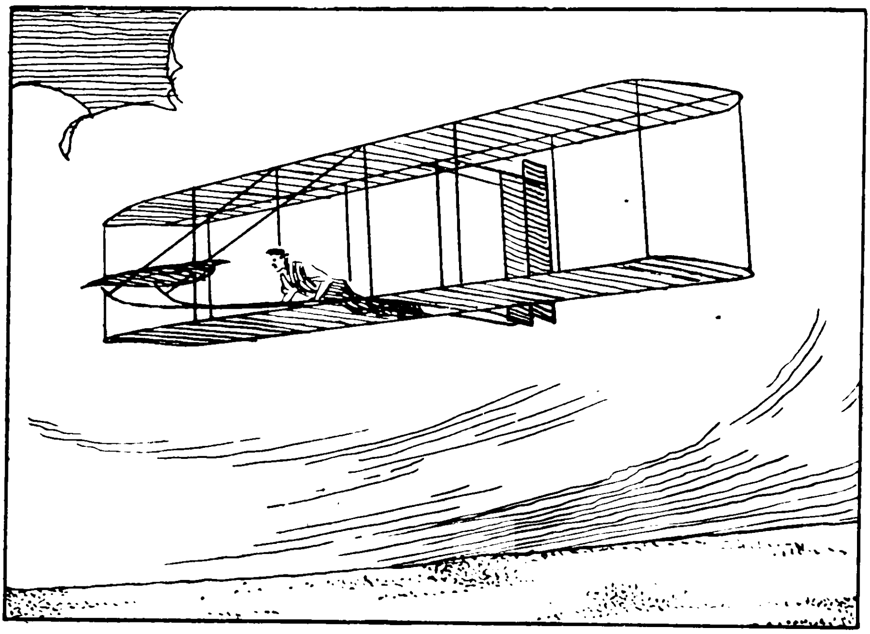


Fig. 15.—A glide with the double tail machine.

The kite experiments having shown that it ought to be possible to glide on the 7-degree slope, we next proceeded to try it. Although, on this first day, it was not considered advisable to venture upon any absolutely free flights, the machine soon demonstrated its ability to glide with this angle of descent. At a later period we made more than a hundred flights the full length of this slope, and landed a short distance out on the level ground. On the second day the machine was taken to the Big Hill and regular gliding was commenced. The wind was somewhat brisk. In one flight the wind struck the machine from the left and began lifting the left wing in a decidedly alarming manner. Owing to the fact that, in the new machine, changes had been made in the mechanisms operating the rudders, so that the movements were exactly reversed, it was necessary to think a moment before proceeding to make the proper adjustment. But meanwhile the left wing was rising higher and higher. I therefore decided to bring the machine to the ground as quickly as possible, but, in my confusion, forgot the change that had been made in the front rudder, and instinctively turned it the wrong way. Almost instantly it reared up as though bent on a mad attempt to pierce the heavens. But, after a moment, it seemed to perceive the folly of such an undertaking and gradually slowed up till it came almost to a stop with the front of the machine still pointing heavenward. By this time I had recovered myself and reversed the rudder to its full extent, at the same time climbing upward towards the front so as to bring my weight to bear on the part that was too high. Under this heroic treatment the machine turned downward and soon began to gather headway again. By the time the ground was reached, it was under fair control, but, as one wing touched first, it swung around in landing and came to rest with the wind blowing in from the rear. There was no unusual shock in landing and no damage at all resulted.

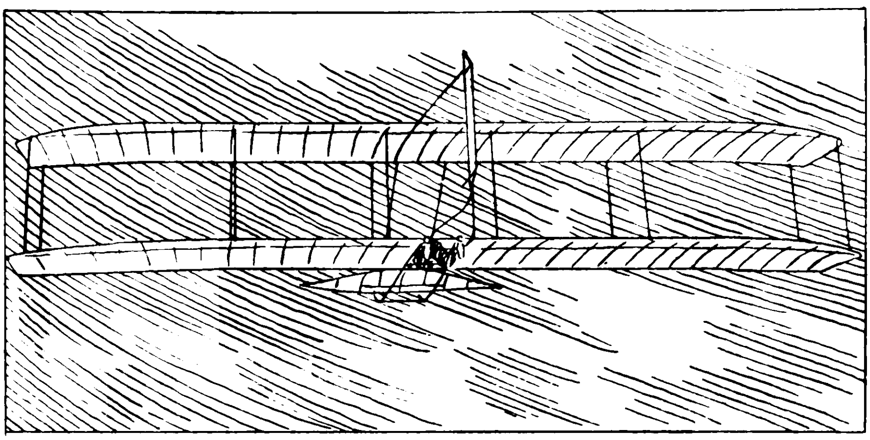


Fig. 16.—Rear view of machine with single tail.

In several other glides there were the disturbances of the lateral equilibrium more marked than we had been accustomed to experience with the former machines, and we were at a loss to know what the cause might be. The new machine had a much greater tip-to-tip dimension than our former machines; it also had a vertical tail, while the earlier ones were tailless, and the wing tips were on a line with the centre, while the old machines had the tips drawn down like a gull's wings. The trouble might be due to either of these differences. We decided to begin alterations at the wing tips, and the next day made the necessary changes in the trussing, thus bringing the tips 6 in. lower than the centre. For several days thereafter the weather was not suitable for gliding on account of rain, but, finally, the sky cleared and the machine was taken out again. As the anemometer indicated a wind velocity of more than 11 metres a second, it was thought best to make use of the Little Hill in testing the effect of the changes that had been made. But later in the day, when the velocity fell to about nine metres a second, the Big Hill was tried again.

On this day my brother Orville did most of the gliding. After a few preliminary flights, to accustom himself to the new method of operating the front rudder, he felt himself ready to undertake the management of the lateral control also. Shortly afterwards he started on a flight with one wing slightly higher than the other. This caused the machine to veer to the left. He waited a moment to see whether it would right itself, but finding that it did not, then decided to apply the control. At the very instant he did this, however, the right wing most unexpectedly rose much higher than before and led him to think that possibly he had made a mistake. A moment of thought was required to assure himself that he had made the right motion, and another to increase the movement. Meanwhile he had neglected the front rudder, by which the fore-and-aft balance was maintained. The machine turned up in front more and more till it assumed a most dangerous attitude. We who were on the ground noticed this in advance of the aviator, who was thoroughly absorbed in the attempt to restore the lateral balance, but our shouts of alarm were drowned by the howling of the wind. It was only when the machine came to a stop and started backward that he at length realized the true situation. From the height of nearly 30 ft. the machine sailed diagonally backward till it struck the ground. The unlucky aeronaut had time for one hasty glance behind him and the next instant found himself the centre of a mass of fluttering wreckage. How he escaped injury I do not know, but, afterwards, he was unable to show a scratch or bruise anywhere, though his clothes were torn in one place. This little misadventure, which occurred almost at the very beginning of our practice with the new machine, was the only thing approaching an accident that happened during these experiments, and was the only occasion on which the machine suffered any injury. The latter was made as good as new by a few days' labour, and was not again broken in any of the many hundred glides which we subsequently made with it.

By long practice the management of a flying machine should become as instinctive as the balancing movements a man unconsciously employs with every step in walking, but, in the early days, it is easy to make blunders. For the purpose of reducing the danger to the lowest possible point we usually kept close to the ground. Often, a glide of several hundred feet would be made at a height of a few feet or even a few inches sometimes. It was the aim to avoid unnecessary risk. While the high flights were more spectacular, the low ones were fully as valuable for training purposes. Skill comes by the constant repetition of familiar feats rather than by a few over-bold attempts at feats for which the performer is yet poorly prepared.

It had been noticed during the day that, when a side gust struck the machine, its effect was at first partly counteracted by the vertical tail, but, after a time, when the machine had acquired a lateral motion, the tail made matters worse instead of better. Although the change that had been made in the wing tips made some improvement, the lateral control still remained somewhat unsatisfactory. The tail was useful at times and at others was seriously in the way. It was finally concluded that the best way of overcoming the difficulty was by making the tail movable like a rudder. As originally built, the fixed vertical tail or vane was double, but, in changing to a movable rudder, it was made single, as the smaller area was believed to be sufficient. As reconstructed, it spread a little less than 6 sq. ft.

With this improvement our serious troubles ended, and, thereafter, we devoted ourselves to the work of gaining skill by continued practice. When properly applied, the means of control proved to possess a mastery over the forces tending to disturb the equilibrium. Since balancing was effected by adjustments of the surfaces, instead of by movements of weight, the controlling forces increased in power in the same ratio as the disturbing forces, when the machine was suddenly struck by a wind gust. For this reason, we did not seem to experience the same difficulty in managing the machine in high winds that Lilienthal, who used a different system, seems to have met.

Fully half of our glides were made in winds of 10 metres a second, over 20 miles an hour. One day we stopped gliding for a moment to take an anemometer reading and found that it indicated 16.7 metres a second, 37 miles an hour. Of course, such high winds require much greater readiness on the part of the operator than the low winds, since everything happens much more quickly, but, otherwise, the difference is not so very marked. In those machines which are controlled by the shifting of weight, the disturbing influences increase as the square of the velocity, while the controlling factor remains a constant quantity. For this reason, a limit to the wind velocity which it is possible to safely encounter with such machines is soon reached, regardless of the skill of the operator.

With the method we have been using, the capacity of control is evidently very great. The machine seems to have reached a higher state of development than the operators. As yet, we consider ourselves little more than novices in management. A thousand glides is equivalent to about four hours of steady practice, far too little to give anyone a complete mastery of the art of flying. Progress is very slow in the preliminary stages, but, when once it becomes possible to undertake continuous soaring, advancement should be rapid. Under special conditions, it is possible that this point is not so far away as might be supposed.

Since soaring is merely gliding in a rising current, it would be easy to soar in front of any hill of suitable slope, whenever the wind blew with sufficient force to furnish support, provided the wind were steady. But, by reason of changes in wind velocity, there is more support at times than is needed, while, at others, there is too little, so that a considerable degree of skill, experience, and sound judgment are required in order to keep the machine exactly in the rising current. So far, our only attempts at soaring have been made on the Little Hill, which has a slope of only 7 degrees. In a wind blowing from 11 to 16 metres a second, we frequently made glides of 8 to 15 seconds' duration with very little forward motion. As we kept within 5 ft. or 6 ft. of the ground, a momentary lessening of the wind speed, or a slight error in management, was sufficient to bring about a landing in a short time.

The wind had too little rising trend to make soaring easy. The buzzards themselves were baulked when they attempted to soar on this hill, as we observed more than once. It would be well within the power of the machine to soar on the Big Hill, which has steeper slopes, but we have not felt that our few hours of practice is sufficient to justify ambitious attempts too hastily. Before trying to rise to any dangerous height a man

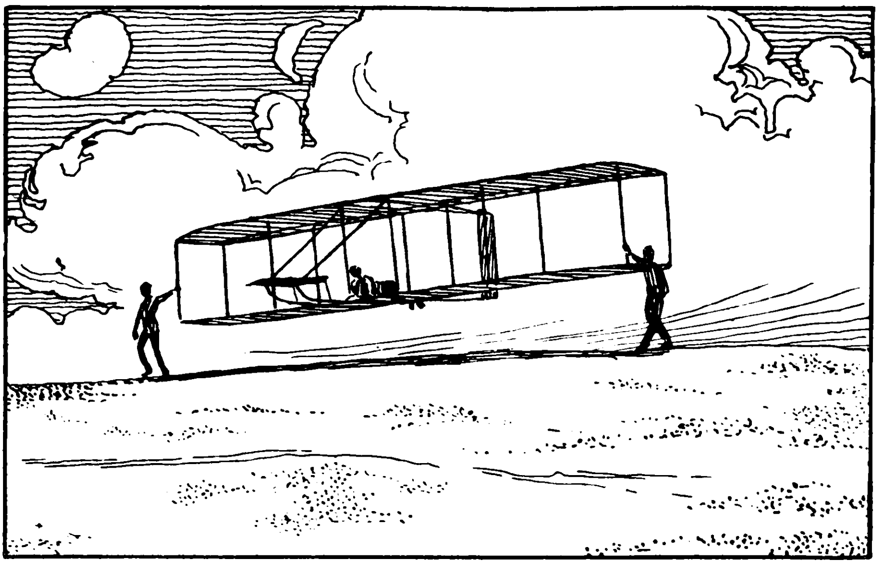


Fig. 17.—Starting a flight.

ought to know that, in an emergency, his mind and muscles will work by instinct rather than by conscious effort. There is no time to think.

During a period of five weeks, glides were made whenever the wind conditions were favourable. Many days were lost on account of rain. Still more were lost on account of light winds. Whenever the breeze fell below six miles an hour, very hard running was required to get the machine started, and the task of carrying it back up the hill was real labour. A relative speed of at least 18 miles an hour was required for gliding, while to obtain a speed of 12 miles by running required very severe exertion. Consequently, unless the wind blew in our faces with a speed of at least six miles we did not usually attempt to practise; but when the wind rose to 20 miles an hour, gliding was real sport, for starting was easy and the labour of carrying the machine back up hill was performed by the wind. On the day when the wind rose to over 16 metres a second we made more than a hundred glides with much less physical exhaustion than resulted from 20 or 30 glides on days when the wind was light.

No complete record was kept of all the glides made during the season. In the last six days of experiment, we made more than 375, but these included our very best days. The total number for the season was probably between 700 and 1,000. The longest glide was 622½ ft., and the time 26 sec.

The prime object in these experiments was to obtain practice in the management of a man-carrying machine, but an object of scarcely less importance was to obtain data for the study of the scientific problems involved in flight. Observations were almost constantly being made for the purpose of determining the amount and direction of the pressures upon the sustaining wings; the minimum speed required for support; the speed and angle of incidence at which the horizontal resistance became least; and the minimum angle of descent at which it was possible to glide.

To determine any of these points with exactness was found to be very difficult indeed, but by careful observations under test conditions it was possible to obtain reasonably close approximations. It was found that a speed of about 16 miles an hour would produce a pressure sufficient to support machine and operator, but the angle of incidence was too great for general gliding purposes. At 18 miles, the angle of incidence was about 8 degrees, and the machine would glide on the Little Hill, descending at an angle of a little over 7 degrees. Although the

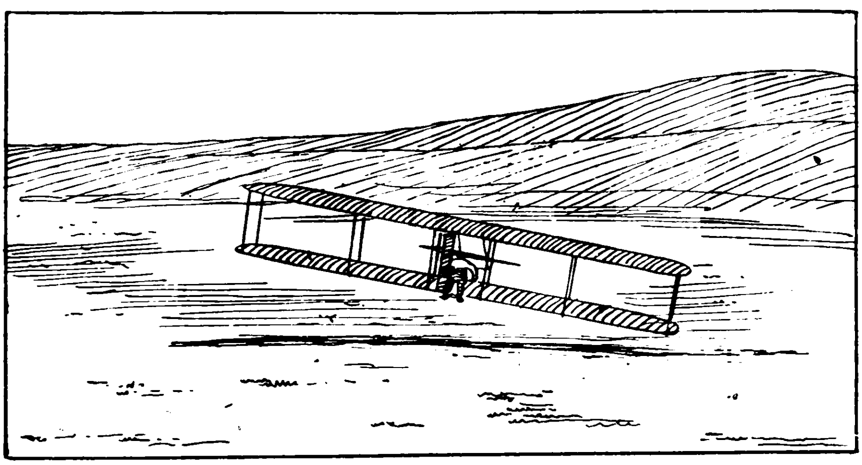


Fig. 18.—Making a turn to the right.

wings were inclined slightly above the horizon, the machine continued to glide without loss of velocity. With a speed of 22 miles an hour, the angle of incidence required for support was 4 or 5 degrees, and the angle of descent a little less than 7 degrees. At this speed, the surfaces were inclined several degrees below the horizon. As the speed became greater, the angle of incidence continued to grow less, but the angle of descent became greater again, thus showing that the point of minimum resistance had been passed. Scores of glides were made at angles of descent under 6 degrees, and, in a few cases, we reached 5 degrees. On the last day of experiment, we made a few attempts at records. A line was drawn a short distance up the slope as a starting mark, and four trials were made. Twice the machine landed on the same spot. The distance was $156\frac{1}{2}$ ft., and the angle of descent exactly 5 degrees. Time, $6\frac{1}{2}$ sec. From a point higher up the slope, the best angle was 5 degrees and 25 min. for a glide of 225 ft. Time, $10\frac{1}{4}$ sec. The wind was blowing about nine miles an hour. The glides were made directly to windward and straight down the slope. Taking 7 degrees as a conservative estimate of the normal angle of descent, the horizontal resistance of the machine was 30 lb., as computed by multiplying the total weight, 250 lb., by the tangent of the angle of descent. This resistance remained nearly constant at speeds between 18 and 25 miles an hour. Above or below these limits, there was a somewhat rapid increase. At 18 miles, the power consumed was $1\frac{1}{2}$ h.p.; at 25 miles, 2 h.p. At the lower speed, 166 lb. were sustained for each horse-power consumed; at the higher speed, 125 lb. per horse-power. Between 18 and 25 miles, the horse-power increased almost in exact ratio in the increase in speed, but above or below these limits the power increased rapidly, and with a constantly accelerating ratio.

On two occasions we observed a phenomenon whose nature we were not able to determine with certainty. One day my brother noticed, in several glides, a peculiar tapping, as if some part of the machine were loose and flapping. Careful examination failed to disclose anything about the machine which could possibly cause it. Some weeks later, while I was making a glide, the same peculiar tapping began again in the midst of a wind gust. It felt like little waves striking the bottom of a flat-bottomed row-boat. While I was wondering what the cause could be, the machine suddenly, but without any noticeable change in its inclination to the horizon, dropped a distance of nearly 10 ft., and in the twinkling of an eye was flat on the ground. I am certain that the gust went out with a downward trend, which struck the surfaces on the upper side. The descent was at first more rapid than that due to gravity, for my body apparently rose off the machine till only my hands and feet touched it. Toward the end the descent was slower. It may be that the tapping was caused by the wind rapidly striking the surfaces alternately on the upper and the lower sides. It is a rule almost universal that gusts come on with a rising trend and die out with a descending trend, but, on these particular occasions, there must have been a most unusual turmoil during the continuance of the gust which would have exhibited a very interesting spectacle had it been visible to the eye.

Irregularities of the wind are most noticeable when the wind is high, on account of the greater power then exhibited, but light winds show almost equal relative variations. An aviator must expect to encounter in every flight variations in velocity, in direction, and in upward or downward trend. And these variations not only give rise to those disturbances of the equilibrium which result from the travel of the centre of pressure due to the changed angle of incidence, but also, by reason of the fact that the wind changes do not occur simultaneously or uniformly over the entire machine, give rise to a second series of disturbances of even more troublesome character. Thus, a gust coming on very suddenly will strike the front of the machine and throw it up before the back part is acted upon at all. Or the right wing may encounter a wind of very different velocity and trend from the left wing and the machine will tend to turn over sideways. The problem of overcoming these disturbances by automatic means has engaged the attention of many very ingenious minds, but, to my brother and myself, it has seemed preferable to depend entirely on intelligent control. In all of our machines the maintenance of the equilibrium has been dependent on the skill and constant vigilance of the aviators.

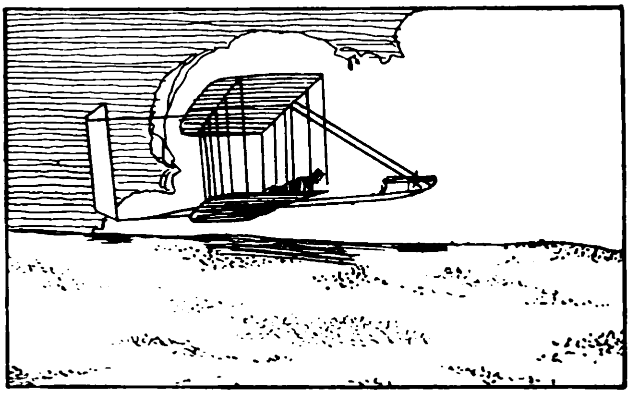


Fig. 19.—Skimming the ground.

In addition to the work with the machine we also made many observations on the flight of soaring birds, which were very abundant in the vicinity of our camp. Bald eagles, ospreys, hawks, and buzzards gave us daily exhibitions of their powers. The buzzards were the most numerous and were the most persistent soarers. They apparently never flapped except when it was absolutely necessary, while the eagles and hawks usually soared only when they were at leisure. Two methods of soaring were employed. When the weather was cold and damp and the wind strong, the buzzards would be seen soaring back and forth along the hills, or at the edge of a clump of trees. They were evidently taking advantage of the current of air flowing upward over these obstructions. On such days they were often utterly unable to soar, except in these special places. But on warm, clear days, when the wind was light, they would be seen high in the air soaring in great circles. Usually, however, it seemed to be necessary to reach a height of several hundred feet by flapping before this style of soaring became possible. Frequently a great number of them would begin circling in one spot, rising together higher and higher till finally they would disperse, each gliding off in whatever direction it wished to go. At such times other buzzards only a short distance away found it necessary to flap frequently in order to maintain themselves. But when they reached a point beneath the circling flock, they began to rise on motionless wings. This seemed to indicate that rising columns of air do not exist everywhere, but that the birds must find them. They evidently watch each other, and when one finds a rising current the others quickly make their way to it. One day, when scarce a breath of wind was stirring on the ground, we noticed two bald eagles sailing in circling sweeps at a height of probably 500 ft.

After a time our attention was attracted to the flashing of some object considerably lower down. Examination with a field glass proved it to be a feather which one of the birds had evidently cast. As it seemed apparent that it would come to earth only a short distance away, some of our party started to get it. But in a little while it was noticed that the feather was no longer falling, but, on the contrary, was rising rapidly. It finally went out of sight upward. It apparently was drawn into the same rising current in which the eagles were soaring, and was carried up like the birds.

The days when the wind blew horizontally gave us the most satisfactory observations, as then the birds were compelled to make use of the currents flowing up the sides of the hills, and it was possible for us to measure the velocity and trend of the wind in which the soaring was performed. One day four buzzards began soaring on the north-east slope of the Big Hill at a height of only 10 ft. or 12 ft. from the surface. We took a position to windward and about 1,200 ft. distant. The clinometer showed that they were $4\frac{1}{2}$ to $5\frac{1}{2}$ degrees above our horizon. We could see them distinctly with a field glass. When facing us, the under side of their wings made a broad band on the sky, but when, in circling, they faced from us, we could no longer see the under side of their wings. Though the wings then made a little more than a line on the sky, the glass showed clearly that it was not the under side that we saw. It was evident that the buzzards were soaring with their wings constantly inclined about five degrees above the horizon. They were attempting to gain sufficient altitude to enable them to glide to the ocean beach three-fourths of a mile distant, but, after reaching a height of about 75 ft. above the top of the hill, they seemed to be unable to rise higher, though they tried a long time. At last they started to glide toward the ocean, but were compelled to begin flapping almost immediately. We at once measured the slope and the wind. The former was $12\frac{1}{2}$ degrees; the latter was six to eight metres per second. Since

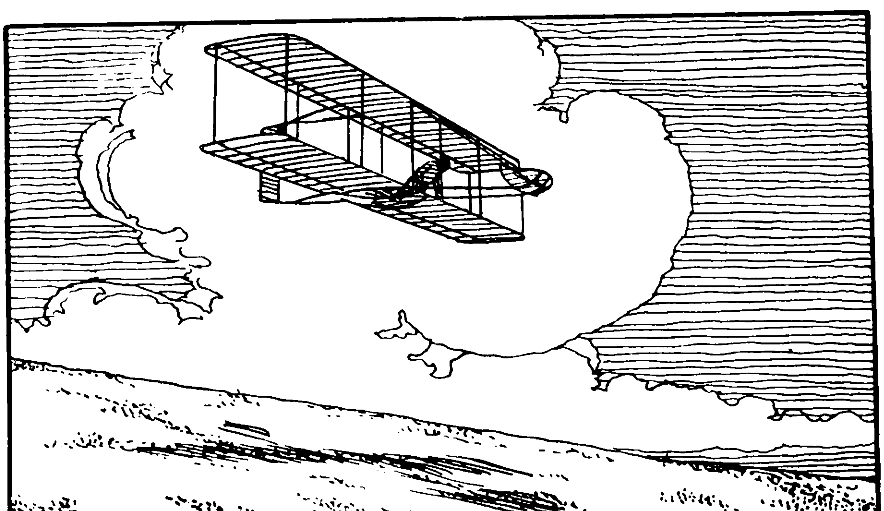


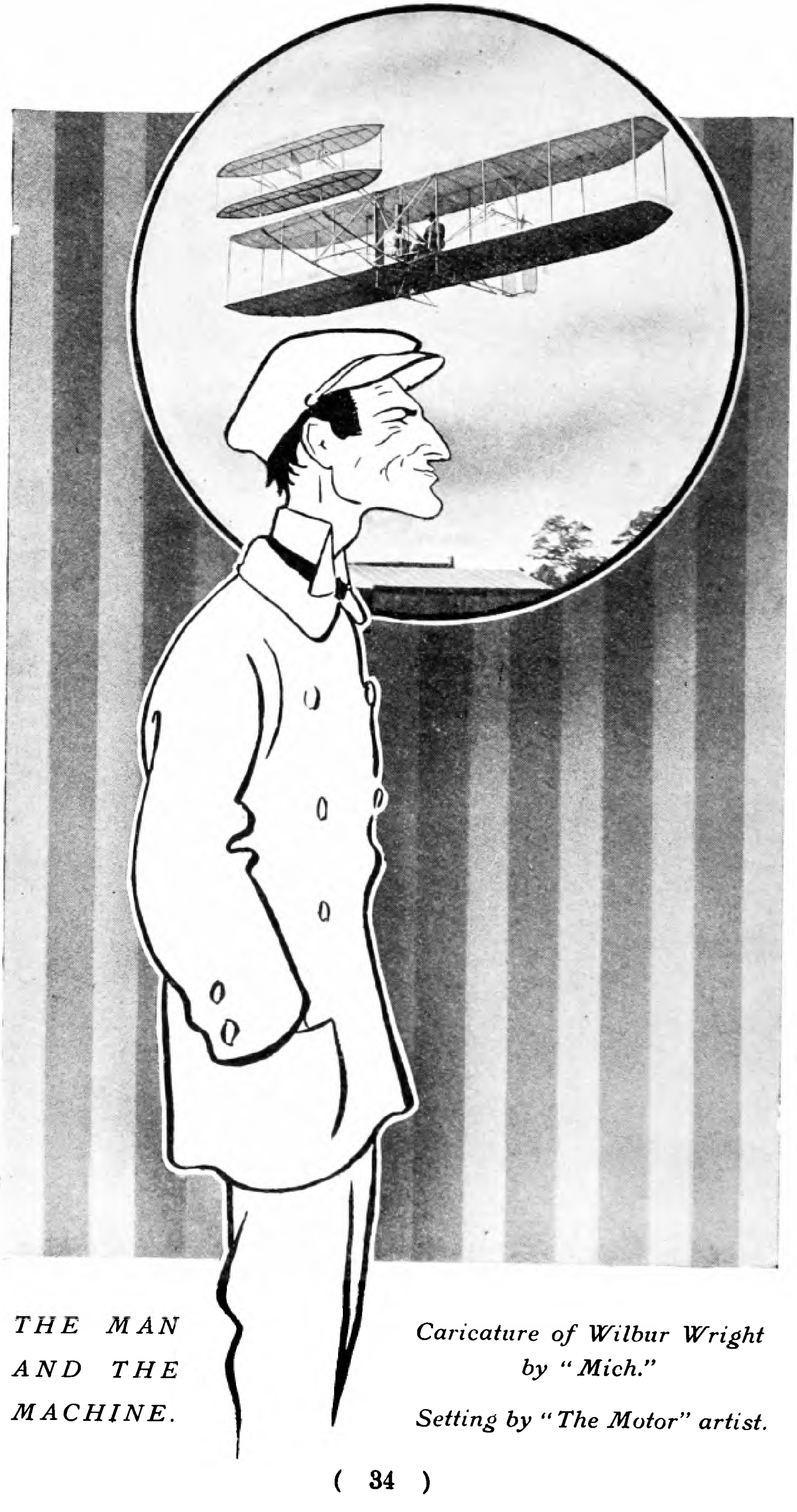
Fig. 20.—One of the most satisfactory flights.

the wings were inclined five degrees above the horizon and the wind had a rising trend of fully 12 degrees, the angle of incidence was about 17 degrees. The wind did not average more than seven metres—15 miles an hour. For the most part the birds faced the wind steadily, but in the hills they were compelled to circle or glide back and forth, in order to obtain speed sufficient to provide support. As the buzzard weighs about .8 lb. per square foot of wing area, the lifting power of the wind at 17 degrees angle of incidence was apparently as great as it would have been had it been blowing straight upward with equal velocity. The pressure was inclined five degrees in front of the normal, and the angle of the descent was 12½ degrees.

On another day I stood on top of the West Hill, directly behind a buzzard which was soaring on the steep southern slope. It was just on a level with my eye and not more than 75 ft. distant. For some time it remained almost motionless. Although the wings were inclined about five degrees above the horizon, it was not driven backward by the wind. This bird is specially adapted to soaring at large angles of incidence in strongly-rising currents. Its wings are deeply curved. Unless the upward trend amounts to at least eight degrees, it seems to be unable to maintain itself. One day we watched a flock attempting to soar on the west slope of the Big Hill, which has a descent of nearly nine degrees. The birds would start near the top and glide down along the slope very much as we did with the machine, but we noticed that whenever they glided parallel with the slope their speed diminished, and when their speed was maintained the angle of descent was greater than that of the hill. In every case they found it necessary to flap before they had gone 200 ft. They tried time and again, but always with the same results. Finally, they resorted to hard flapping until a height of about 150 ft. above the top of the hill was reached, after which they were able to soar in circles without difficulty.

On another day they finally succeeded in rising on almost the same slope, from which it was concluded that the buzzards' best angle of descent could not be far from eight degrees. There is no question in my mind that men can build wings having as little as, or less relative resistance than, that of the best soaring birds.

The bird's wings are undoubtedly very well designed indeed, but it is not any extraordinary efficiency that strikes with astonishment, but rather the marvellous skill with which they are used. It is true that I have seen birds perform soaring feats of almost incredible nature in positions where it was not possible to measure the speed and trend of the wind, but whenever it was possible to determine, by actual measurement, the conditions under which the soaring was performed, it was easy to account for it on the basis of the results obtained with artificial wings. The soaring problem is apparently not so much one of better wings as of better operators.



THE MAN AND THE MACHINE.

Caricature of Wilbur Wright by "Mich."

Setting by "The Motor" artist.

THE PRINCIPLES UNDERLYING HUMAN FLIGHT.

There are three stages in which the study of the principles of aviation must be taken, whether the investigation be experimental or theoretical. It is necessary first to discover means whereby the weight which is to be carried can be supported in the air. Secondly, the machine must be so designed that, when in the air, it will not capsize if its direction be altered slightly or if the velocity of the wind change. Lastly, when an efficient glider has been evolved, the question of a suitable propelling agency has to be considered, or in the words of Lilienthal, "stability first, propulsion afterward."

Everyone is aware of the force with which the wind can blow and of the pressure that it can exert on buildings and walls exposed to the fury of its blast. To utilize this force for lifting any weight into the air, some sort of exposed surface must be employed in such a manner that the wind, in blowing against it, exerts an upward supporting force.

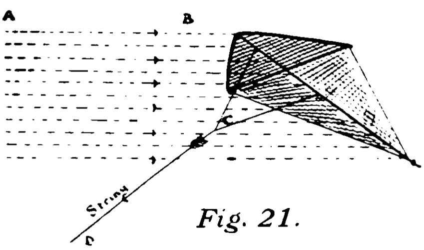


Fig. 21.

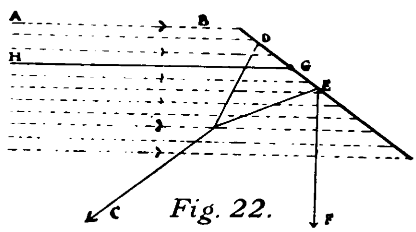


Fig. 22.

An ordinary kite is an example of the way in which this principle is put into practical use. Let the kite be represented as in Fig. 21, with the wind blowing as shown by the arrows in the direction A B, and with the string by which the kite is flown being pulled in the direction C D. If the weight be far enough back and the string properly fixed, the kite will be inclined at an angle to the wind, which, blowing upon the surface, will then exert a lifting force upon the kite. A diagram of the forces acting on the kite is given in Fig. 22. There are the downward pull on the string in the direction D C, the upward pressure of the wind, which may be considered as acting at the "centre of pressure" of the kite surface, and the weight of the kite. The force due to the latter acts downward at the centre of gravity. When the kite is being flown in the air, these three forces are balanced, the tail supplying the steadying effect.

Thus far, it is the question of a wind blowing against a stationary surface that has been considered, but a similar lifting effect can be obtained if the air be still and the surface be moved through it. The only necessary condition is that the air must meet the surface at such an angle that a downward velocity be given to it after the plane has passed over it. The actual velocity of flight that is required will depend on the

C2

amount of weight that has to be carried, and on the supporting surface that is used. The greater the weight or the less the surface, the greater must be the speed of the machine, and vice versâ.

Just as in flying a kite in the air a considerable pull must be exerted on the string by which it is flown, so in an aeroplane or glider which is in flight there must be a force exerted to push it through the air. This force has to overcome the resistance caused by pushing the framework, etc., of the machine through the air, and is similar in effect to that which has to be exerted to drive a car at high speeds. It is usually termed the "drift," as distinguished from the upward or lifting force called the "lift." Both lift and drift will vary considerably with different types of machines, with the loads carried, and with the speeds of flight. If, however, the area of supporting surface and the weight that has to be carried both be limited, it is evident that, by trying all manner of shapes of plane with varying cross-sections and thicknesses, different values for the drift will be obtained, supposing that in each case the area were sufficient to support the weight. The most efficient shape would be that requiring the least force to push it through the air, that is it would have the least drift. For this plane the ratio of lift/drift would be the highest.

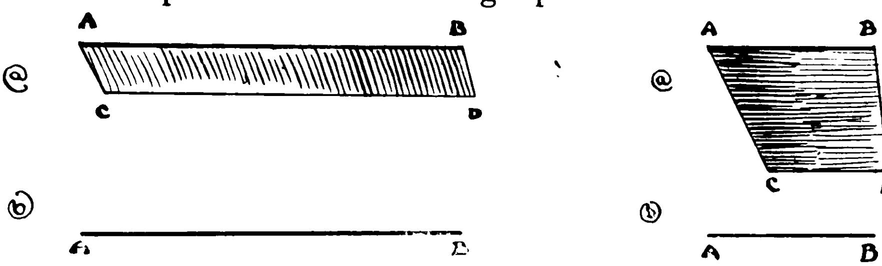
The aim in designing an aeroplane is to make this value as high as possible, provided that it does not involve a very high speed of flight. It is well to investigate the factors on which the efficiency depends.

If one could see the air as the plane meets it when gliding, it would be apparent that the air does not flow closely round the contour of the plane but forms a "dead water" region at the back of the plane. With the plane inclined at a large angle the effect is much more pronounced, usually resulting in turbulence, i.e., a churning up of the air all round the surface of the plane. This turbulent effect requires energy to set it in motion, so that if one obtains a certain lift with a plane the drift will be much less if the turbulence can be eliminated. This is effected by making the cross-section of the planes such that it is of "stream line" form, so that the air flows evenly around with a minimum disturbance.

The pioneer work in the experimental investigation of the best form to be used for plane cross-section was carried out by Horatio Phillips, whose dipping front edge forms are treated in a separate chapter in the book.

Phillips also advocates the use of wood for plane surfaces, because it forms a hard polished surface, offering much less resistance than a surface formed of canvas stretched over a frame. For Phillips's machine (described on page 46) wood was, no doubt, the best substance, but, for the modern aeroplane, its weight would, probably, be excessive.

In addition to the cross-section of the planes there is still the plan form to be considered, and this, too, has a considerable effect on the efficiency. The ratio of the spread of the planes to the fore and aft depth is usually termed the "aspect ratio" of the plane. It has been found experimentally, with a plane in which the span or spread is large compared with the fore and aft depth, or in other words with one where the aspect ratio is large, that the efficiency is much greater than where the span is smaller and the depth greater. The reason for this will be easily understood from a consideration of Figs. 23 and 24, where there are shown planes of small and large span.



Figs. 23 and 24, showing aspect ratios.

The air meets the " cutting edge " A B of the large span plane (Fig. 23) and is deflected downwards at the angle at which the plane is placed, causing a difference of air pressure between the upper and lower surface of the plane. This pressure difference between the air above and below the plane tends to set up a flow of air from below to above, with a greater loss of energy in the case of the small-span plane with its wide ends than in the case of the narrow plane. In addition, practically the whole of the narrow plane surfaces is effective in acting on the air, whereas with the wide plane the rear edge is to a certain extent shielded by the front and exerts very little effect on the air, to which a downward velocity has already been imparted.

Many of the modern aeroplanes have one, two, three, and sometimes more surfaces arranged in various ways according to the inventor's design.

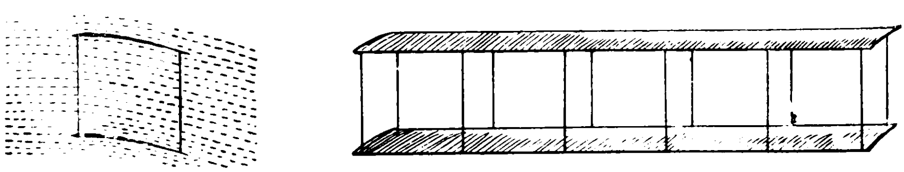
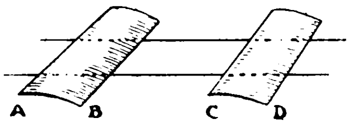
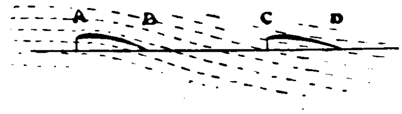


Fig. 25.—Superposed biplane.

The single surface or monoplane acts upon air which is undisturbed both above and below the plane. Where two planes are superposed as in Fig. 25, even if they be spaced a good distance apart, the lifting effect is not twice that of the single one, for they both act to a certain extent on the same cushion of air. With a triplane or multiplane this relative diminution of lifting effort is even more pronounced.

Instead of fitting the planes one above the other they may be placed in tandem, as shown in Fig. 26. Fig. 27 shows the end view and how the air would flow round such an arrangement. The back plane would be in the wash of the front plane, and, if placed at all close to the first one, would have to be inclined at a much greater angle to have any effect at all. It is doubtful if





Figs. 26 and 27.—Tandem biplane.

the efficiency of this system is as high as the previous one, in which the planes are superposed.

There are many combinations of the above two systems, such as a double biplane, a quadruplane, etc. In most machines planes for steering and balancing are used in addition to the main planes, but they are small in comparison with the main ones, and do not need to be considered in regard to their lifting effect.

The stability of the machine when in the air depends on the movement of the " centre of pressure " of the supporting surface, and it will be well to consider this factor, which has already been mentioned above.

If, as in Fig. 28, there is a wall A B exposed to the force of the wind which is blowing in the direction D A, a certain pressure is exerted on the wall tending to blow it over. Instead of supposing the air to be rushing against the whole surface of the wall, it can be imagined to concentrate in one strong jet. By choosing the point on the surface where this jet should then act, there could be obtained just the same tendency for the wall to be blown over as with the wind blowing over the whole surface. For the sake of clearness the pressure due to the wind is imagined to be concentrated thus at a point. This point is termed the centre of pressure.

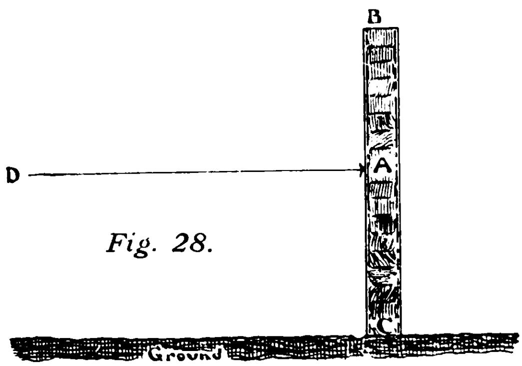


Fig. 28.

Turning to the study of an aeroplane in the air, there are two forces acting upon it: the upward lift due to the air and the force due to the weight acting downward. The upward lift will act at the " centre of pressure " and the other force at the centre of gravity. Fig. 29 represents this diagrammatically. A B is the end view of the aeroplane, E C is the direction of the upward force acting at the centre of pressure C, and D F is the weight acting downward at the centre of gravity D.

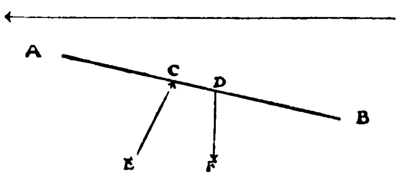


Fig. 29.

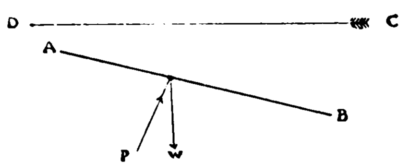


Fig. 30

Neglecting the question of propulsion for the moment, these are the only two forces that need be considered, and if they are balanced there will be no tendency for the machine to capsize. As shown in Fig. 29, the centre of pressure is ahead of the centre of gravity, and if this state of affairs were allowed to continue the front of the machine would tip right over. Some means must therefore be employed whereby if the machine is balanced when the aeroplane is inclined at a certain angle, the aeroplane will come back to the correct angle if the latter is altered. There are two ways of effecting this, one being by hand control as in the Wright machine and the other being more or less automatic.

In the Wright machine the tips of the planes are flexible and their angle of incidence to the air can be altered by a controlling device operated by the aeronaut. This, in conjunction with the rudders, is continually in operation by the aviator, so that the centre of pressure of the planes is made always to coincide with the centre of gravity.

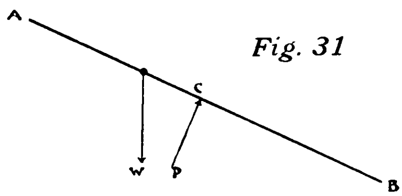


Fig. 31

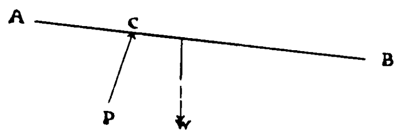


Fig. 32.

Automatic stability depends for its action upon the movement of the position of the centre of pressure when the angle of incidence varies. It is found that, as the angle of incidence decreases, the position of the centre of pressure moves forward towards the front edge of the plane, and vice versâ. This does not hold good for one or two shapes of planes if the angle is less than 10 degrees, as will be explained later. When the angle of incidence increases, the reverse takes place, the centre of pressure moving backward away from the front edge.

Let it be supposed that there is a plane A B (see Fig. 30) moving through the air in the direction C D shown by the arrow. Let it also be supposed that the whole arrangement is balanced for the speed at which it is travelling, i.e., the positions of the centres of pressure and gravity coincide. At any moment it is possible that the speed of the wind may suddenly increase, and at that instant the machine, which will still be travelling at the same speed relatively to the earth, will meet the air at a greater velocity. The lifting effect is increased and the nose of the machine will rise in the air. The angle at which the surface meets the air is now greater and the centre of pressure will move back to some point (C) as shown in Fig. 31.

From this diagram it will be seen that the force due to the weight is trying to pull the nose down and the upward pressure is trying to push the tail up. The result is that the angle of incidence will be altered, until it takes the original value as indicated in Fig. 30, where the positions of the centres of pressure and gravity coincide.

The opposite effect is shown in Fig. 32. If a wind were

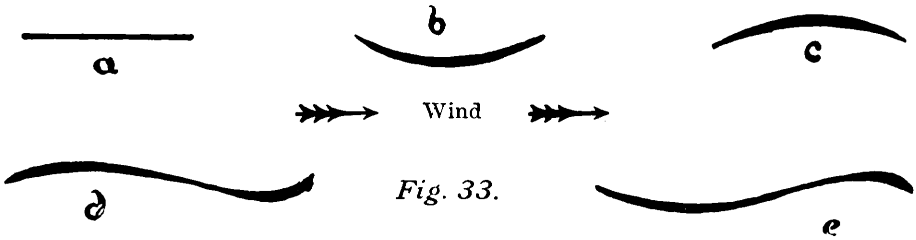


Fig. 33.

blowing when the machine was travelling in a balanced state and then suddenly dropped, the speed of the machine relatively to the air would not be sufficient for support. The front edge would drop, the machine tending to dive to get up the necessary speed. The angle of incidence is diminished and the centre of pressure moves forward. There is then the upward pressure acting at some point (C) tending to push the nose up, while the weight is tending to pull the tail down. The net result is that the machine, having got up speed, resumes the position of equilibrium shown in Fig. 30.

It is evident that, in a wind which is constantly changing and gusty, some auxiliary device is necessary to damp any oscillations that may take place in the line of flight due to the changes in the position of the centre of pressure. This is to a large extent effected by making the rear edge of the plane flexible, but hand operation of the steering devices must also be used to " trim " the machine occasionally. This is based upon the assumption that the centre of pressure will always move towards the front edge as the angle of incidence decreases. This, however, is not the case with every type of plane. It has been found experimentally that, of the planes with cross sections as shown in Fig. 33, this change in position of the centre of pressure only occurs with those of section similar to (a), (b) and (d). If the planes are of the cross section (c) or (e), the centre of pressure moves forward until a certain critical angle of incidence is reached, and after this it moves backward. If one wish to make the plane stable without any auxiliary device, its cross section must be shaped similiar to (a), (b) or (d).

The lateral balance of the machine in the direction of line of flight can be made to a certain extent automatic by inclining the two sides of the plane at a dihedral angle as in Fig. 34 (a),

Fig. 34.

or by turning up the tips of the wings as at (b) or (c). The addition of a keel also improves the stability.

The proper shaping of the cross section of the planes so as to make them of " stream line " form greatly increases the efficiency, and every part should be torpedo-shaped, which allows the air to flow round the body with a minimum disturbance. It is also necessary to have the surface of all exposed parts as taut as possible. Wherever there is a looseness, the covering will bag and little pockets will be formed, all tending to increase the resistance of the machine.

BRIEF HISTORY OF THE AEROPLANE MOVEMENT.

I.—Early History.

To Leonardo da Vinci, the versatile Italian genius, famed equally for his work in painting, sculpture, music, architecture, mathematics and physical science, belongs the honour of having first set on paper some rational notions of human flight. Several remarkable principles are to be found in da Vinci's manuscript. He shows very clearly that he understood the relation between the centre of pressure and the centre of gravity, for he states that a bird which finds itself in equilibrium with the centre of resistance of the wings more forward than the centre of gravity will descend with the head inclined downwards.

This he wrote after a note on "The kite and other birds which beat their wings little, go seeking the course of the wind, and when the wind prevails on high, then will they be seen at a great height, and if it prevails low they will hold themselves low. When the wind does not prevail at all, then the kite beats its wings several times in its flight in such a way that it raises itself high and acquires a start, descending afterwards a little and progressing without beating its wings, repeating the same performance time after time."

An even clearer exposition of the principles of flight is shown by his note that the bird that wishes to rise "will raise its shoulders so that the air may press between its sides and the tip of the wings, so that the air will be condensed and will give the bird the movement towards the ascent and will produce a momentum in the air which will push the bird upward."

Further, this remarkable genius of the 15th century states that when, without the help of the wind, the bird remains in the air without flapping its wings, this shows that the centre of its resistance coincides with its mass centre. In referring to his classical illustration of a man in a flapping-wing machine, he foresaw that the chief difficulty in gliding or soaring is to keep the centre of gravity at all times in the right place. In one of his notes he wrote that the man in the flying machine should "be free from the waist upwards in order that he might keep himself in equilibrium as one does in a boat, so that the centre of his gravity and that of the apparatus may set itself in equilibrium and change, when needful, as the centre of resistance changes."

Leonardo da Vinci, born in 1452, died in 1519, and there can be no doubt that this extraordinary man was the first to recognize, as he was certainly the first to enunciate, the elementary principles of flight, and he should be given foremost rank in the annals of aeronautics. The only picture of him which exists is a peculiar proof of his versatility, the picture having been drawn by himself in red chalk; it now hangs in the Royal library at Turin.

The Italian master's work is generally prefaced by a reference to the legends of Dædalus, Icarus and others, which merely show how the problem of human flight captivated the imagination of men from the earliest times of which records exist. In every country, also, the folk-lore is rich in tales of flying men, but in none more than in the Scandinavian countries. These tales it is hard to accept as well-founded.

There may, perhaps, be truth in the legend of Simon the Magician, who during the reign of the Emperor Nero attempted

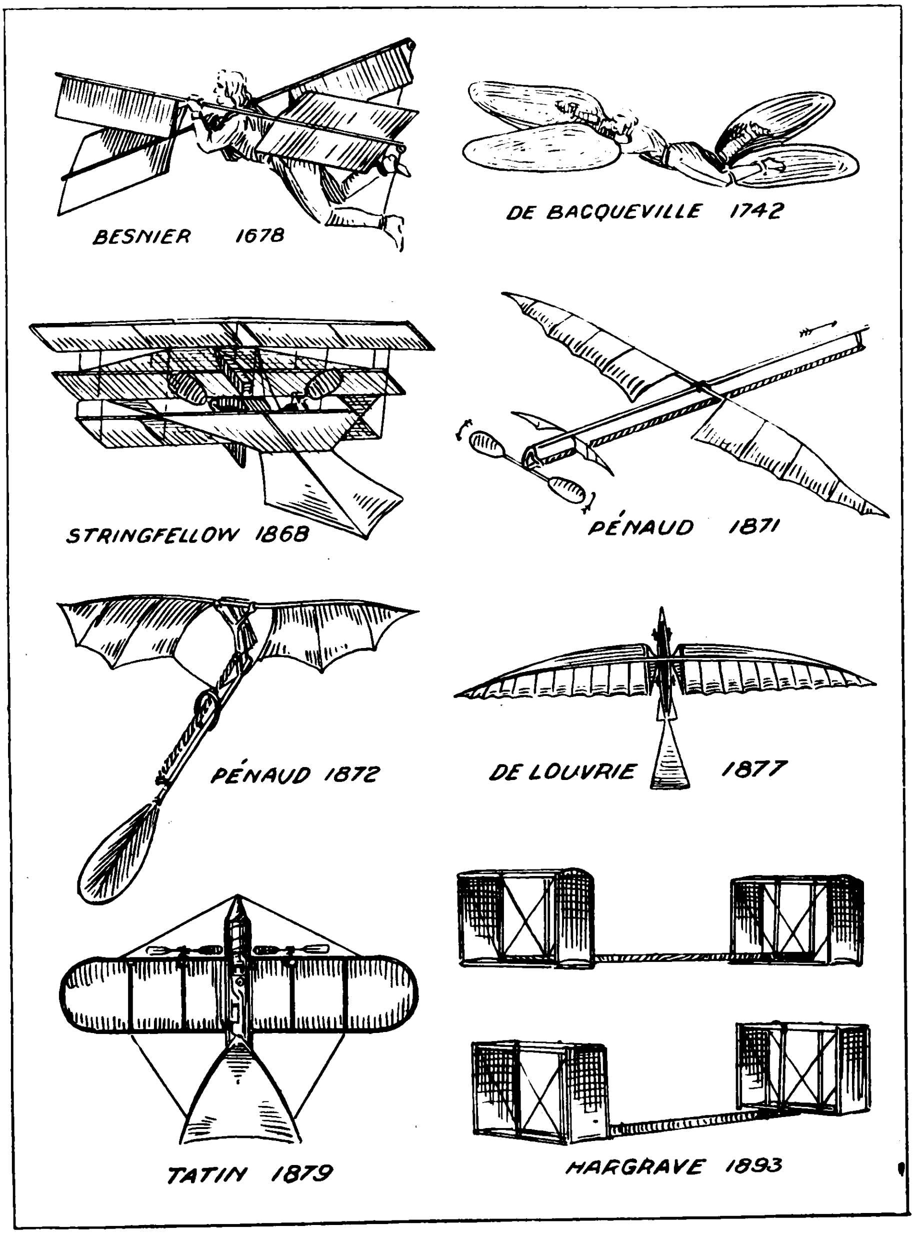


Fig. 35.—A page of early history

"to rise towards heaven." The legend recounts that Simon rose in the air "through the assistance of Beelzebub," but that St. Peter offered up a prayer, the power of the demon was crushed and the magician fell to earth and was killed by the fall. It is possible that the man used a large plane surface and that he discovered, by accident or otherwise, that he could in that manner be lifted from the earth if he made use of a rising current of air. In the southern countries the vertical air currents are very much more frequent than they are in this country, for which reason the soaring birds are in those regions far more common.

An English Benedictine monk, Elmerus or Oliver, of Malmesbury, appears to have used wings (whether flapping or fixed the tradition does not state), and to have sprung from the top of a tower against the wind. He is said to have actually glided for some distance and then to have experienced a sudden fall, which broke his legs, preventing further experiments. That was in the 11th century, and the flight may just as well have taken place as that of the Saracen who towards the end of the 12th century glided from the top of a tower in Constantinople. The account given in the history of Constantinople by Cousin very clearly describes the apparatus used. The man was clothed in a white robe, the folds of which were stiffened by willow wands, to serve as sails for the wind. Evidently he was making use of rigid surfaces in place of the flapping wings which earlier legends record. In the presence of the Emperor the Saracen waited until he caught a favourable wind, and then "rose in the air like a bird," but, like most of the early investigators of flight, he fell and broke his bones, the accident causing considerable merriment, so the historian relates.

Towards the end of the 14th century Dante, the Italian mathematician, is recorded to have flown with artificial wings over Lake Trasimene. Later he tried to improve upon this experiment by jumping from the top of the highest tower in his native city of Perugia. He sailed over the crowd in the public square beneath, and was supported for a long time stationary in the air, but the iron forging which controlled his left wing is said to have broken and to have been the cause of his unchecked drop upon the roof of a neighbouring church. Having broken one leg in the experiment, he abandoned his efforts to solve the problem of flying.

There is, until the beginning of the 19th century, no further interesting history to relate, the numerous attempts at flight that were made in France (especially at the courts of Louis XIV. and Louis XV.) showing no proof of any great genius, all the investigators—of whom those that did not kill themselves were at least seriously injured—being men of ambition who sought the favour of the French kings. Most of them used four wings, some operated respectively by the hands and feet, as that of Besnier.

II.—In England: From Cayley to Modern Times.

At the commencement of the 19th century there arose another great student of flight, Sir George Cayley, whose writings might be read with benefit by many at the present day, for he certainly had very clear notions of what was required and how it had to be done.

Sir George Cayley was the first to point out that two planes at a dihedral angle form a basis of stability. For, if the machine heel over, the side which is required to rise gains resistance by its new position, and that which is required to sink loses it, the operation very much resembling what takes place in an ordinary boat. In dealing with the principle of stability in the direction of the path of the machine, he pointed out that experiments showed that in very acute angles with the current the centre of resistance in a plane does not coincide with the centre of its surface, but is considerably in front of it. As the obliquity of the current decreases these centres approach and coincide when the current becomes perpendicular to the sail. Hence, any heel of the machine backward or forward removes the centre of support behind or before the point of suspension, and operates to restore the original position by a power equal to the whole weight of the machine acting upon a lever equal in length to the distance the centre has moved. To render the machine perfectly steady and to enable it to ascend and descend in its path it becomes necessary, he wrote, to add a rudder in a similar position to the tail in birds.

In 1809 he made a machine with a surface of 300 sq. ft., which was accidentally broken before there was an opportunity of testing the effect of its propelling apparatus. Its steerage and steadiness were perfectly proved, so he relates, and when any person ran forward with it at full speed, taking advantage of a gentle breeze in front, it would frequently lift him up and convey him several yards. For his motive power he endeavoured to obtain a steam engine working at a very much higher pressure than the couple of pounds per square inch which was usual in those days, and he also invented a gunpowder engine. It is probable that it was simply owing to the fact that there was at that time no light prime mover that his experiments did not lead him further.

He fully recognized the importance of eliminating every possible rib or strut that could offer any resistance to the air, the poles that were used in his wings being covered with the cloth that formed the plane. He was also aware that the shape of the after part of any body offering resistance to motion through the air was of as much importance as that of the front portion.

It is said that some ten years later he succeeded with mechanical power in raising a man from the ground with his apparatus, but this has not been properly authenticated.

From that time most of the serious work connected with human flight in heavier-than-air machines was carried out in England until Lilienthal made his famous experiments in Germany.

About 30 years after Sir George Cayley first made public his researches into the problem of flight there came Henson, who patented a large aeroplane of canvas, stretched upon a rigidly-trussed frame and propelled by screws operated from a steam engine. In his patent specification he gave the surface of the planes as measuring 4,500 sq. ft., that of the tail being 1,500 sq. ft. extra, and with a total weight of 3,000 lb. he intended to use an engine of 25 h.p. His drawings show the main surface to have been about 150 ft. in spread by about 32 ft. in

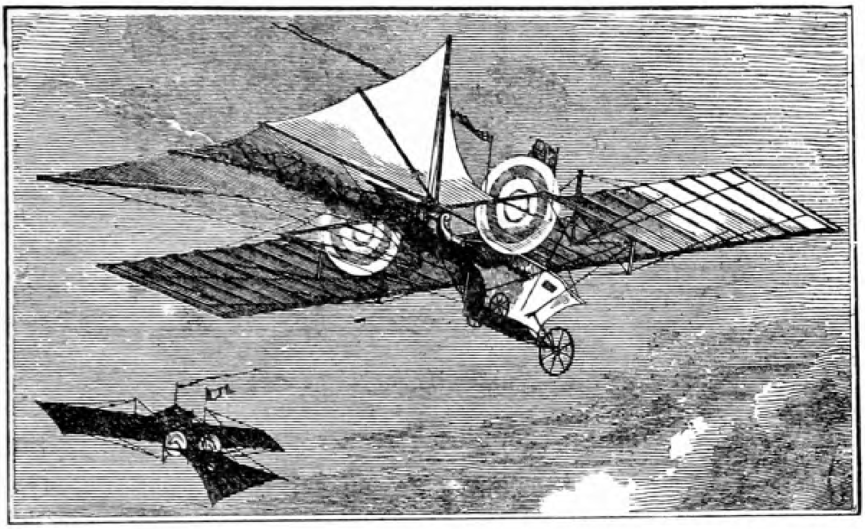


Fig. 36.—Henson's projected aeroplane of 1814.

length, but Henson never completed such a machine. With his friend, Stringfellow, he completed in 1845 a model of 70 sq. ft., weighing just under 30 lb. It is evident from the accounts of these experiments that the machine lacked stability and was never able to make any flight. Stringfellow later, on his own account, made a much more stable model, which he found was able to sustain itself in the air in an enclosed space, but not out of doors.

The most important contribution to aeronautical knowledge before the modern era of flight commenced was afforded by Mr.

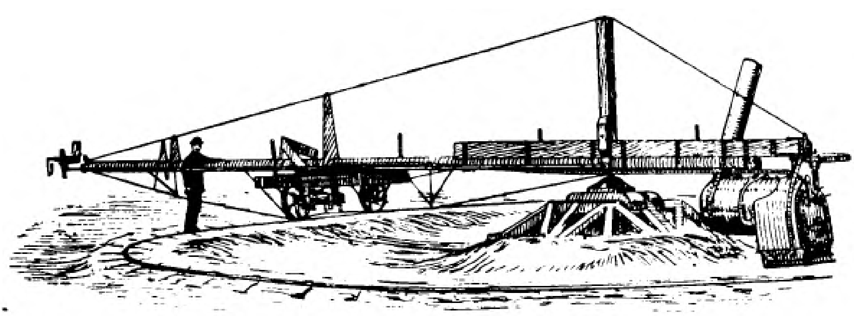


Fig. 37.—Phillips's whirling machine for testing the lifting power of planes.

Wenham in 1866. He was the first to point out that the supporting surface of an aeroplane could be best utilized by disposing it in such a manner that it offered a broad spread with little fore and aft depth, instead of arranging it with considerable depth. He entirely repudiated all imitations of natural wings, but considered that a successful flying apparatus could be constructed. He actually made a large model of a kite or glider sufficient to carry the weight of a man, the supporting surface being arranged in six narrow planes after the fashion of a venetian blind. His diagram shows that he intended the operator to lie prone, just as the Wright Brothers did in their early experiments. He found that when the wind approached 15 or 20 miles per hour the lifting power of this apparatus was all that was required, but the capricious nature of the ground currents was a perpetual source of trouble. Wenham is also notable for having first used the hyperbole of a man skating over thin ice, the ice not being deflected in any way so long as rapid motion is maintained. This same illustration was later used by Langley.

Wenham, like most other capable students of flight, based all his theories upon the soaring powers of birds, and his great theory was published in this form: "Having remarked how thin a stratum of air is displaced between the wings of a bird in rapid flight, it follows that, in order to obtain the necessary length of plane for supporting heavy weights, the surfaces may be superposed or placed in parallel rows with an interval between them. A dozen pelicans may fly one above the other without mutual impediment, as if framed together, and it is thus shown how 2 cwt. may be supported in a transverse distance of only 10 ft."

Phillips, who, in 1884, patented the dipping-edge section of planes, expended a considerable amount of time and money with a peculiar form of flying machine previous to 1893. The apparatus had the appearance of a huge venetian blind with the slats open, the total number of slats or sustainers being 50,

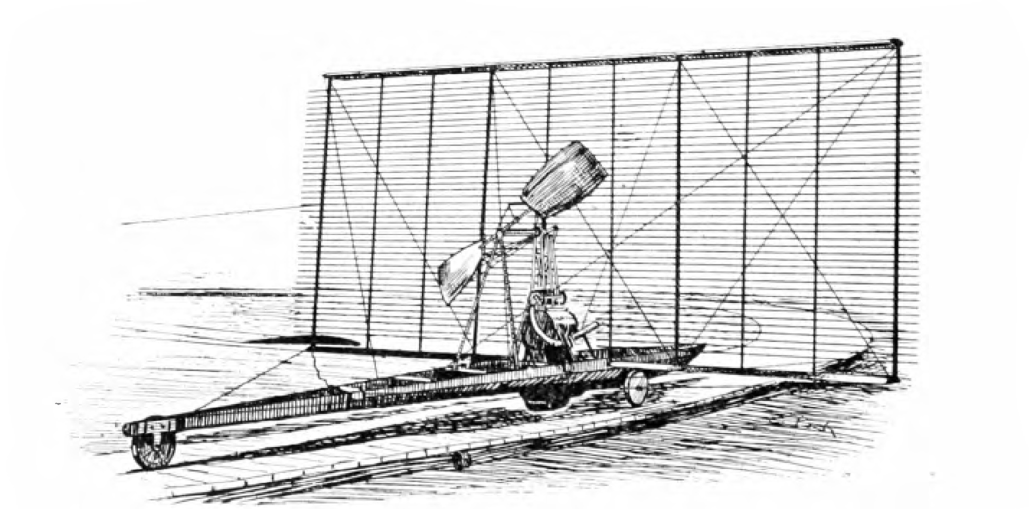


Fig. 38.—Phillips's steam-driven multiple plane captive flying machine.

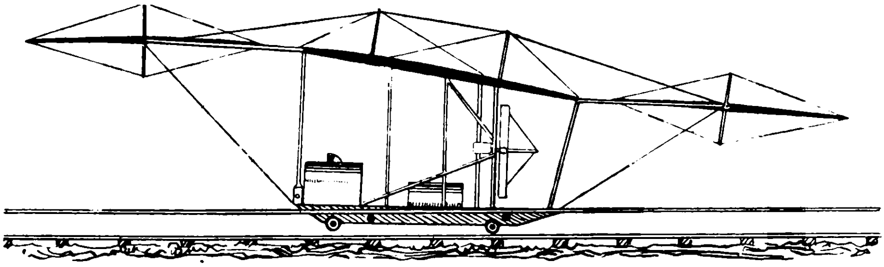


Fig. 39.—Maxim's aeroplane of 1893.

each $1\frac{1}{2}$ in. wide and 22 ft. long, fitted 2 in. apart; the total supporting area thus obtained was 136 sq. ft. The frame holding these slats was fitted on a light carriage mounted on three wheels, each 1 ft. in diameter, one in front and two at the rear. A small boiler and compound engine, with a two-bladed screw turning at 400 revolutions per minute, was employed for the motive power. The machine followed a circular path of wood of 200 ft. diameter, and wires were carried from different parts of the apparatus to a central pole in order to prevent erratic flights. This notion for testing a machine originated with Tatin in 1879.

The forward wheel was so balanced that it would never leave the track and served, therefore, as a guide, carrying less than 20 lb. of the weight, the remainder being on the hind wheels. With 72 lb. dead weight added, the hind wheels of the machine rose a couple of feet clear of the track when the apparatus was set in motion. Whilst, therefore, the ability of the machine to raise itself from the ground was amply demonstrated, the net results of the experiments were of little value, for no provision was made for maintaining equilibrium on such a machine in free flight.

About this time Sir Hiram Maxim was carrying out his experiments on a full-sized machine; the total lifting surface of his apparatus was 6,000 sq. ft., and the total weight with 600 lb. of water in the tank and boiler, and with naphtha and three men on board was no less than 8,000 lb. Two compound engines were specially designed for the work (one of these is to be seen at the present day in the South Kensington Museum). Weighing only 310 lb. each, they each developed 180 h.p., using steam at 320 lb. to the square inch. A lifting effect of 3,000 lb. to 4,000 lb. was obtained at a speed of about 40 miles an hour. The apparatus was not allowed to rise from the ground, but ran over a track. The wheels on which the machine was carried ran over steel rails of 9 ft. gauge, and the safety track of 3 in. by 9 in. Georgia pine, placed about 2 ft. above the steel rails, was 30 ft. gauge. Maxim calculated that the lifting effect upon the machine on the occasion when it got off the rails and was badly smashed could not have been less than 10,000 lb.

Maxim's experiments with the large machine extended from 1890 to 1893, and were abandoned only owing to their costly nature. The main aeroplane was 50 ft. wide and 47 ft. long in the direction in which the machine travelled. Five long and narrow aeroplanes projected from each side. Those that were attached to the sides of the main aeroplane were 27 ft. long, the total width of the machine thus being 104 ft. The machine was also provided with a forward and an after rudder made on the same general plan as the main aeroplane.

Lawrence Hargraves, the inventor of the well-known cellular or box kite, was for some years engaged upon the subject of mechanical flight, and in 1892 he constructed a very successful model. He employed at first compressed air, but later adopted steam. The general idea of the model was that two fixed wings were carried at a very obtuse angle on the main keel, while in front were two flapping wings, which afforded the propelling power. The wings were driven by a little engine. One of the models, when compressed air was used, flew 343 ft. in 23 seconds. These experiments were apparently discontinued.

A clever young engineer, Pilcher by name, commenced in 1895 to work on Lilienthal's system. His first glider, with which he made many flights between 50 ft. and 350 ft. in length, weighed 50 lb., and gave a sustaining surface of 150 sq. ft. A larger machine, double-decked, which he constructed in the following year, he found difficult to control. A third and somewhat lighter machine in 1896 made many good flights. It was equipped with wheels for grounding. In gentle winds his method was to rise into the air like a kite, the glider for this purpose being towed by a horse, the tow rope passing over a pulley block which made the glider travel five times as fast as the horse. At any desired altitude, Pilcher cast off and glided to earth. He designed in 1899 an aeroplane to be driven by a 4 h.p. petrol motor of his own design, but a rib of one of the wings of his glider broke during a trial in the same year, and falling from a height of 30 ft., he broke his collar-bone and succumbed within 24 hours.

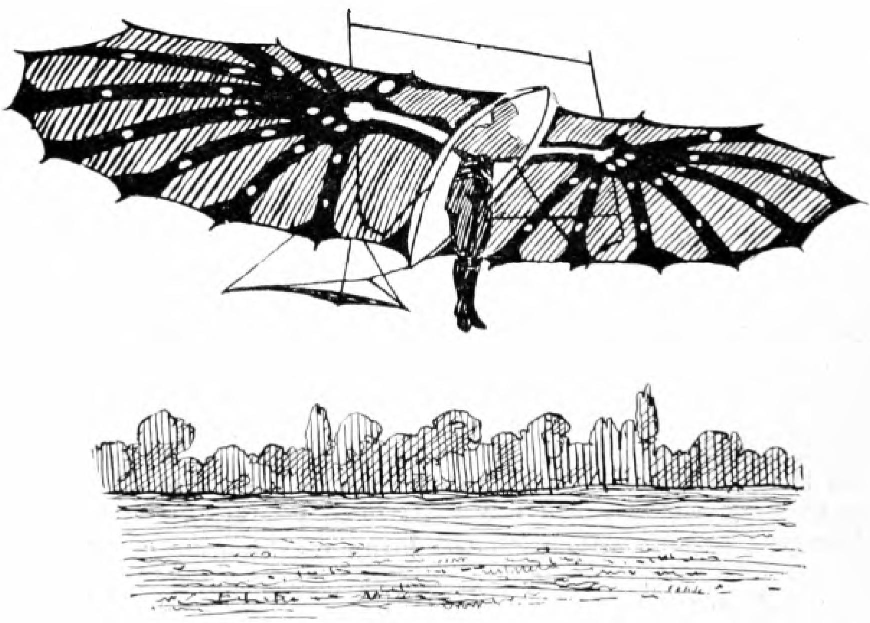


Fig. 40.—Pilcher making a gliding flight in 1895.

From the time when credence was given to the reports of the doings of the Brothers Wright, interest in the heavier-than-air machine began to revive in Great Britain, but it cannot be said that as much enterprise has been shown in these islands as has been the case in France. Clever designers have been regarded as cranks, and money requisite for the development of their plans has been denied them. However, there is this to be said, the "cranks" (who appreciate the fact that cranks are the little things that make the wheels go round) have not lost heart, and some of them have succeeded, despite the constant discouragement meted out to them.

Amongst those who have carried out original work are Sir Hiram Maxim (whose earlier efforts have already been mentioned), Mr. A. V. Roe (who won the highest prize at the Aero Club's competition of models in 1906), Capt. J. W. Dunne, Mr. S. F. Cody and others who have not met with a full measure of success. Of Capt. Dunne's work, carried out on behalf of the War Office in secrecy at Blair Atholl, little has been allowed to leak out, but, as he has now left the Service and has constructed an aeroplane at Shellbeach, he will no doubt soon be able to demonstrate his ideas in public. Mr. Roe is the only exponent of the triplane, and he has undoubtedly achieved a measure of success, for he has flown with only a 9 h.p. two-cylinder J.A.P. engine. However, he has now adopted higher powers, and is

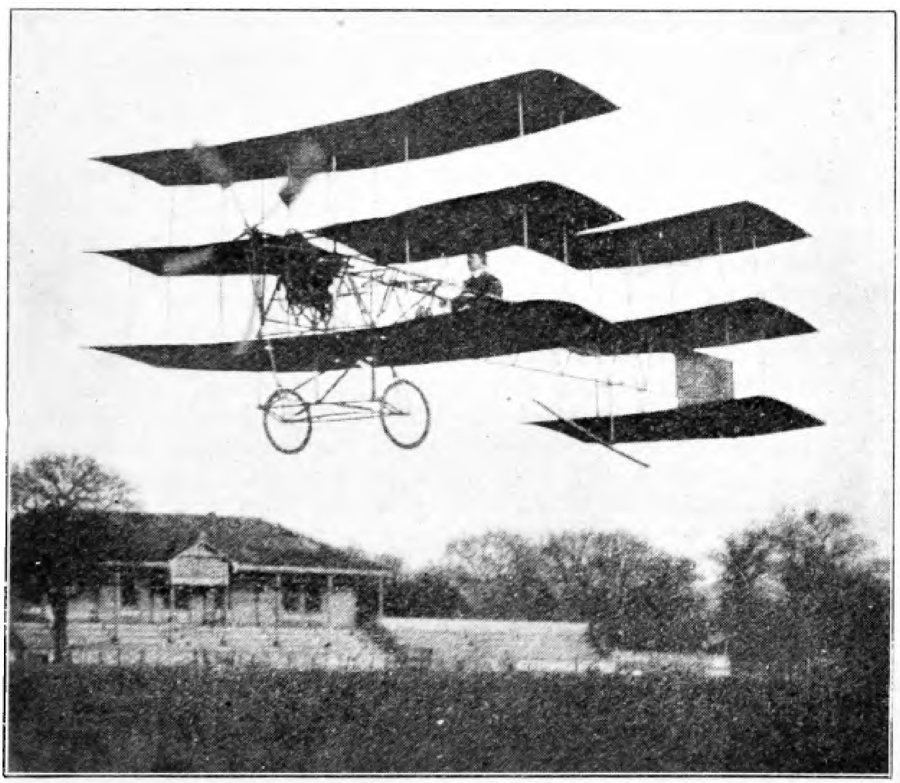


Fig. 41.—Roe's triplane in flight at Wembley in the autumn of 1909.

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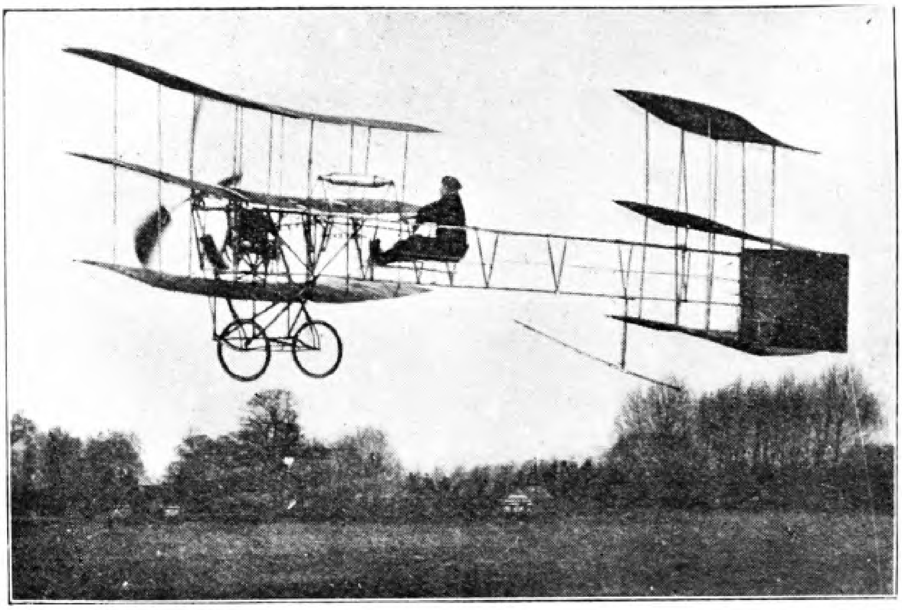

Fig. 42 —A. V. Roe (broadside view) flying at Wembley in the autumn of 1909.

satisfied that he can soon be making long flights. His early work, when he was towed by a motorcar at Brooklands, and when he made a few jumps with an Antoinette engine, was virtually the pioneer of recent efforts in England.

Considerable credit will have to be given to Messrs. Horace and Eustace Short, of the firm of Short Bros., one of the most enterprising of firms dealing with ballooning, who took up the study of the aeroplane very early, and who established an aeroplane factory at Shellbeach in 1909, securing the sole right to manufacture biplanes to the design of the Wright Bros. Their work has been carried out beautifully, and the machines have flown well, the Hon. C. S. Rolls, Mr. A. Ogilvie, Mr. Searight, Mr. F. McClean and Mr. Maurice Egerton having nothing but praise for the machines built by them. The Short biplanes bear the impress of the Wright Bros.' influence. Yet there is a great difference between the two types, balancing ailerons being employed to balance the drift in a way which, it is claimed, cannot be done on a wing-warping machine. Mr. J. T. C. Moore-Brabazon bought the "Short No. 2" and equipped it with a Green engine, winning the "Daily Mail" prize of £1,000 and the Aero Club's prize for the first British-built aeroplane to cover a mile in circular flight.

Mr. Cody's work has been sneered at and under-rated, but such an attitude towards a persistent worker in some new direction is to be expected in this country. He has made a number of short flights carrying a passenger, and also one long flight of about 40 miles. He was the only aviator who seriously contemplated an attempt in 1909 on the flight from London to Manchester for the "Daily Mail's" prize of £10,000. That this prize will be won in 1910 is confidently expected by many.

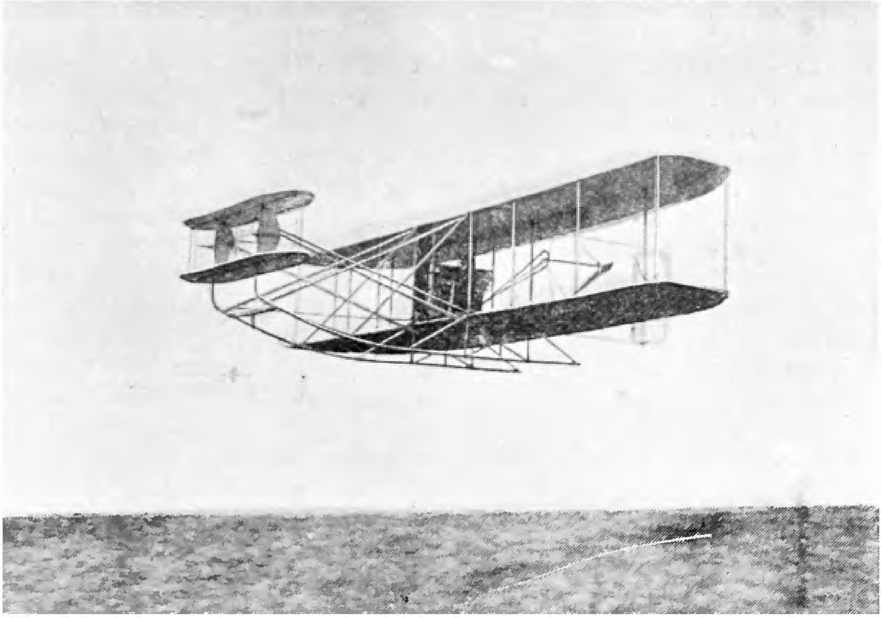

Fig 43.—The Hon. C. S. Rolls and his Wright aeroplane in flight in the Isle of Sheppey.

The aviation ground at Shellbeach proved, by no means, to be ideal, and Mr. Rolls discovered a convenient hillock at Eastchurch, further inland on the Isle of Sheppey, and there learned to glide with a Wright glider. Later he flew there on his Wright aeroplane, and now the Aero Club (which was honoured by permission from His Majesty the King, in February, 1910, to use the prefix Royal) has made its headquarters there, and it promises to be a popular and convenient aviation centre. A space has been cleared at Brooklands, and sheds have been erected for the housing of nine aeroplanes, considerable work having been done there since Paulhan made his flights over the track and away over the surrounding country.

Britishers, however, have been content to buy machines that fly rather than to carry out original work for themselves. Thus about two dozen machines of known types—such as Wright, Blériot, Antoinette, Farman and Voisin—were in use in this country in February, 1910, and altogether about 75 aviators were giving a deal of time and attention to the subject in these islands, many of them having gone to the aviation schools at Mourmelon, Pau, etc., for tuition.

Messrs. Humbers, Ltd., constructed some aeroplanes after the designs of Blériot and also produced a monoplane of their own design. These were tried in January and successful flight will probably be attained very shortly with them. The Star Engineering Co., Ltd., of Wolverhampton, have also produced a monoplane, but it has not made a flight at the time of going to press. Messrs. Howard T. Wright and Co. have designed and constructed a number of aeroplanes and now catalogue six distinct types, four being monoplanes and two biplanes.

III.—In Germany: Lilienthal, the Founder of the Modern School.

Otto Lilienthal has undoubtedly inspired all the modern efforts which have finally led up to the conquest of the air. As a boy of 15 this distinguished engineer, who for so many years spent his spare time in the study of aviation, showed an early desire to investigate the mysteries of bird flight. His name appears first in aeronautical annals in 1889, when he published his famous book "Bird Flight as a Basis of the Flying Art." In this treatise he gave to the world the practical result of 25 years' research and study. Much of his early attention was devoted to the flight of sea birds—Otto Lilienthal in the course of his work having been occupied on sea work; he was the inventor of a fog-horn adopted for German lighthouses. Later he spent a great deal of time in following the movements of storks, which are to be found in great numbers in the south of Germany, where their soaring feats are regarded as commonplace. In much of this work Otto Lilienthal was aided by his brother Gustav, but the brother's help was probably seldom sought, for the 1889 book bore the name only of Otto Lilienthal.

When he satisfied himself that curved surfaces such as birds apparently use would be essential to human flight, he was still uncertain about the ability of man to lift himself by flapping wings. This problem he solved in an interesting manner: he suspended himself by a rope counterpoised over a pulley supported from a beam projecting from a house. He equipped himself with three pairs of wings to be operated by his own muscular efforts, using both hands and feet, with the wings opening and closing like venetian blinds. The total weight of the wings and of Lilienthal himself amounted to 176 lb., and after a few experiments he employed a counter weight of 88 lb., and with considerable effort lifted himself in this wise 30 ft. from the ground. This satisfied him that flapping flight was

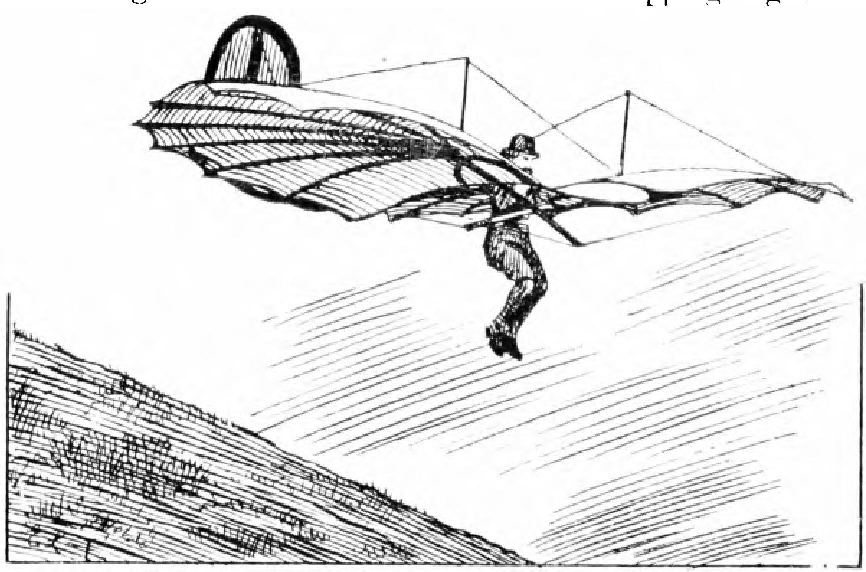

Fig. 44.—Lilienthal gliding in 1891 with his first model.

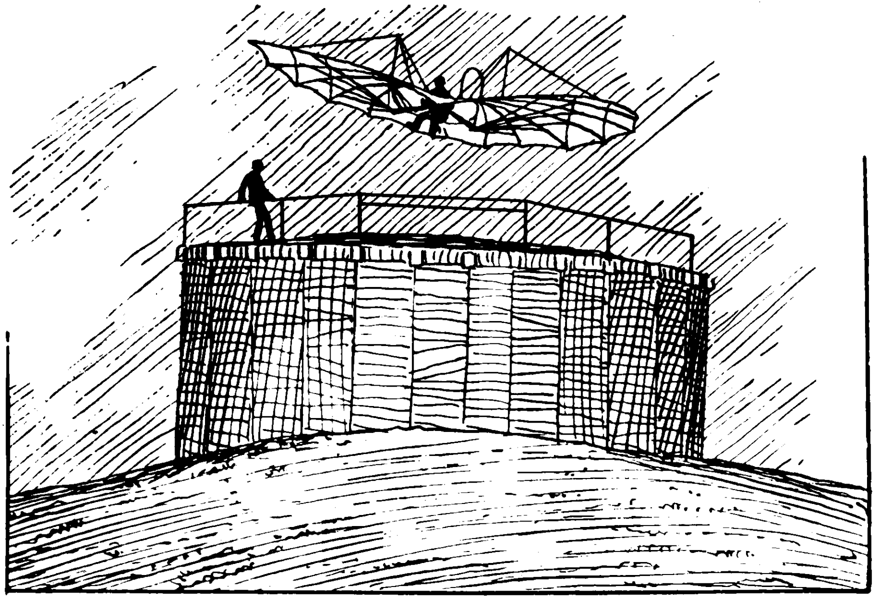

Fig. 45.—Lilienthal's starting tower

out of the question, but he was encouraged to proceed further, and for the investigation of the supporting power of curved surfaces he made almost countless experiments with a whirling table, the invention of which, though often attributed to him, seems rightly due to Professor Marey, who employed such a device about the year 1870. Lilienthal enumerated in his book a number of conclusions which he drew from his 25 years' experience. The most important of these were that:

1. The construction of machines for practical operation is independent of the development of a light and powerful motor.
2. Hovering flight is impossible by man's unaided strength, but can be attained by means of proper surfaces in winds of 22 miles per hour or more.
3. The application of an additional bearing surface, for example, a tail, is of minor importance.
4. Wings must be curved in transverse section and concave on the under side.
5. The depth of flexure should be 1-12th width.
6. A sharp cutting edge should be used at the front edge of the supporting surface, if possible.
7. Flexure should be parabolic, with the greater curvature in front and the flatter surface to the rear.

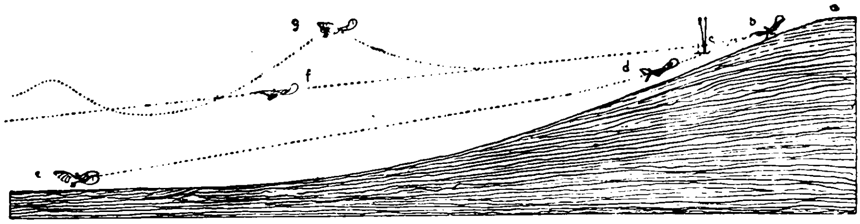

Fig. 46.—Trajectories of three of Lilienthal's flights.

In 1890 Lilienthal commenced a series of experiments that must, and will be, for ever regarded as classical. In the following year he made his first trials with gliders, and in 1893, with a glider weighing 44 lb. and measuring 150 sq. ft., he went cautiously to work to lift his own weight freely in the air. He

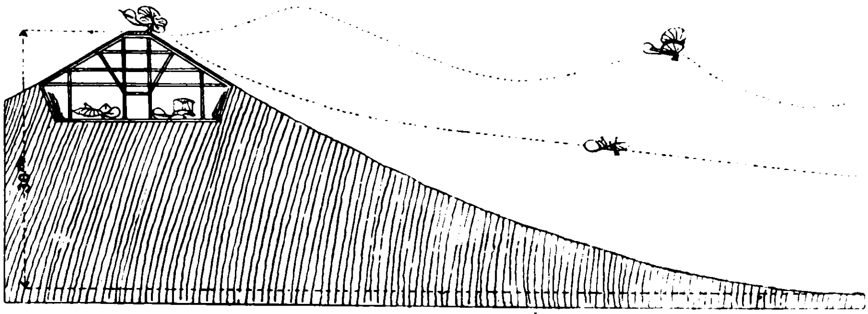

Fig. 47.—Trajectories of two Lilienthal flights from his later artificial hill with shed at summit.

started in his garden by jumping from a spring board 3 ft. high, and gradually increasing the height of the board to 8 ft., and taking bounds from it, he satisfied himself that he could come safely to earth. He then built a low tower on a hill, and from the top of this made many successful glides. Later he was led to construct an artificial hill 50 ft. in height near Gross Lichterfelde, near Berlin. In 1895 he adopted two superimposed planes each 18 ft. broad and of 100 sq. ft. area, the upper surface being about three-quarters of the breadth of the lower. He wanted to fly in a wind of 10 metres per second. Previously he flew nearly horizontally in winds measuring from six to seven metres per second. In a strong wind he

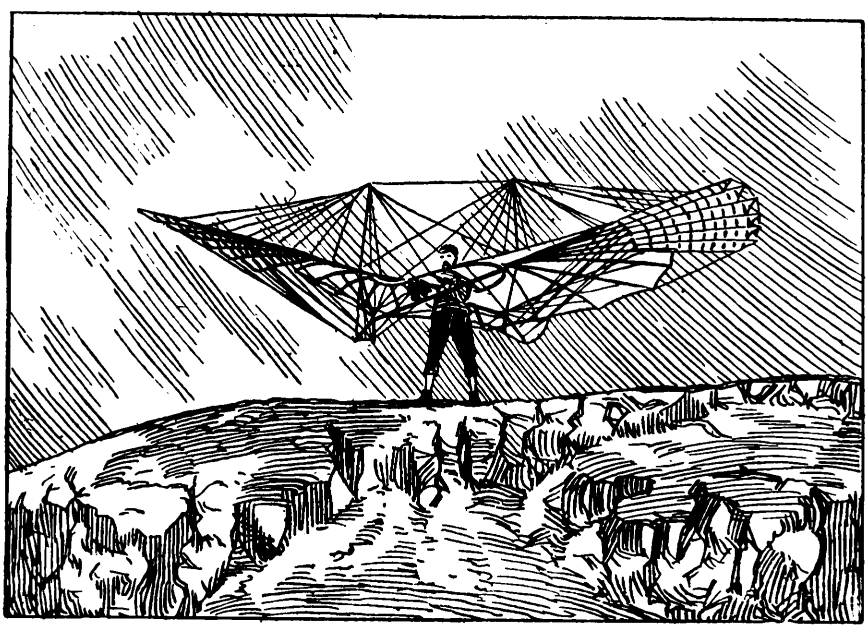

Fig. 48.—Lilienthal's glider of 1893, made to fold for portability.

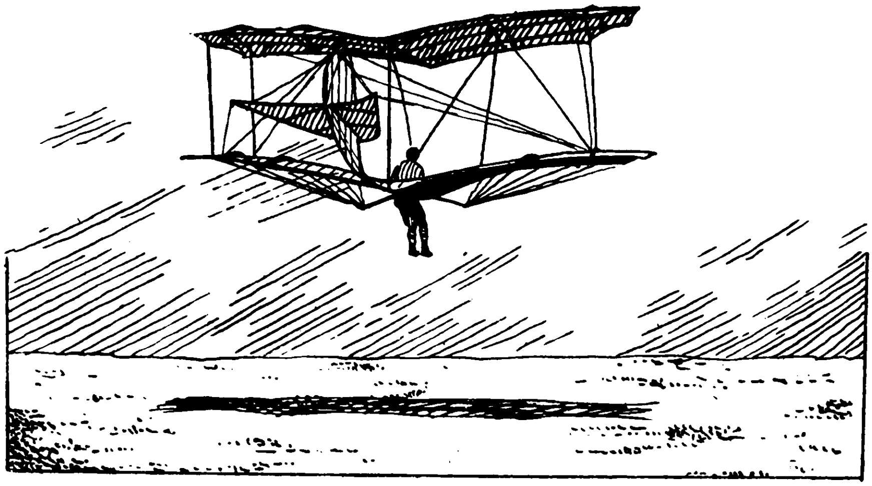

Fig. 49.—Lilienthal's double-deck glider of 1895.

frequently allowed himself to be lifted from the top of the hill without the necessity for running down the slope, and oftentimes he found himself higher than the top of the hill. To take longer glides, he went in 1896 to the Rhinerow Hills, where he had been in 1893 for a fair time. From the top of some hills there 250 ft. high he glided sometimes 750 ft. or more. Unfortunately, in the search for that soaring flight which seemed to fascinate him, he was caught in an awkward current, and the machine, losing its equilibrium, carried him plumb to the ground, breaking his collar bone, from which injury he died within 24 hours. With him the study of flight had always been a hobby. Gliding with him became a sport. How much further he would have progressed had

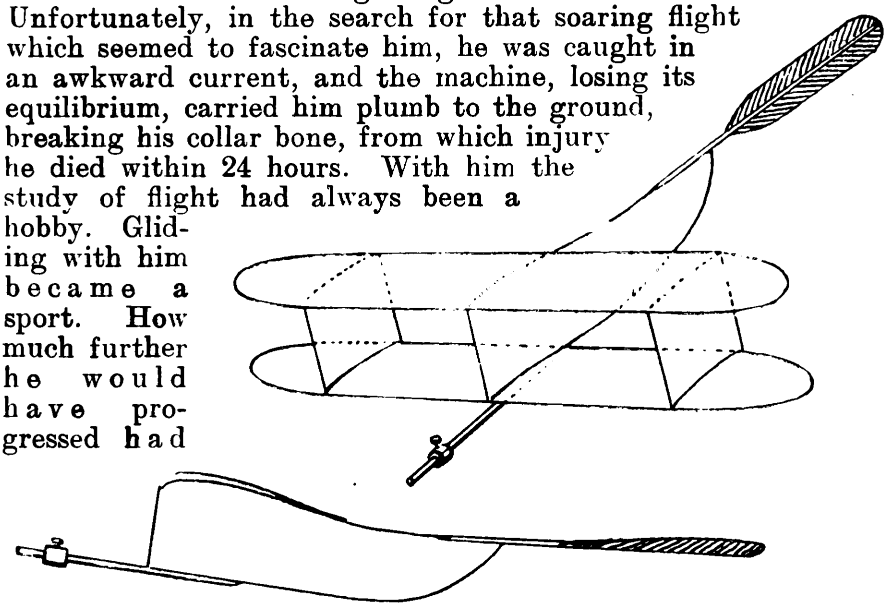

Fig. 50.—The model arrived at by Lilienthal just before his death.

he been spared from that accident on 12th August, 1896, it is impossible to say, but from his work has proceeded all the great and important success which has within the last few years been attained in the art and science of human flight.

From his pupils Herring, Pilcher and Ferber have grown the schools of America, England and France, respectively.

IV.—In America: Langley and Chanute.

The history of the American aeroplane resolves itself in the popular mind to the doings of the two Wrights. However, it must be borne in mind that, though these two clever inventors accomplished the feat of flying before anyone else, they had a vast amount of work already done for them.

Langley—with whom was associated Dr. Graham Bell—Chanute and Herring were first in the field; Langley and Bell, who were working on their own lines, had been co-operating for two years before Chanute came on the scene, for Langley started in 1893. Chanute began with the assistance of Herring, who had been a pupil of Lilienthal, and, while in no wise discounting the Americans' achievements, we see in Lilienthal the groundwork of Chanute's success. But Langley and his adviser Bell, Chanute and his engineer Herring were all handicapped by the absence of light motive power such as that of the petrol engine. They all stopped, because progress was impossible until the day of the light efficient engines.

Langley is recognized as being one of the first to make an aeroplane that would actually fly. In making his report on the subject, Langley modestly stated that, "to prevent misapprehension, let me state at the outset that I do not undertake to explain any art of mechanical flight, but to demonstrate experimentally certain propositions in aerodynamics which prove that such flight under proper directions is possible."

Langley recognized that to try to imitate the action of a bird was useless, and in his endeavour to master the problem of flight he employed an aeroplane, or, as he called it, aerodrome. To assist him in his pioneer work he used the whirling table. With this he was able to prove that the figures prepared

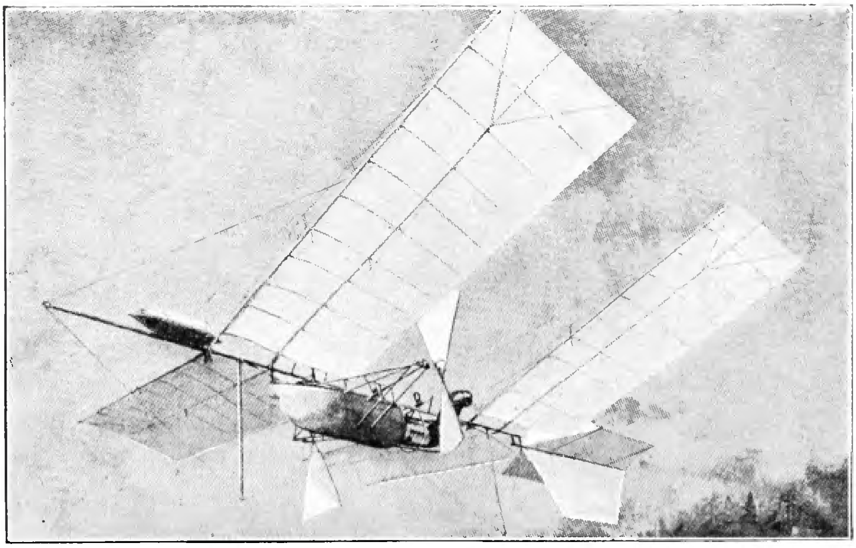

Fig. 51.—Langley's model devised in 1893 and first flown in 1896.

by a well-known French mathematician were wrong, likewise Newton's rule for finding the resistance to advance through air. Otherwise, as he pointed out, the swallow would have to be nearly as strong as a man to enable it to travel at 60 miles per hour. Since he first propounded his famous theory, well known as Langley's law, he has qualified the remarks to the extent that, though it still reads as it did at first, to the effect that less power is spent in making a plane surface travel fast through the air than would be spent in making it travel slowly, that statement applied only to the ideal condition of a frictionless plane, and not to an actual flying machine.

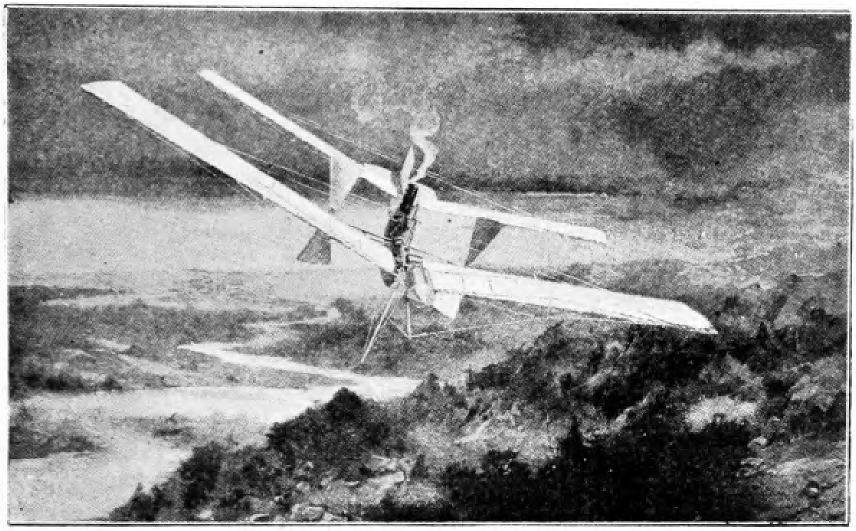

Fig. 52.—The Langley model in actual flight, 6th May, 1896.

Undoubtedly Langley would have furthered that art of flying if he could have had the assistance of the petrol motor. He experimented with compressed air, carbonic acid gas, electricity and other means of obtaining power. Finally, he settled upon steam, though he stated that he thought the gas engine would be the motive power of the future. When using steam he was terribly handicapped, for the engine, generator, etc., weighed 7½ lb. per h.p., and his water supply would only last long enough for a flight of 1½ min.

The innumerable difficulties that he had to overcome can be gauged from the fact that it was not until 1st May, 1896, that his machine actually flew, although it was three years previously that he first started his experimental work.

As the illustration shows, Langley's aerodrome was shaped like a butterfly, and consists of a main girder lying in the direction of flight, to which the four plane surfaces are attached fore and aft, the power unit and propellers being placed immediately behind the front pair of wings. Langley claimed that with this model he had proved flight to be possible.

Herring and Chanute were very closely allied in aeroplane work, though together they never got beyond the experimental

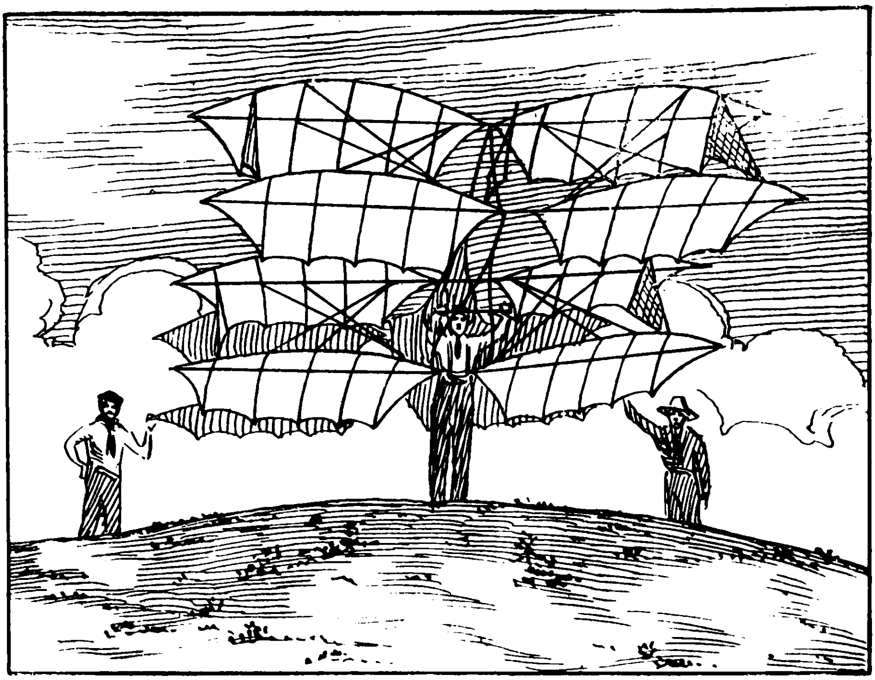

Fig. 53.—Chanute's experimental multiplane glider.

stage in gliders. Herring was a pupil of Lilienthal, but he soon broke away from the lines of the German engineer. He brought to Chanute's notice the German inventor's discoveries, and appears to have really started the latter's interest in gliding experiments as a means towards the conquest of the air, so that in 1895 he and Chanute constructed a glider like Lilienthal's, though slightly modified. This glider was shaped like the outstretched wings of a bird, the top surface being concave and

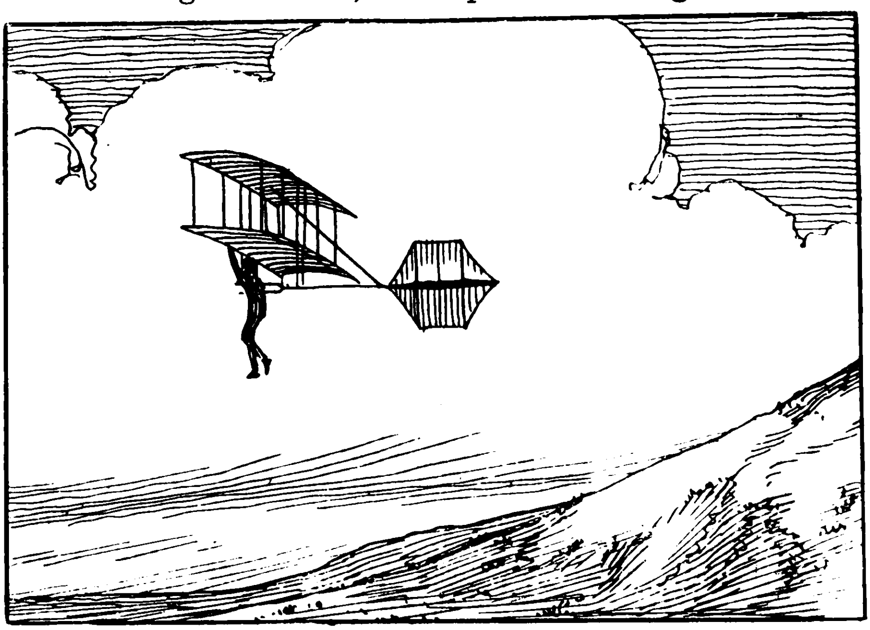

Fig. 54.—Chanute's final form without vertical planes.

the under convex. With this machine, which had a sustaining surface of 168 sq. ft. and weighed 36 lb., he made a number of experiments. His longest glide was 168 ft. Chanute found that this type of glider was quite safe, and landed gently, but it would not travel any real distance unless the experimental hill was steep as well as long. In other words, it dropped too much in gliding. His next machine had eight separate planes, placed in pairs above one another. The point to notice with this glider, which had the position of the planes definitely altered seven times, irrespective of adjustment, is this: it had the planes curved from the front view, though flat from the side aspect. This glider gave longer flights. Chanute then abandoned this glider, and constructed a biplane with planes flat

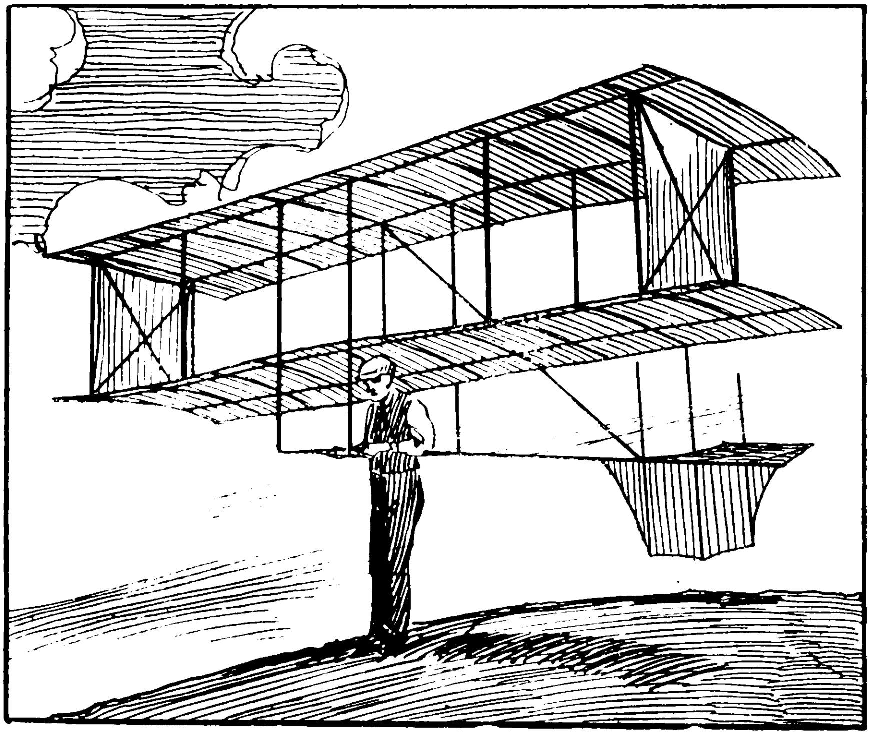

Fig. 55.—Chanute's penultimate form of double-deck gliding machine—the side planes were finally abandoned.

from the front aspect, but arched from the side. This was a most important step. The result was that he immediately doubled the length of his flights. With the biplane he had a certain amount of unsteadiness that he had not previously experienced, and which he does not account for. However, he overcame that by attaching a vertical rudder to his glider some distance at the rear and on the same level as the load.

Chanute was of the opinion that not much was to be learned from studying the action of flying creatures, because they vary so in the amount of their supporting surface. He thinks that his most valuable discovery was when he found that a plane presenting a flat appearance from the front and arched from the side had the greatest lifting capacity.

V.—*In France: From Ader onwards.*

Although the aeronautical research work undertaken in France seems to have been very meagre until the last half of the nineteenth century, the work of Tatin and Pénaud with models in the 'seventies and 'eighties was not insignificant.

It is necessary to go further back than that first flight of Santos-Dumont, made at Bagatelle on the afternoon of 23rd October, 1906, and popularly regarded as the starting point of the aeroplane in France, to get at the true beginning of this revolutionizing movement. Before that first soar could be made, years of patient experimenting had been carried out, and Santos-Dumont should be more correctly regarded as the happy instrument than the originator of the first real flight made in France. The rapid rate of progress since that October afternoon, and the immense enthusiasm in France prove that there was a wealth of activity unknown to the ordinary observer.

Ignoring the small army of inventors, who dreamed of discovering the secret of the birds and worked towards that end to receive no other reward than the title of "Fools," the first person in France directly connected with the present movement is Ader, who, in 1892, started practical experiments with flying machines, and in 1897 made the first known flight in Europe. Ader had succeeded in interesting the Government,

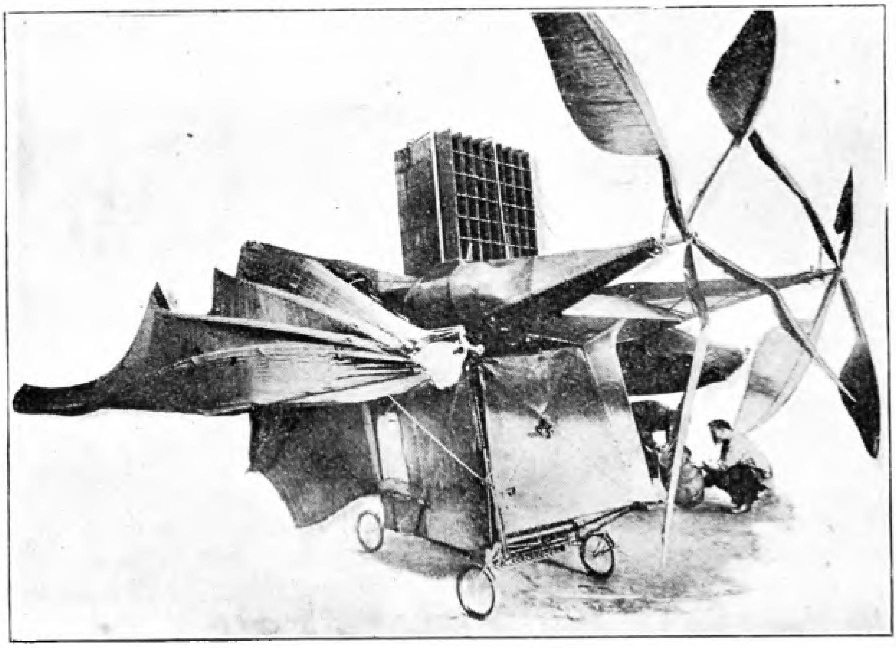

Fig. 56.—The Ader, the first power-propelled aeroplane.

Fig. 57.—Experiments at Issy with a glider in 1900, power being obtained by towing the glider with a car.

and after a very short flight on 12th October, 1897, on the Satory ground, in the presence of General Mesnier, a demonstration was ordered to be made on the following day before a military commission. The 14th October, which was later fixed as the date of the trial, was a gusty autumnal day most unfavourable for aeronautical experiments, and although Ader was able to rise from the ground, his machine was incapable of struggling against the strong wind, and made such a poor display that the Government lost interest in the matter. Ader was abandoned, and, discouraged after 40 years' labour and the expenditure of two million francs, he commenced the destruction of his machines. One of them, however, was saved, and now figures in the Arts et Metiers Museum, at Paris, by the side of the biplane with which Wright first flew in France.

M. Tatin, one of the most distinguished of French explorers in the realms of aeronautics, built a model flying machine in 1896 for M. Richet. The machine flew, but during one of the experiments near the sea it travelled for a distance of 150 yds., capsized and disappeared in the water. As the little experiment had cost nearly one thousand pounds sterling, the supporter lost all interest in flying with the disappearance of the machine.

It was in 1899 that the late Captain Ferber began a long series of experiments with gliders, endeavouring to take up the work that had been carried on with so much success by the German Lilienthal, but he was unable to make the least gliding flight until 1901. Like Lilienthal, he attached himself to the apparatus by the shoulders and arms, steering by carrying his legs ahead, to the rear, or to left and right, but was not able to glide on the layers of air as had been done by his German master. In 1901, he suddenly perceived that flights of this nature could only be made with an ascending wind. It was not sufficient to run down a gentle slope, for the speed of 3 ft. to 6 ft. a second thus obtained would be altogether insufficient to support a man on such an unbuoyant element as air. A horizontal head wind was altogether unfavourable, for if it caught the wings on the upper surface the effect would be to hold the apparatus down to earth. On the other hand, if the apparatus were at such an angle that the wind struck the under surface, the apparatus would be raised, but would not be able to advance in the face of the wind, and, after a flutter in the air, would be driven backwards towards the ground. With the wind blowing up the slope, it was possible for the aviator to run down, with the front of his apparatus inclined towards the ground, in what would appear to be in the face of the wind; the upward current of air, however, would have a lifting effect which would allow the experimenter to glide ahead, gradually descending all the time.

Captain Ferber, in France, kept in touch with the work being done in America by Chanute, Herring and Avery, as well as with the earlier experiments of the Wright Brothers, with the result

Fig. 58.—Experiments in gliding in 1900-1902 by M. Ernest Archdeacon and Gabriel Voisin.

that progress was being made simultaneously on each side of the Atlantic. The " Ferber No. 5," of the Chanute and Wright type, after a few unsuccessful initial attempts, made satisfactory gliding flights at Beuil, in 1902. The experiments were continued the following year at Conquet, in Finisterre, with equal success, the apparatus, which had then a very strong resemblance to the one being used on the other side of the Atlantic by Wilbur and Orville Wright, making numerous gliding flights with perfect stability. It was considered so satisfactory that the problem of driving it mechanically was taken into consideration.

Captain Ferber estimated that the weight of engine he could put on the machine was 220 lb. In 1903 all the power he could obtain for this weight was 6 h.p., delivered by a Buchet petrol motor. A new biplane, known as " No. 6," was built on the same lines as the preceding one, fitted with the Buchet engine

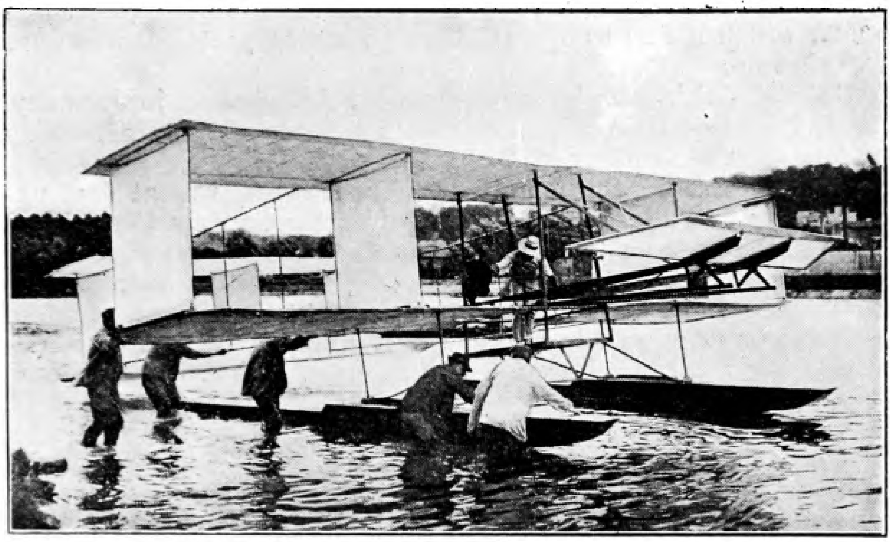

Fig. 59.—The Voisin float-borne glider.

driving two large propellers in opposite directions by means of a kind of differential, and arrangements made for it to be tested in 1903 on an aerodrome at Nice.

He hung this from an arm 100 ft. in length pivoted on a tower 60 ft. high, and drove the machine round, but the power available was not sufficient to sustain the machine in the air, centrifugal force prevented a high initial speed, and, further, the propellers were much too large for the engine. Afterwards experiments were made with the aeroplane hung on a cable and running upon it, to be released and shot into the air, but the aeroplane merely glided, the motor failing to keep it aloft. A larger motor was ordered, but before further work could be attempted the Government required the shed in which the aeroplane was housed, and the experiments came to an end.

Captain Ferber went on half-pay immediately after this, and was not able to rebuild his apparatus until the spring of 1908. In July of that year, it was tested at Issy-les-Moulineaux, flying the full length of the ground after a few slight adjustments. This result, which might have been obtained in 1905, but for the lack of War Office sympathy, passed unnoticed, for in the meantime Farman, Delagrange, Bleriot, and Santos-Dumont had all made flights.

While Captain Ferber was carrying out the most important experimental work in France, M. Ernest Archdeacon was no less active in the capacity of aeronautical evangelist, seeking to arouse enthusiasm in the subject of flight by lectures in various parts of the country, and by financial and moral encouragement to all experimenters in this field. Mr. Chanute having visited France in 1903, and given particulars of the wonderful success achieved by the Wright brothers with gliders during the years 1900, 1901, and 1902, M. Archdeacon had a machine of a similar type constructed at Chalais-Meudon. The possession of the machine, however, was not sufficient, and, in view of the lack of experience in its handling, as well as the different conditions under which it had to operate there, nothing practical was done in this line.

Gabriel Voisin was introduced to M. Archdeacon in January, 1904, and less than three months later the two were making gliding flights together at Berck-sur-Mer.

Gabriel Voisin, who mounted the apparatus, was at first unable to make a flight, and it was only after Captain Ferber had been brought from Nice to explain that they must operate in an ascending wind, that practical results were obtained. Berck-sur-Mer was not an ideal spot for gliding experiments, and in order to be nearer their workshops, the party returned to Paris, where, for want of a hill on which to make glides, the aeroplane was towed by a motorcar across the military drill ground at Issy-les-Moulineaux. The method of operation was to place the aeroplane, without motor, but with a pilot on board, on suitable rails, attach it by means of a tow-rope to the motorcar, and pull it until it rose in the air in the same way as a kite. It was not a very satisfactory arrangement, and after an accident on 25th March, 1905, when the machine flopped to the ground and was completely destroyed, these experiments were abandoned. Fortunately, on this day the pilot had been replaced by a sack of sand.

Believing there was less danger on the water, the aviators abandoned Issy and took up their headquarters at the Surcouf establishment at Billancourt, on the River Seine. The most remarkable performance was made on 8th June, 1905, when the aeroplane, mounted on two long floats, piloted by Gabriel Voisin, and towed by the motor boat "Rapière," rose to a height of 55 ft. and covered a distance in the air of not less than 160 yds. The apparatus had then very closely approached the form to be adopted later by the aeroplane with which Farman was so

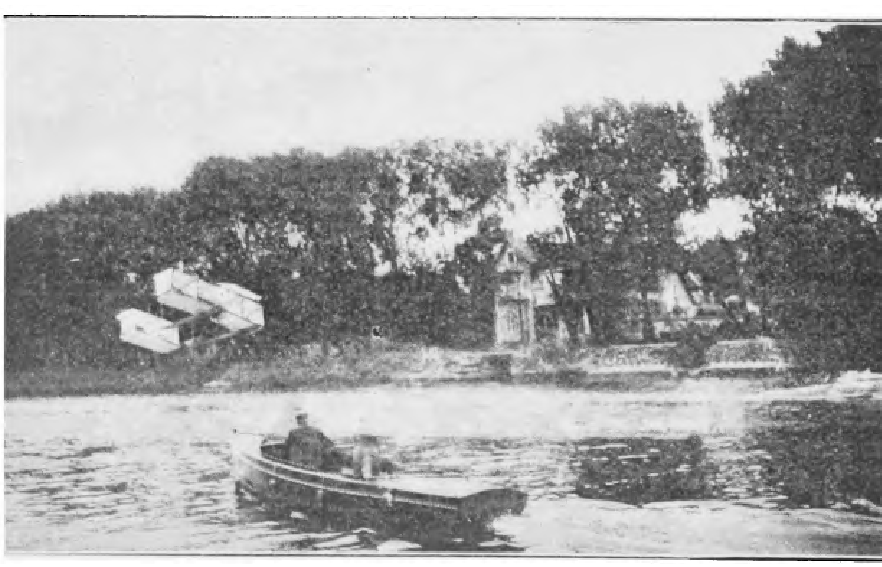

Fig. 60.—Gabriel Voisin in his glider towed over the Seine by a fast motor-boat.

successful. It had two main superimposed planes, about 60 in. apart, united by four vertical planes to give lateral stability. In the rear was a tail, composed in the same manner, but of much smaller dimensions than the main bearing surfaces. In the front was a single horizontal plane performing the functions of an elevation rudder.

It was not long before experiments on water were proved to be even more dangerous than those on land. Six weeks after the experiment just mentioned, Voisin again tested the Arch-

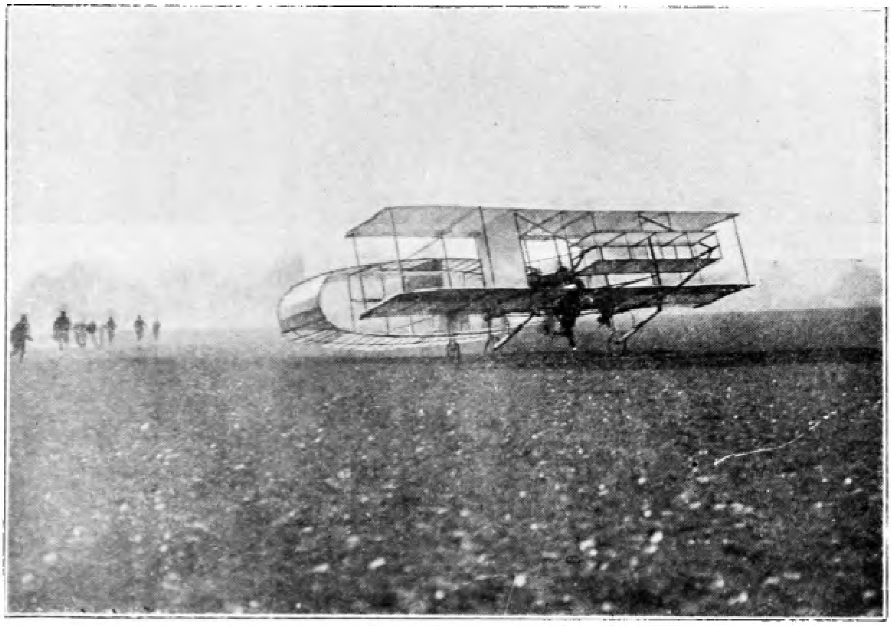

Fig. 61.—Bleriot "9bis" running over the ground in 1906.

deacon aeroplane on the Seine with but moderate results, and a few hours later took out a new apparatus which he had built for M. Louis Bleriot. While being towed by the motor boat "Antoinette," the aeroplane suddenly dived under the water, taking Voisin with it. The aviator only succeeded in extricating himself from under the planes at the end of 20 seconds, which appeared to be 20 minutes to the anxious spectators. A little later, M. Archdeacon removed to the Lake of Geneva, hoping there to get a powerful motor boat which would tow him constantly head on to the wind, a thing which was practically impossible on such a narrow river as the Seine. A suitable boat could not be found, and the only practical result of the visit was a little experiment made by Gabriel Voisin when the aeroplane was lying at anchor on the lake. In a very strong wind Voisin discovered that he could cause the aeroplane to rise from the surface of the water merely by operating the elevation rudder, and remain in the air, struggling at its cable until a lull in the wind or the manipulation of the rudder caused it to descend.

The year 1906 opened with tremendous activity among French

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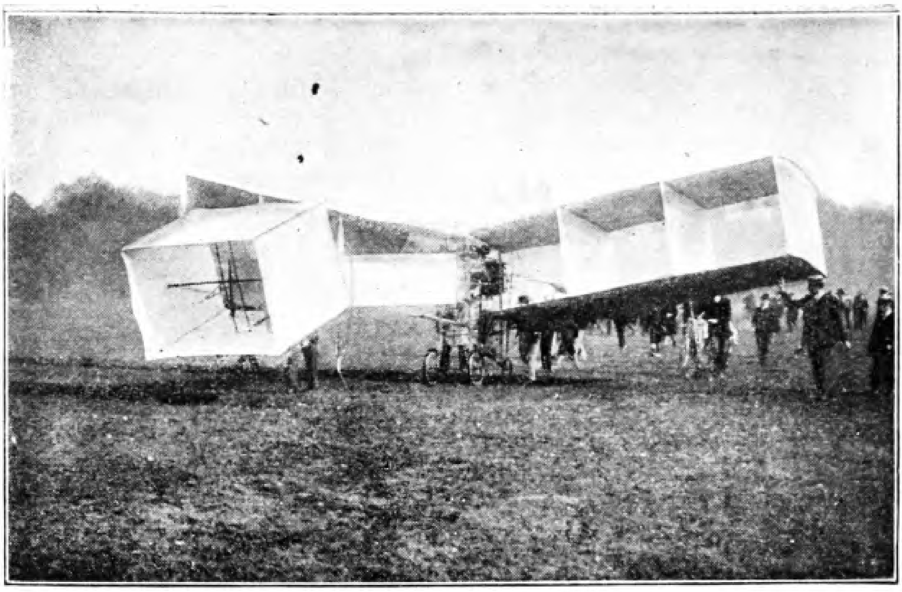

Fig. 62.—Santos-Dumont's famous aeroplane "14bis" coming up for the start of its first flight. The elevation planes were carried at the forward end of the body.

aeronauts, and a firm belief on the part of enthusiastic inventors that the day was very near when a mechanically-driven machine would rise from the ground and maintain itself in the air, a feat which had never been accomplished in Europe, with the exception of the brief and almost-forgotten soar of Ader in 1897. The Wright brothers claimed to have made flights the previous year varying from 25 to 38 minutes' duration, and, although their statements were far from being generally accepted in France, the mere possibility of the Americans having made a flight at all incited everyone to increased efforts on this side of the Atlantic.

Gabriel Voisin had joined Louis Blériot in business as aeroplane constructors, and, together, the aeroplanes Nos. 3 and 4 were built and experimented with on the lake at Enghien, near Paris, and at Issy-les-Moulineaux.

Santos-Dumont's first idea was to build a helicoptere; several technical advisers persuaded him that this would be a waste of time and energy, and, in consequence, an aeroplane of the Hargraves box kite type was constructed and shown to the members of the Aero Club in July, 1906. The first Santos-Dumont aeroplane, known as the "14bis," was attached to No. 14 dirigible balloon, the young Brazilian sportsman at that time not having sufficient confidence in the heavier-than-air type of flying machine to attempt a flight from the ground in the generally accepted manner. It was immediately seen that the dirigible balloon was more a hindrance than a help, and other aids were looked for. After various experiments with an inclined cable and, later, with an inclined wooden track, the machine was sent away over the Bagatelle ground on its four wheels and under the efforts of its 24 h.p. Antoinette motor.

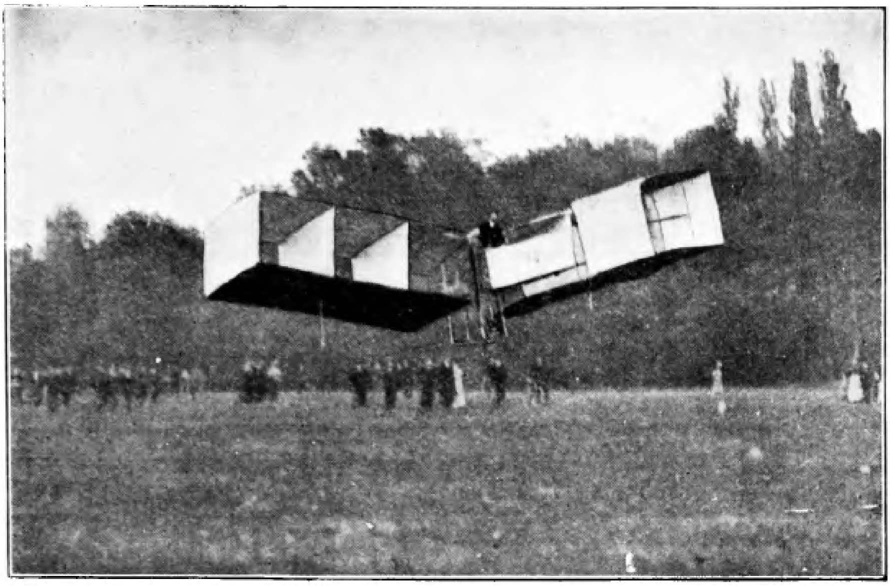

Fig. 63.—The starting-point of the aeroplane movement in France. The flight of Santos-Dumont's "14bis" at Bagatelle, 23rd October, 1906.

There was an immediate improvement, and it was not many days before the apparatus was running about in all directions. The motor was changed for a larger one developing 50 h.p., while, longitudinal stability having proved to be perfect, the two rear wheels were abandoned, leaving the front ones only. From July to October had been spent in experiments; but so rapid was the progress that, on the 23rd of that month, Santos-Dumont called together the Aviation Commission of the Aero Club of France, and at 4.45 in the afternoon won the Archdeacon prize for the first flight of not less than 25 metres. Excitement was at such a high pitch when this huge motor-driven box kite rose from the ground, that the Commission forgot to measure the distance covered in the air. Although officially given as 25 metres, it was generally recognized that the actual distance was not less than 70 yds. The first flight ended with the breaking of the wheels of the aeroplane, for, the apparatus having set up a slow lateral roll while in the air, Santos-Dumont switched off the ignition and allowed his machine to descend abruptly, instead of guiding it down gently.

A month later, the flying record had been carried to 220 metres, and enthusiasm in French aero circles had reached its height. Among the general public, however, the belief was prevalent that the so-called flights were only jumps, comparable to the leaps that could be made by a man running at high speed, or even by a motorcar when driven fast. Santos-Dumont's first success was not rationally followed up, and, after various unsuccessful attempts with small area high-speed flyers, the young Brazilian abandoned the aeroplane to endeavour to construct an apparatus to travel at 100 kilometres an hour on water.

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Fig. 64.—Henry Farman wins the Archdeacon-Deutsch prize of £2,000, by covering a triangular course of one kilometre, on 13th January, 1908.

Gabriel Voisin, who, during 1906, had dissolved his partnership with Blériot and had been joined by his brother Charles, had developed his own type of aeroplane while working out the ideas of his customers. He discovered, however, that inventors who were willing to pay for aeroplanes wished to have them according to their own ideas. It was not until the Parisian sculptor Leon Delagrange came forward in the early part of 1907 that he could find anybody to accept the machine produced as the result of the gliding flights at Berck-sur-Mer, and the experiments on the Seine and elsewhere. The first Voisin machine, known as the "Delagrange No. 1," was tested at Vincennes on 28th February, 1907, Charles Voisin mounting it. It was so lightly constructed that the backbone of the machine broke. A fortnight later it was out again at Bagatelle, but failed for lack of lateral balance. Finally, on 30th March, still on the Bagatelle ground, the machine went into the air for a magnificent flight of 60 yds.

Instead of continuing his training after this very satisfactory début, Leon Delagrange abandoned the Voisin machine to carry out experiments with M. Archdeacon on the Lake of Enghien. In June, Henry Farman came forward with a request for a machine, and the "Henry Farman No. 1," differing from the "Delagrange No. 1" in the method of attachment of the wheels only, was supplied to him.

With true Anglo-Saxon thoroughness, for Henry Farman is of British parentage, the new recruit set to work for a thorough training. A shed was built on the edge of the Issy-les-Mouli-neaux ground—the first of its kind—and for a whole month Farman scurried over the ground, thoroughly familiarizing himself with the handling of the machine. The first flight was made on 30th September, when a distance of about 90 yds. was covered in a straight line.

For almost a month very little progress was made, the aeroplane never being able to remain in the air for a greater distance than 100 to 150 yds. The fault was that the elevation rudder was carried at too great an angle from the horizontal, and, as the machine rose in the air, it lost speed and

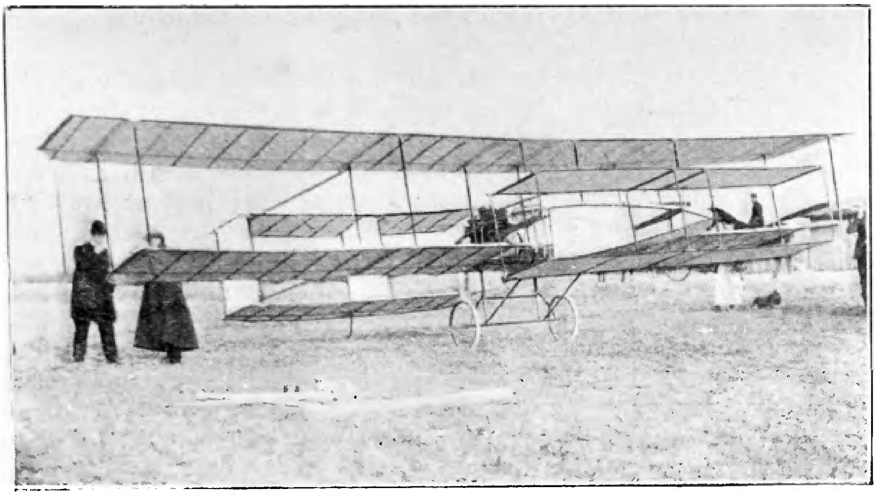


Fig. 65.—Kapferer's aeroplane (built by Voisin Freres) at Issy in 1907.

fell. This was soon remedied, and on 26th October Farman made another record by a flight of 843 yds. On every possible occasion during the months of November and December Farman trained on the Issy-les-Moulineaux ground, making numerous modifications in the machine and familiarizing himself with the handling of it. By January he was sufficiently skilled to attempt a complete turn, and on the 13th of that month called together the Commission of the Aero Club of France, in view of an attempt to win the Deutsch-Archdeacon prize of £2,000 for a circular flight of one kilometre.

The conditions of the flight were that the machine should fly over a given line, 50 yds. in length, follow an imaginary line at right angles to the starting line, rounding a flagpost 546 yds. ahead, then return and recross the starting line. Obviously, it was much more than a kilometre that must be covered, for the distance from the starting point to the flagpost and return alone equalled that distance. It was a perfectly calm January morning when Farman started up his Antoinette engine, and, after a preliminary soar, shot over the line, rounded the flagpost, and in 1 min. 28 sec. was back again at the starting point, the winner of the Deutsch-Archdeacon prize.

It was an epoch-making day, for those sceptics who had previously maintained that aeroplanes were huge jumping machines, capable of making wild leaps in the air, but were altogether incapable of a real flight, were silenced for ever. That circular flight of roughly one mile had proved to the world that the aeroplane was a practical machine.

Soon after the winning of the Deutsch-Archdeacon prize, Leon Delagrange returned to the Voisin biplane, and commenced training with such ardour that on 14th March he covered 328 yds.; two days later he had covered twice that distance; towards the end of the month he began to attempt circles, and on 11th April won the Archdeacon Cup by a circular flight of nearly 2½ miles.

The first half of the year 1908 was a period of friendly rivalry between Farman and Delagrange, first over very short distances, then for comparatively long periods. Farman, whose long experience as a motorist stood him in good stead, and who also owed much to his regular methods of training, at first had the advantage, being able on several occasions during the month of May to make short flights with M. Archdeacon on board. While giving demonstrations in Rome, Delagrange took the lead by making a flight lasting 15 min. 25 sec., and on 22nd June, at Milan, remained in the air for 16 min. 30 sec. Had these flights been made in France, he would have been entitled to the Armengaud prize of £400 for the first machine remaining in the air not less than a quarter of an hour, which had been coveted by both aviators for several months. It remained, however, for Farman to secure this prize, and at the same time to break the flying record by a flight lasting 19 min., on the evening of 6th July on the Issy-les-Moulineaux ground.

Up to this time the only other aeronaut in France who had made flights of any importance was Louis Blériot. Several types of machines had been constructed, but it was the No. 5, a monoplane modelled after Professor Langley's machine, which first proved successful. After this had made several short flights and been the cause of a sensational fall, it was abandoned for another type of monoplane, the Blériot No. 8, embodying

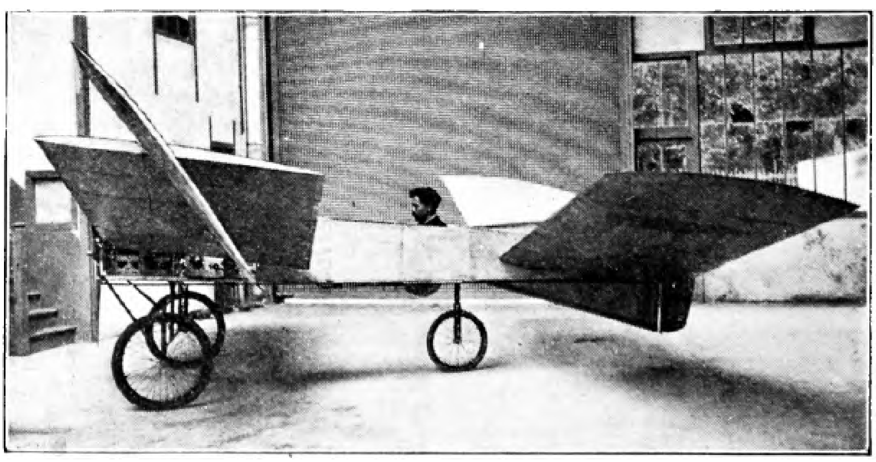


Fig. 66.—Bleriot's double-winged aeroplane of 1907, with ailerons on the forward planes.

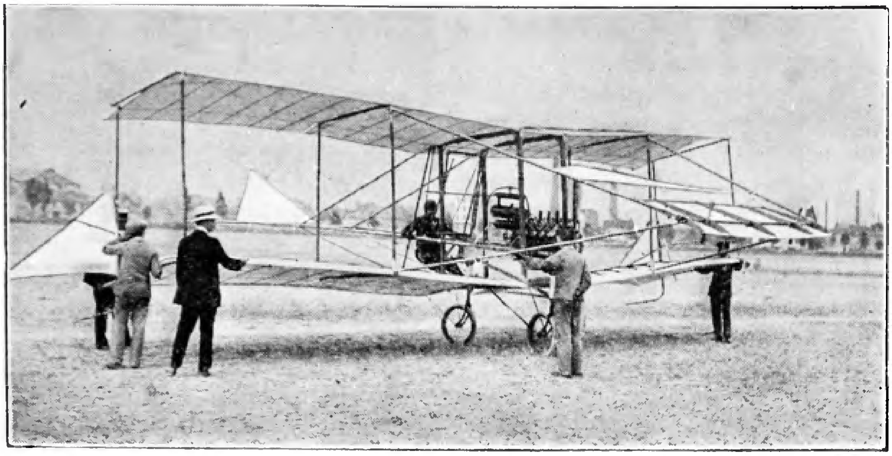


Fig. 67.—Capt. Ferber's later experiments at Issy in July, 1908.

many of the ideas of M. Tatin, which proved to be the most successful monoplane then known in France. The morning that Farman won the Armengaud prize Blériot made a flight of 8 min. 24 sec., his progress only being stopped by the failure of the pressure in the petrol tank.

Activity, however, was not confined to these three. But the score or so who were endeavouring to fly had not been able to realize anything more important than trips lasting a few seconds. In 1906 Vuia had left the ground on a monoplane for a distance of five or six yards, lengthened a year later to a flight of 60 yds.; Robert Esnault-Pelterie flew as early as October, 1907; Comte de la Vaulx flew 60 yds. in November of the same year; De Pischoff flew a kilometre on a biplane in December, 1907, and Gastambide-Mengin made his first flights with an Antoinette monoplane in February, 1908. Paul Cornu's helicoptere managed to rise from the ground to a height of about 16 in. on

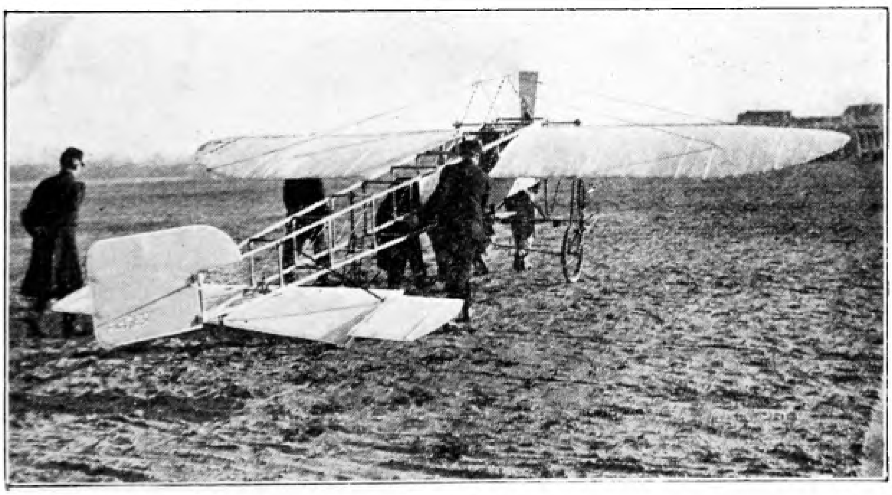


Fig. 68.—Bleriot No. XI. at Issy.

16th March, 1908, and the Breguet gyroplane, in July of the same year had attained a height of 14 ft. and travelled a horizontal distance of about 20 yards. The success of the leaders had already attracted a host of experimenters and imitators, with the result that flying machines were being built and tested on all sides, not always with any degree of success.

The situation in France was entirely changed by the arrival of Wilbur Wright during the month of July, 1908, with the object of fulfilling conditions imposed by a syndicate of which M. Lazare Weiller was the head. The syndicate undertook to pay to Wilbur Wright the sum of 500,000 francs on condition that he made two flights of not less than 50 kilometres (31 miles) each with a passenger on board and sufficient petrol for a flight of 200 kilometres. The syndicate secured the sole rights to construct and sell the Wright type of aeroplane in France and her colonies.

Wilbur Wright made his first flight on the Hunaudieres racecourse at Le Mans on 8th August, 1908. It was the first time the machine had been brought out since May of the previous year, and, in view of his lack of training, the American aeronaut was content to remain in the air 1 min. 45 sec. It would have been a triumph for his detractors but for the fact that during those 105 seconds the machine readily rose to a height of 36 ft. and described a couple of circles in a manner that was altogether unknown to Europe.

The flights were continued on the following days, and gradually lengthened, until, on 13th August, the machine remained in the air 8 min. 13$\frac{2}{5}$ sec. Naturally, these experiments had

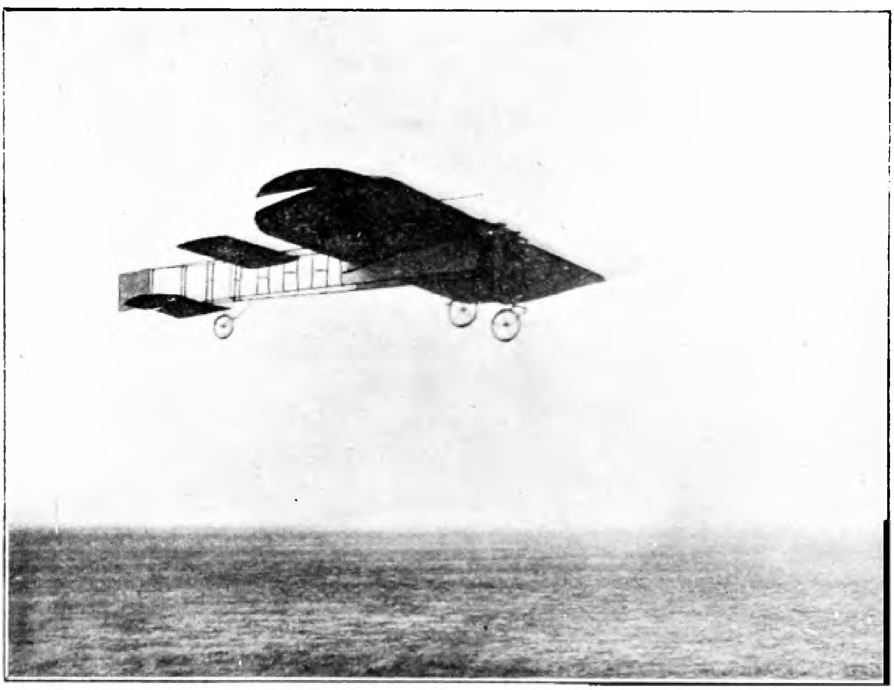


Fig. 69.—One of Bleriot's innumerable flights.

attracted enormous crowds of spectators, much to the annoyance of Wright, who had innocently imagined that, after the first two or three flights, he would be left to work alone. A removal was therefore made to the Camp d'Auvours, a vast pine-bordered plain about seven miles out of town, difficult of access and unused except for military manœuvres.

Almost immediately after the arrival at the Camp d'Auvours, the flights were lengthened, Wilbur Wright remaining in the air 19 min. 48⅗ sec. on 5th September, almost equalling the distance covered by Delagrange and Farman in the previous month. But there were still more important flights in store, and, after a soar of 2 min. 20 sec. with M. Ernest Zens as passenger, on

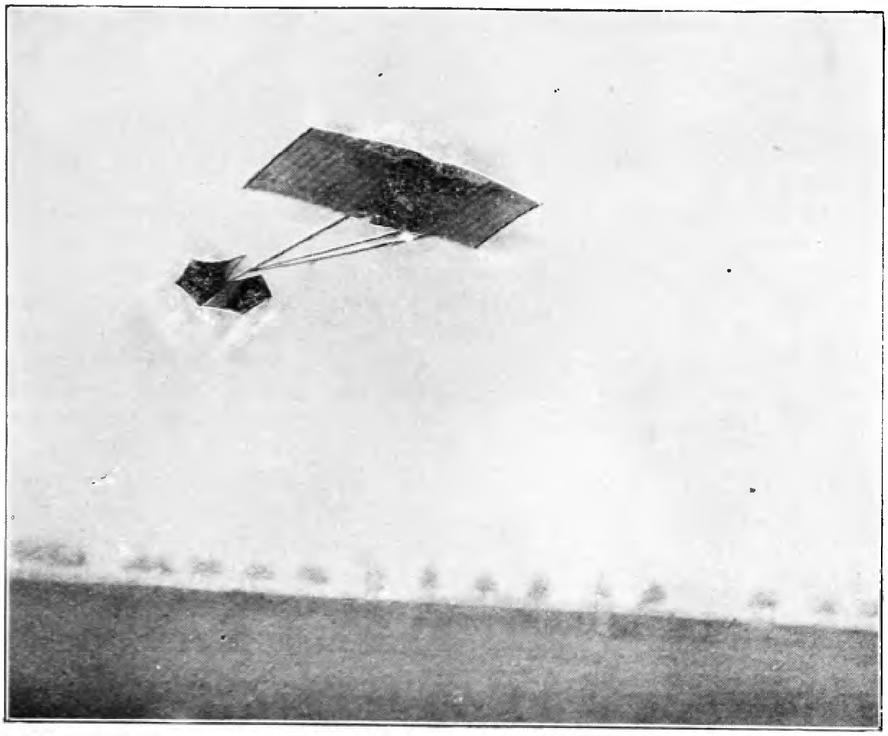


Fig. 70.—"La Demoiselle," Santos-Dumont's miniature flying machine at St. Cry in the autumn of 1908.

16th September, Wilbur Wright sent in his entry for the Michelin Cup and the Prix de la Commission d'Aviation of the A.C.F.

In the afternoon of 21st September, after three false starts, due to the rail being badly placed, Wilbur Wright remained in the air for 1 hr. 31 min. 25⅘ sec., thus creating a world's record for both time and distance, and provisionally securing the Michelin Cup and the Commission d'Aviation's prize. As he stepped from the machine amid the tremendous excitement of the mass of spectators gathered on the ground, he remarked: "That will cheer up Orville a bit." The conditions of the two prizes were that the flight should take place before sunset; thus

Wright was only credited with 19 rounds of the triangle, or a total distance of $23\frac{1}{2}$ miles. The actual distance covered, however, was more than 55 miles, equal to three times the crossing of the Channel from Calais to Dover. That this could have been considerably lengthened was shown by the fact that only $4\frac{4}{5}$ gallons of petrol out of a total of 11 had been used, and but three pints of water had been lost out of the radiator containing $2\frac{1}{4}$ gallons. On 24th September another attempt was made for the Michelin trophy, with the result that the official distance was carried from 38 to 39 kilometres (24 3-10 miles). The total distance, however, was less than on the previous occasion, the flight having to be arrested owing to the rising wind and the invasion of the ground by over-eager spectators. Four days later the distance for the Michelin Cup and Aviation Commission's prize was increased to 48 kilometres 120 metres (30 miles), this latter being won outright, and on the same day Wilbur Wright took a passenger for the second time, flying for 11 min. $35\frac{2}{5}$ sec. with M. Paul Tissandier by his side. Finally a flight of 7 min. 45 sec. was made with Comte de Lambert.

On 3rd October, after certain modifications to the machine, and interesting demonstrations of flying so low that the runners touched the top of the heather and coarse grass of the military ground, Wilbur Wright invited Franz Reichel, the representative of the "Figaro," to fly with him. Although the sun had set when the flight began, the machine did not settle down again until 55 min. $32\frac{1}{5}$ sec. later, thus creating a new record for flights with a passenger on board. On 4th October this record was broken by a flight of 1 hr. 4 min. $26\frac{2}{5}$ sec., with M. Fordyce on board, and on 5th October this record in turn was beaten by one of 1 hr. 9 min. $45\frac{2}{3}$ sec., the passenger being M. Painleve.

In view of the remarkable results obtained by Wilbur Wright, French aeronauts had almost ceased to exist for the general public, and it needed the remarkably daring trip of Henry Farman on 30th October to prove that the American was not the only man who knew how to fly. Farman, who had been training for some time on the vast plain near Chalons, started

Fig. 71.—The snow-covered plain at Issy in the winter of 1908-9, when Santos-Dumont continued his experiments with "La Demoiselle."

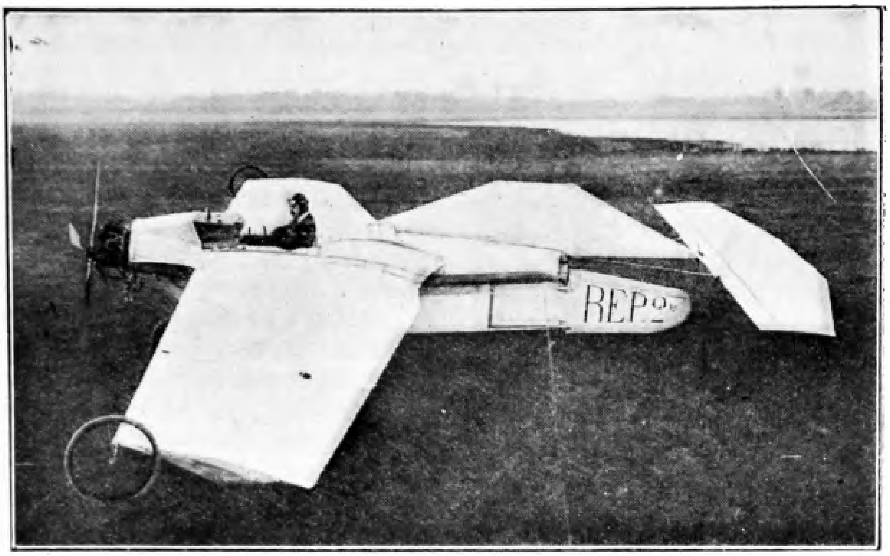


Fig. 72.—The R.E.P. aeroplane "2bis." M. Esnault-Pelterie is an advocate of the monoplane.

a little before four o'clock on a cross-country flight, his destination being Rheims, about 17 miles away. The machine, the one which had won the Deutsch-Archdeacon prize in January, was immediately carried up to a height of over 130 ft., in order to be absolutely certain of clearing the tall poplar trees, telegraph wires, and other obstacles. In a few minutes the aeroplane was lost to sight, and was not long in getting clear away from the motorcars which attempted to follow it. Exactly 20 minutes from the time he started, Henry Farman descended on the military ground just outside the city of Rheims, having made the first cross-country flight at a speed of 45 miles an hour, and at an average height of 130 ft. It had been intended to return in the same manner, but, owing to certain adjustments being necessary, this idea had to be abandoned. The following day Farman competed for the height prize of the Aero Club of France, and succeeded in passing over a couple of balloons placed 80 ft. above the ground.

Louis Blériot, who alone had been devoting attention to the monoplane type of flyer, was not to be outdone by the Farman exploit, and, on 31st October, set out on a round trip from Toury to Artenay and return, a distance of about 19 miles. The machine used was the "Blériot VIII.," equipped with a 50 h.p. eight-cylinder Antoinette engine. In 11 min. the machine passed over Artenay, but a few seconds later had to descend owing to irregularities in the working of the magneto. After 1 hr. 30 min. spent in making adjustments, the monoplane went into the air again, homeward bound. After covering about three miles a second descent had to be made; this time, however, the stop was only of a few minutes' duration, and, on going up again, the machine flew remarkably well until it reached its starting-point, where a descent was made. The first round trip across country had begun at 10.5 a.m. and ended at 5 p.m. A few days later, while making trials near Toury, the Blériot monoplane was smashed through striking a hillock when running over the ground at high speed. The pilot, who had had more tumbles than any other aeronaut in France, fortunately escaped with his usual good luck.

The last flying competition in 1908 was for the Michelin Cup, to be awarded to the aviator making the longest flight during the year. Since his cross-country flight, Henry Farman had considerably modified his machine, with a view to beating Wright's record for the Michelin prize. Several different makes of motors were tried, whilst the structure of the aeroplane was also changed, the most important modification being the addition of another plane making the machine a triplane. It was impossible, however, to make the aeroplane as satisfactory as the Wright apparatus, and, although Henry Farman made some clever flights towards the end of the year, he never seriously threatened Wilbur Wright's supremacy. Early in January Farman sold his aeroplane to an Austrian syndicate, and, having broken with the Voisin Frères, commenced business as an aeroplane constructor on his own account.

Although Wilbur Wright practically had the field to himself, he did not in the least relax his efforts to make a record flight. On 18th December he covered an official distance round a triangular course of 99 kilometres (61$\frac{1}{2}$ miles), his time in the air being 1 hr. 53 min. 59$\frac{3}{5}$ sec. The actual distance covered was not less than 75 miles, and his actual time 1 hr. 54 min. $\frac{3}{5}$ sec. On the same day Wilbur Wright competed for the height prize of the Aero Club of France, the minimum for which was 328 ft. Although a strong wind was blowing, this was won with ease, the small balloons being passed with a good margin, the actual height being given as 377 ft.

As if afraid that the Michelin trophy would escape from him at the last moment, Wilbur Wright made another attempt to beat his own record on the last day of the year, and admirably succeeded. He started just after two o'clock, and did not settle down again until sunset, having remained in the air 2 hrs. 20 min. 23$\frac{1}{5}$ sec. His official distance for the Michelin Cup was 123 kilometres 200 metres (76$\frac{1}{2}$ miles), while the actual distance covered was estimated at 93 miles.

The year 1909 was a memorable one in France, though it was faced with this formidable feat of Wilbur Wright. An event took place on 23rd January, however, which was destined to be the forerunner of a historical event, as Louis Blériot made his first flight with the No. XI. machine, with which he afterwards crossed the Channel. At the end of February, Hubert Latham first mounted an aeroplane, and at the end of March the Comte de Lambert and Paul Tissandier, the pupils of Wright, first gave proof of their ability to handle this machine. The flight of 1 hr. 2 min. accomplished by the latter was claimed as a French record, as it was longer than any except the flights made by the Brothers Wright themselves. On the 20th May Hubert Latham showed his skill by winning a prize for a flight of 500 metres, and immediately afterwards took his companion, Demanest, over the same course. Tissandier's record was not broken until the

5th June, when Latham stayed in the air for 1 hr. 7 min. 37 sec., and the next day won the Goupy prize for a cross-country flight, covering about 14 kilometres. Louis Blériot created a record on the 8th June by carrying two passengers at the same time, and it was during this month that the young mechanic, Louis Paulhan, had a standard biplane placed in his hands for trial flights, and in less than a month had beaten Tissandier's record of 1 hr. 2 min.

The first six months of the year, therefore, contained nothing very startling, but now the eyes of the whole civilized world were turned to the English Channel, as Hubert Latham had announced his intention of flying across it. He attempted it on 19th July, but fell into the sea, owing to his motor stopping, probably through short circuiting. He was rescued, however, and, still undaunted, resolved to try again, but Blériot, who had also designs on this feat, took advantage of the calm prevailing

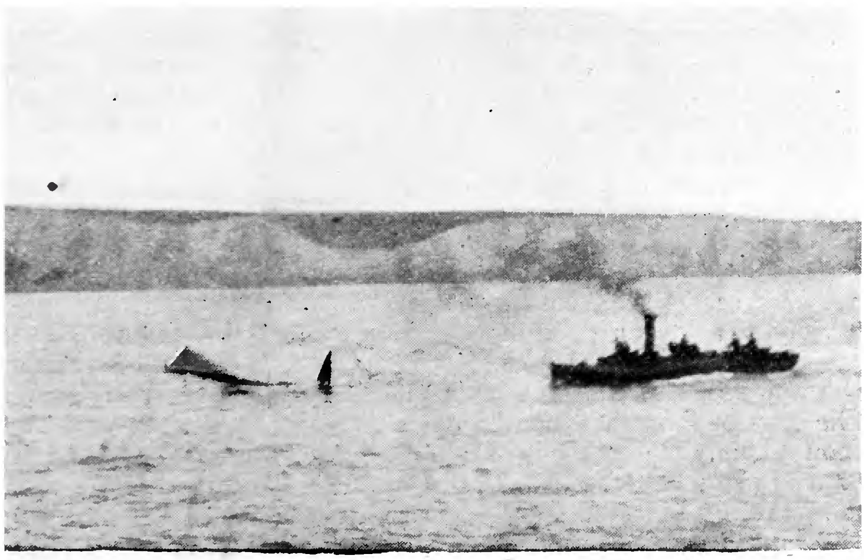


Fig. 73.—The end of Latham's second unsuccessful attempt to cross the channel.

on Sunday morning, 25th July, and in a little more than half an hour landed on the cliffs of Dover, the exact spot being now marked by a stone monoplane which is let into the ground. Two days later, Latham made another attempt, but fell into the sea again when only a few hundred yards from the English coast. It was said to be Blériot's opinion that Latham did not fly high enough on his second attempt to avoid being beaten down by the wind that came off the cliffs. On the same day that Latham made his first attempt, 19th July, Farman made a flight of 1 hr. 23 min., thus creating a new French record, whilst Paulhan flew over a captive balloon which was placed at a height of 492 ft. On the 4th July Roger Sommer made his meteoric appearance and mounted his first machine—a Farman biplane. On the 27th of the same month he beat the French record by half a minute; on the 1st August he flew for 1 hr. 50 min.

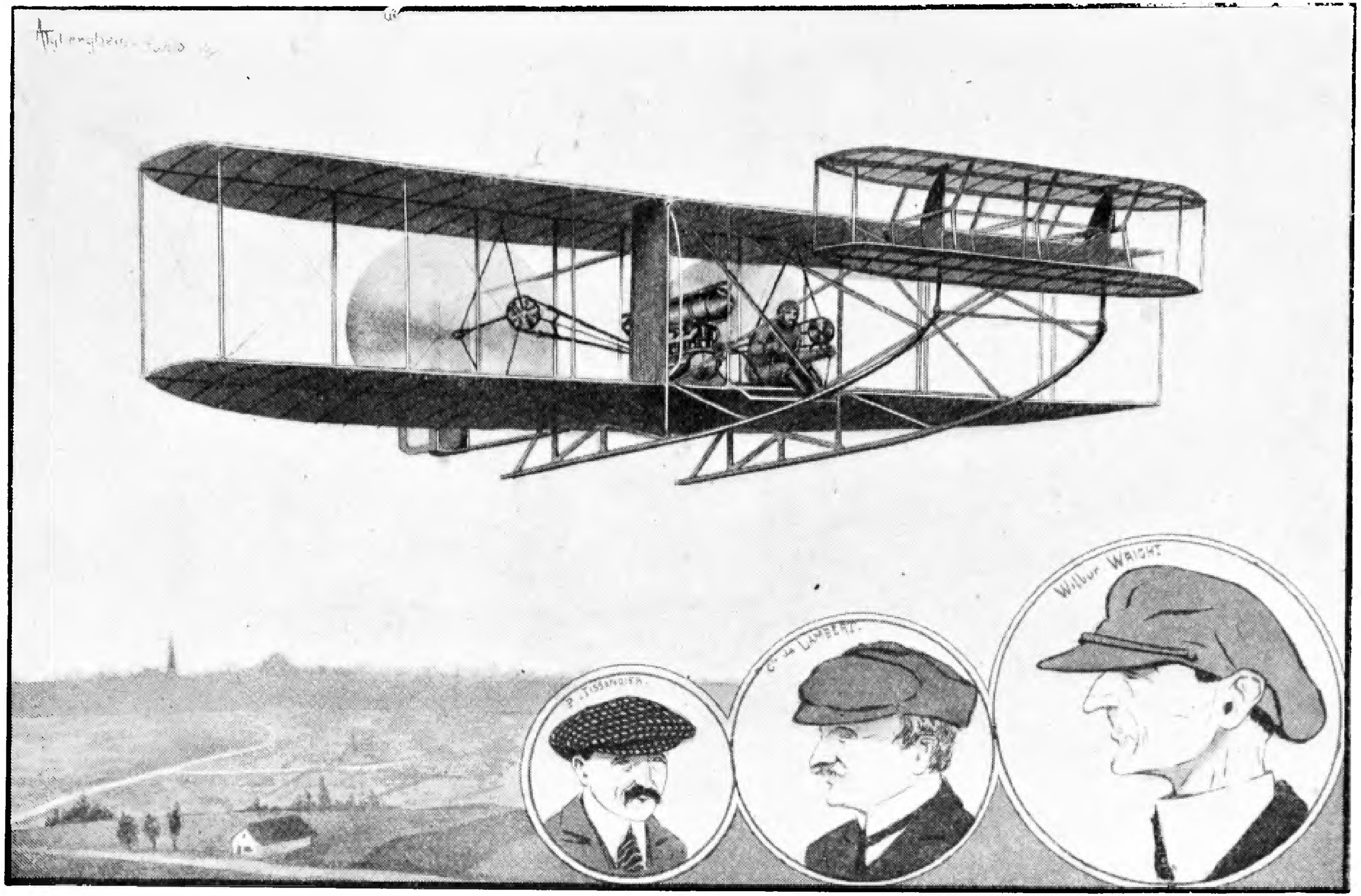
30 sec., and the following day made a 10-mile cross-country trip; two days later he flew for 2 hr. 10 min., and created a world's record on the 7th August, when he stayed in the air for 2 hr. 27 min. 15 sec. These flights were at no very great altitude, and some were not officially observed, but this latter fact must not be taken as any reason for doubting their genuineness.

The Rheims week was the next important event, and flights were made in winds which had hitherto been considered prohibitive, the results obtained being due to keen competition among the various aviators and their respective machines. At this meeting Wilbur Wright's and Sommer's performances were beaten, as the endurance record was carried to 3 hr. 15 min. The total distance of the flights was over 1,500 miles, Latham's contribution to this being 353½ miles, Paulhan's 189, Farman's 142, and de Lambert's 119. The Rheims meeting was the forerunner of many more. but none could come up to the original, though, incidentally, Latham's flights at Blackpool in a very heavy wind deserve to be chronicled.

What is probably the most daring feat of the year was accomplished by the Comte de Lambert, who, during the Juvisy meeting, flew away towards Paris, rounded the Eiffel Tower at an altitude of more than 1,000 ft., and returned to the starting point in about an hour. When it is considered that, during half the time, he was over a densely populated district, and that he was not considered a member of the reckless school of aviators, the confidence which he had in his machine is easily seen. On the 3rd November, Henry Farman stayed in the air for 4 hr. 17 min. 53 sec., covering a distance of 143 miles, or considerably the larger portion of a flight from London to Manchester, the distance of which would be about 185 miles. This flight was made during the competition for the Michelin Cup.

The fastest long distance flight, and also the time record for a monoplane, 125 miles in 2 hr. 35 min., was made by Leon Delagrange on a cross-Channel type Blériot, but before this feat was really digested the unfortunate man had fallen a victim to the cause of science and progress, and his life was lost through one wing of his monoplane breaking, the other one naturally assuming a vertical position, the machine then crashing to the ground, and poor Delagrange being killed instantaneously. Some controversy took place as to the cause of the wing breaking, but it is more than probable that it was due to the fitting of too powerful an engine, and the removal, by Delagrange, of the stretcher on the fuselage between the planes, so that when submitted to a speed of 60 miles an hour, and struggling against a head wind, the wing collapsed under the strain. At the same time it must be pointed out that identically the same machine had made many flights, some of which had extended over 2½ hrs.

On the last day of the year 1909, Maurice Farman did a cross-country flight of 47 miles in 50 min., quickly leaving behind the motorcars which were following him. On 7th January, 1910, Hubert Latham rose to the great height of 3,608 ft., or approximately ¾ mile. This wonderful performance was accomplished safely at Mourmelon, the aeroplane passing over the village of Bony, and the flight terminating in 42 min. 11¾ sec.



AVIATORS AND THEIR MACHINES.

Mr. Wilbur Wright, the Comte de Lambert and M. Paul Tissandier, and the Wright biplane.

THE MILITARY VALUE OF AIRSHIPS AND AEROPLANES.

Imagination necessarily playing the chief part in criticism of any new and untested force, we always get extremes. The truth as to the potentialities of the airship and aeroplane in war probably lies midway between the popular novelist's high-coloured pictures of uncontrolled—and uncontrollable—carnage and devastation, and the unimaginative, placid citizen's belief that comparatively little danger can come from the air—at least for many years. The latter is ignoring the lessons of the motor's remarkable progress and modern military utility, the equally rapid developments in air craft and the significant competition among Continental military powers for machines: the former is ignoring the lesson taught by history that new weapons of destruction are always curbed by nearly corresponding improvements in defensive armaments. Brain combats brain, thus

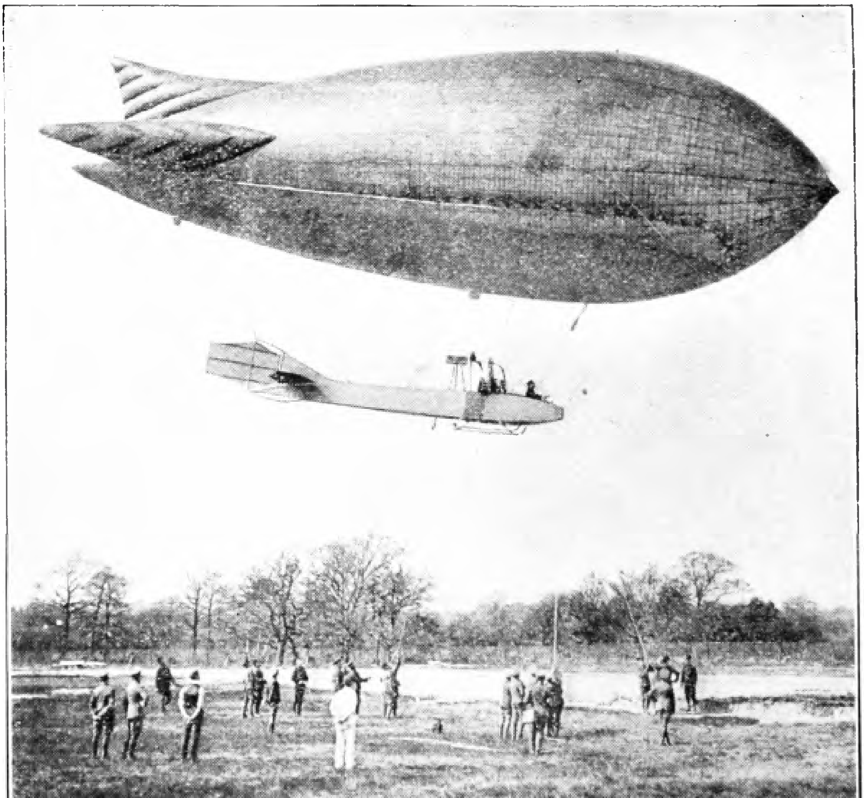


Fig. 74.—"Baby," the War Office dirigible made in the spring of 1909.

equalizing matters. The future will probably prove the aeroplane's propensities for death-dealing to be as capable of limitation as the torpedo's; it will also prove that all such appliances are two-edged!

Whatever happens, a nation's war strength will continue to be measured by its financial resources—its capacity to keep ahead of its rivals in regard to the number and quality of new destructive engines; war could only reach the height of unrestrained holocaust portrayed by the novelist if a nation were powerful and rich enough to make a "corner" in any new and secret murderous machine—though it is more probable that this would mean the end of bloodshed, either because any such country could dangle its diabolical invention, like the sword of Damocles, over the heads of its rivals and exact any terms it chose, or because all other nations would combine to prevent the use of such a weapon. The alarmist may rest assured that the airship and aeroplane do not come within this category.

Probably the greatest misconception exists in regard to invasion viâ the air. A German councillor has gone so far as to state in public that a fleet of airships could land an army of 100,000 men on the Kentish coast in half-an-hour. Some 30 men can be carried on a Zeppelin airship, so that over 3,000 of

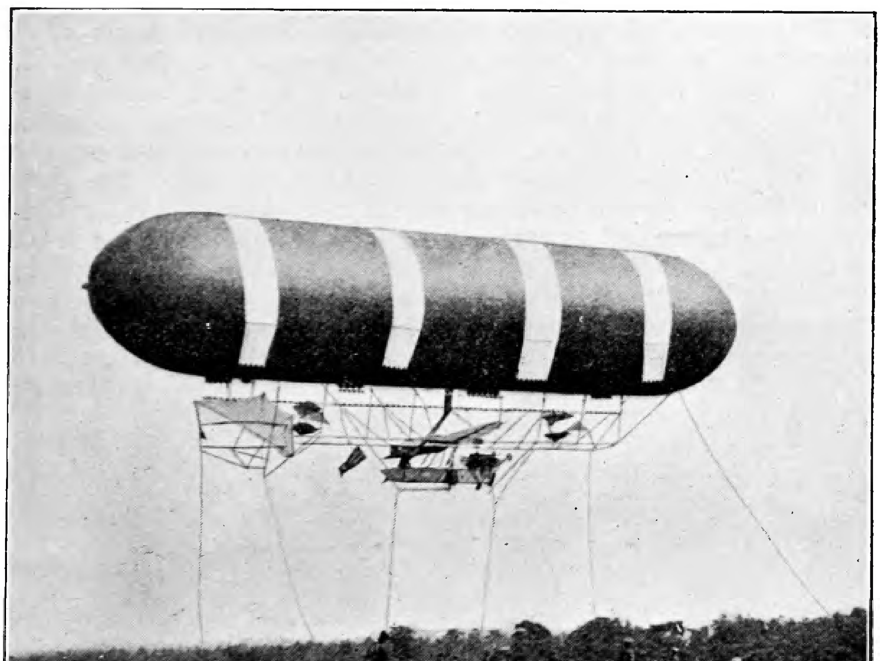


Fig. 75.—Dirigible No. 1 (the ill-fated "Nulli Secundus") of the British Army.

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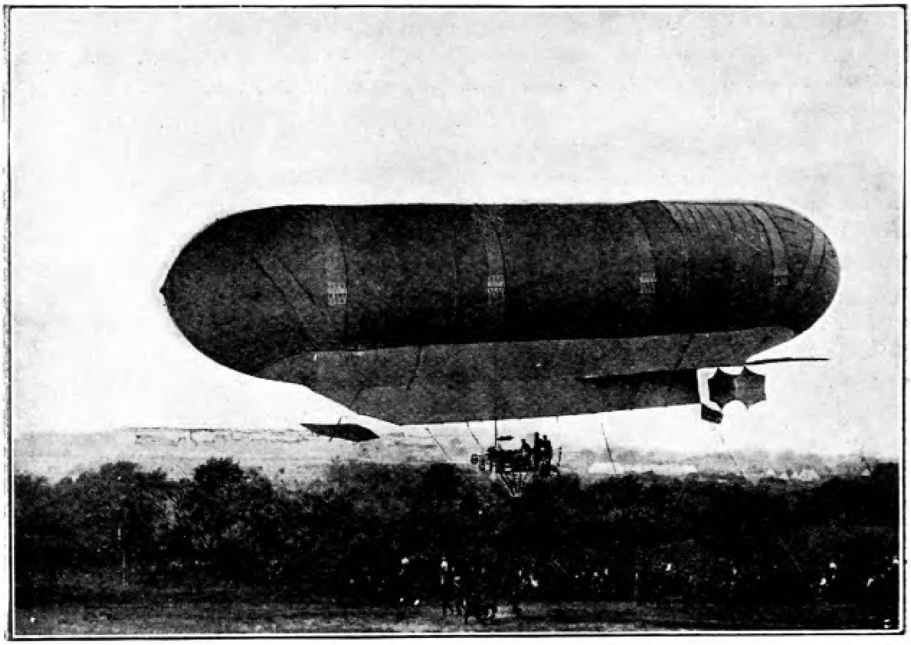


Fig. 76.—The rebuilt and enlarged "Dirigible No. 1."

the latter would be required to transport the above force. The construction of such a number could scarcely be kept secret, and we would thus have time in which to make adequate preparations, whilst it is doubtful whether even Germany possesses the resources, financial and chemical, to build, equip and supply with sufficient gas in a short time so many machines. The last-named, indeed, should prove an almost insoluble problem, seeing that one airship of the above type requires anything from 350,000 to 400,000 cubic feet of gas. But a more important point is that only an airship of such size as to be almost unmanageable in bad weather could take heavy supplies and munitions, or guns of any size; and without ample cavalry or artillery

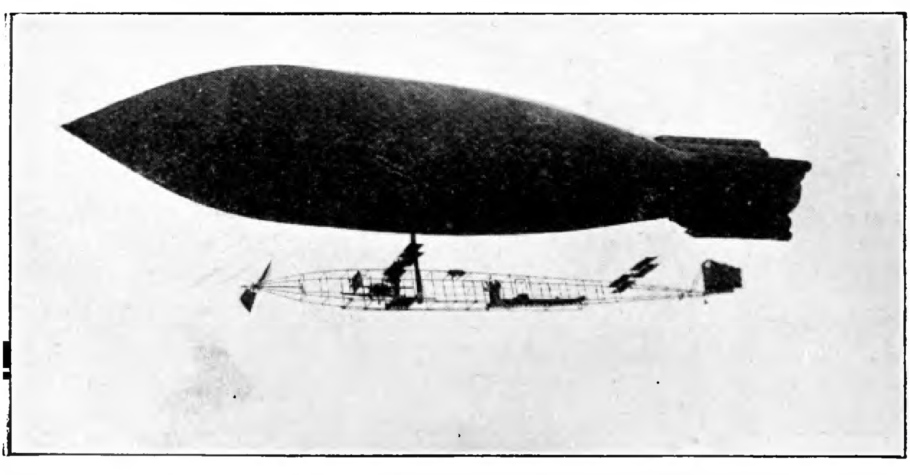


Fig. 77.—The "Ville de Paris" attached to the French Army.

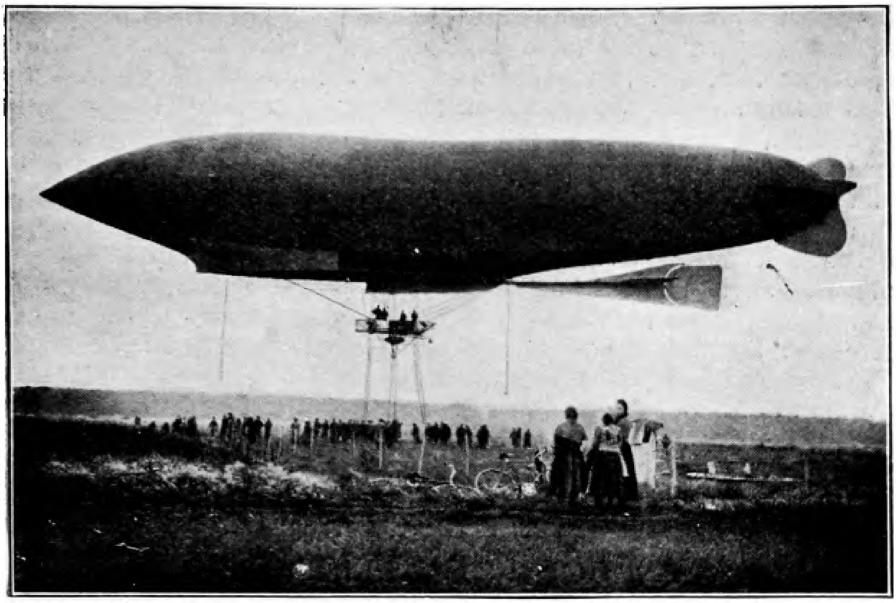


Fig. 78.—"La Patrie," the dirigible which, in 1907, was blown away into the Atlantic.

an infantry force of the strength mentioned would be dangerously handicapped in a strange country—if not comparatively useless. Machine guns might be brought over; indeed, one of the latest French airships is fitted with two guns of the Hotchkiss type; but they lack the range and moral effect necessary to cover the advance of infantry. Invasion by airship would,

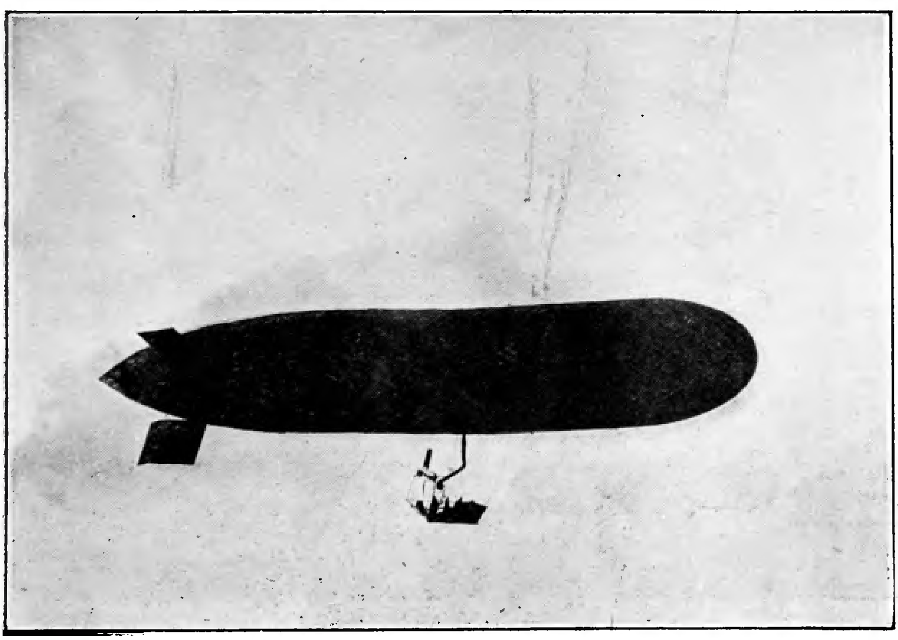


Fig. 79.—The Parseval dirigible.

in short, prove to be so stupendous an undertaking, and attended by so many risks, contingencies, and almost prohibitive cost that one can agree with the Hon. C. S. Rolls that it "is quite out of the question."

The main drawback to the airship from the military point of view is that it cannot be implicitly relied upon in all weathers and under all circumstances. This terrible uncertainty would, to some extent, put all commanders on a level; military genius becomes a mockery when one is at the mercy of one's instruments. There could be no dependence on an airship turning up at a definite spot within a given time; a commander whose main strength lay in airships might be suddenly crippled in violent weather and compelled to capitulate to a force strong only in the field. Military commanders might shun such machines, preferring to put their trust in the unmatchable resource, adaptability and intelligence of human beings. Air craft will be indispensable adjuncts to an Army, but of secondary importance only. The construction of gun carriages that will admit of fire almost up to the zenith is only a question of time, and, properly equipped in this respect, our forts and naval bases would be able to bring such a sustained bombardment to bear on any hovering airships as to make the latter's position absolutely untenable. The failure of recent experiments of this kind at Gibraltar need cause no uneasiness; for much better results

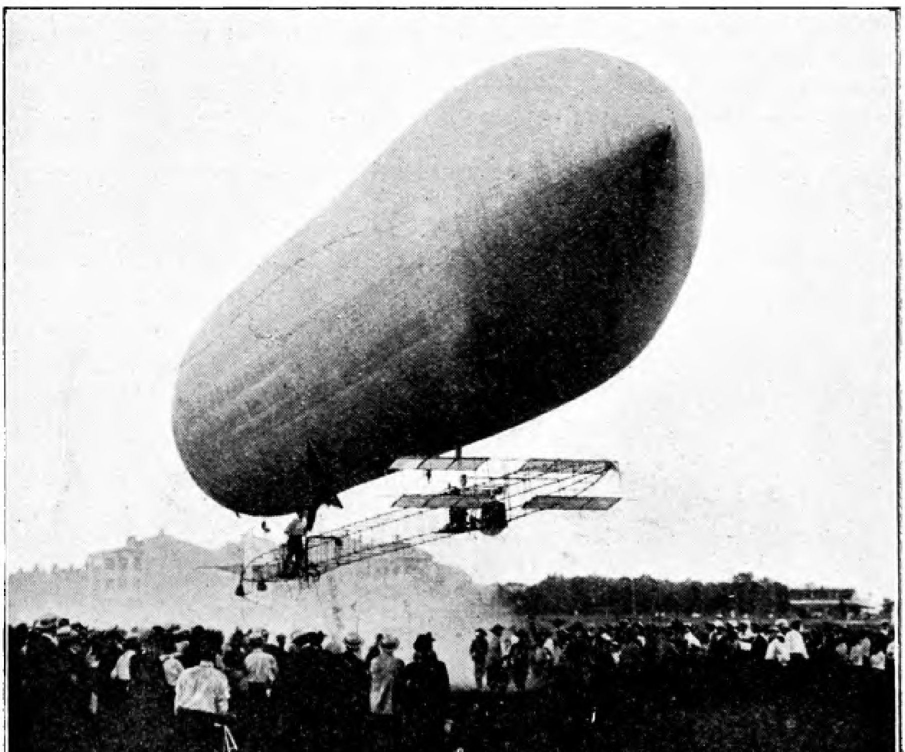


Fig. 60.—The Baldwin dirigible attached to the American War Department.

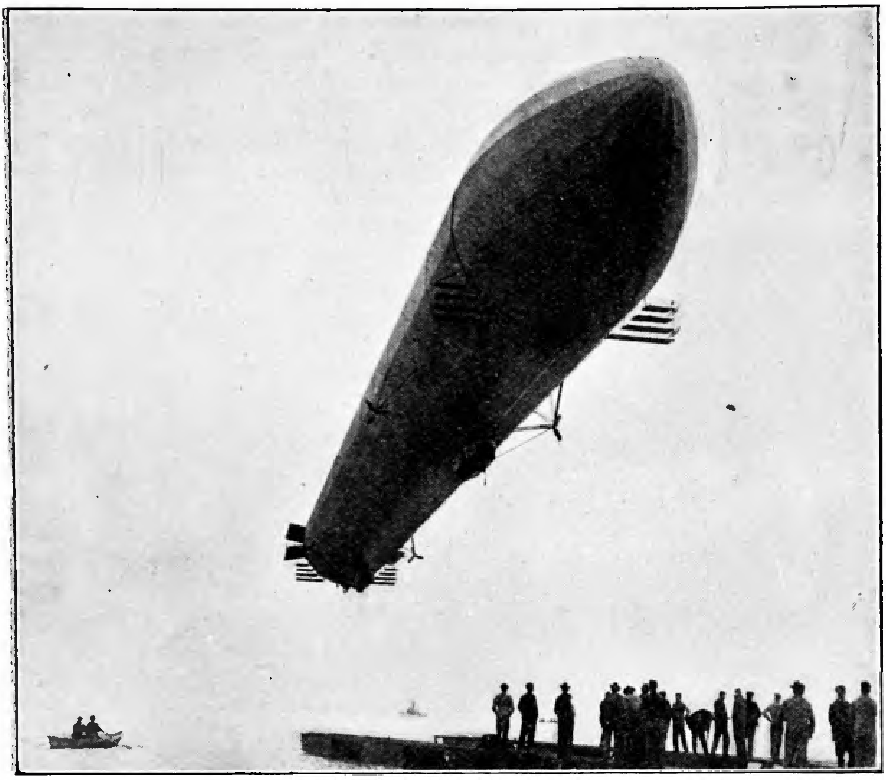


Fig. 81.—The Zeppelin airship manœuvring before the Kaiser.

have been obtained in France and Germany, and Rear-Admiral Sir Percy Scott is said to have all but solved the question.

For serious offensive purposes the airship can rely on no greater degree of accuracy than is to be attained in the dropping of explosives, which needs no little practice. But buildings and thoroughfares cannot be readily recognized from a height, and to aim with certainty an airship would have to approach comparatively close to the earth and hover above its objective for a few moments—which might prove fatal if picked marksmen were on the look-out in favourable positions. There is a doubt, moreover, whether an airship can always be got in a position exactly over any comparatively small spot and at the necessary height, and, as magazines are usually situated in obscure and isolated spots it would be not only difficult to locate them, but their destruction would involve little more than a monetary loss; for we do not station soldiers in magazines, and the chief constituent in the latter, cordite, merely burns away with a sort of fizz, so long as it is not rigorously confined. Sir Hiram Maxim has pointed out that an added danger for those on land will be from the falling shells fired at airships; but to balance this we have Captain Tulloch's very pointed reminder in the "Nineteenth Century" that explosives exert their force upwards, thus constituting a very real danger to the airship that drops them! It is doubtful, however, whether our garrison gunners will ever be able to exhibit the mathematical accuracy towards the travelling aeroplane which characterizes their firing at rapidly-moving battleships, simply because the flight of the former may be both vertical and horizontal in direction, making of it a most baffling target.

The possibilities of the airship on night manœuvres have been exaggerated. It could place no check on an enemy's movements, seeing that only the darkest nights are chosen for surprise attacks. Under such circumstances it would neither be able to observe and report the operations nor to make a counter-attack. If all lights on land were extinguished it would have nothing but a compass to rely on. On the other hand, it would be clearly visible against the sky on a moonlight night, and thus a positive source of danger to its main force. The one great disadvantage of the airship in actual campaigning is that it would disclose the whereabouts of an opposing force, and the direction it was taking. Even on the blackest nights, powerful electric searchlights could sweep the sky and disclose the position of any hovering airships. When certain developments have taken place in regard to the former, another check will have been placed on the destructiveness of airships. The latter will supplement railways for the more direct conveyance of dispatches, members of the staff, special supplies, and so on, but will never supplant them. For airships will be unavailable for heavy goods, and they will be too dependent on weather conditions, and for this reason they can never equal the railways or motor when the rapid concentration of troops at any given point is desired.

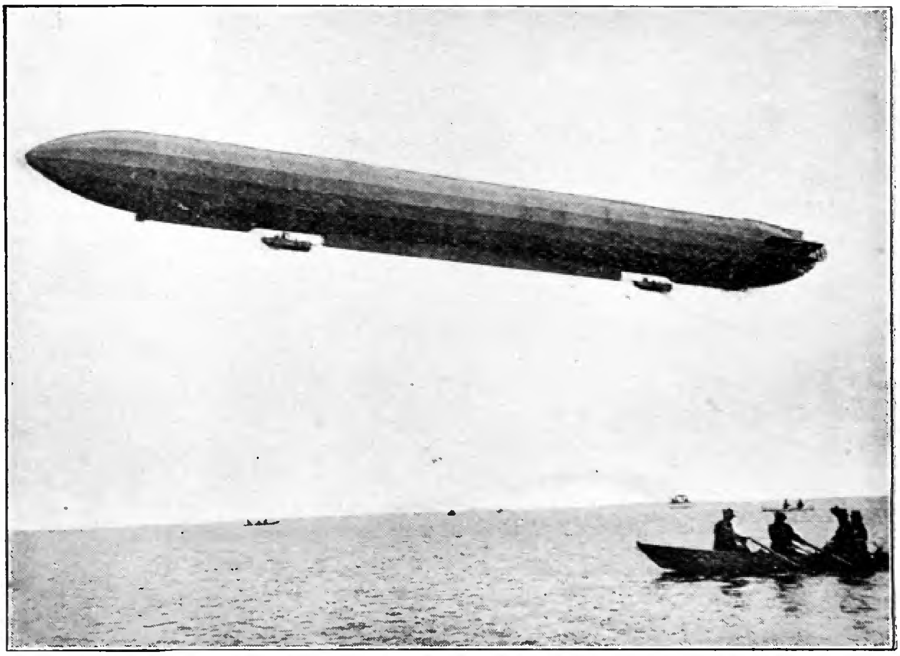


Fig. 82.—The Zeppelin over Lake Constance.

No one will dispute for a moment the airship's utility for reconnaissance work, observing the effects of artillery fire, photographing positions, making rough maps of the country, and so on; but the military captive balloon has answered all these purposes for over a hundred years, and the airship has the same limitations, namely, fairly calm weather is essential for making careful observations, and in a very mountainous country the range of outlook is restricted, for if the reverse slopes of hills be steep they can effectually conceal an enemy's position. The difficulty of communication has also yet to be satisfactorily solved, for, unless airships can be relied on to keep in direct touch with headquarters, and, perhaps more important, with one another, the commander must leave them entirely out of his calculations as being irresponsible and useless. Wireless telegraphy will in due time doubtless step in here with complete success, though it is claimed that the aeroplane is not so well adapted for the installation as the airship, and that even in the latter case there is some risk of fire. The latter's superiority over the aeroplane in yet another military requisite is worthy of note, for it can in certain circumstances rise direct from an enclosed space, descend at any desired spot, and manœuvre more easily.

The airship and aeroplane bid fair to revolutionize gunnery, musketry, and even the uses of cavalry, in the future. There can be no forecasting the composition of the army of the future —supposing such things are still in existence. Nor, apparently, would the present-day rules of strategy answer. For commanders will have to take the weather into consideration, as being an additional weapon to use against airships, to an extent hitherto undreamed of. Campaigning may consist of protracted manœuvring, mere dilly-dallying so as to ensure that battles are fought on days when the climatic conditions place the enemy's airships at a grave disadvantage. A snowstorm, which will practically kill an airship, will be one of the few occasions when contending armies will have an equal chance.

The real war value of airships lies, as Captain Tulloch has graphically portrayed, in their unlimited capacity for incendiarism. With everything carefully mapped out beforehand, they could operate over dense commercial districts and harbours, where untold stores of combustibles, such as oil, timber, and gas could be found. These are also, in regard to population, the most congested centres; and it needs little imagination to picture the black ruin, desolation, and mad, reckless, fatal panic that might be brought about in a few short hours by a group of airships in skilful, determined hands. Mr. H. G. Wells has driven this truth home with ghastly realism in his vivid description of the destruction of New York in "The War in the Air." "As the airships sailed along they smashed up the city as a child will shatter its cities of brick and card. Below, they left ruins and blazing conflagrations and heaped and scattered dead." In the same book he anticipates, too, the recent remark made by Lord Montagu of Beaulieu at the Mansion House, to the effect that "the little island in the silver seas" is near the end of its immunity, its insularity. To make that good by the establishment of a two-power standard in airships is the only solution of the problem for politicians. There is only one way in which a great city can hope to escape wholesale destruction under the above circumstances, namely, by levelling all its fortifications and withdrawing its troops; for according to the Law of Nations no unfortified and undefended town should be bombarded; but history proves that rather than suffer such a blow to their patriotism and pride the inhabitants of a beleaguered town will endure anything.

In conclusion, it may be said that airships will probably prove of greater assistance in naval than in military warfare. For it is common knowledge that when one is over the sea at some altitude with the water smooth it is usually possible to see to the bottom, and thus the presence of mines and submarines could be detected and reported. Airships could serve as eyes and signal-stations to a fleet, as guides in long-range bombardments, and as pilots in low-lying fogs.

A figure carved on the tomb of Rameses III. in the Louvre Museum, Paris.

DIRIGIBLE BALLOONS.

The Zeppelin Airship.

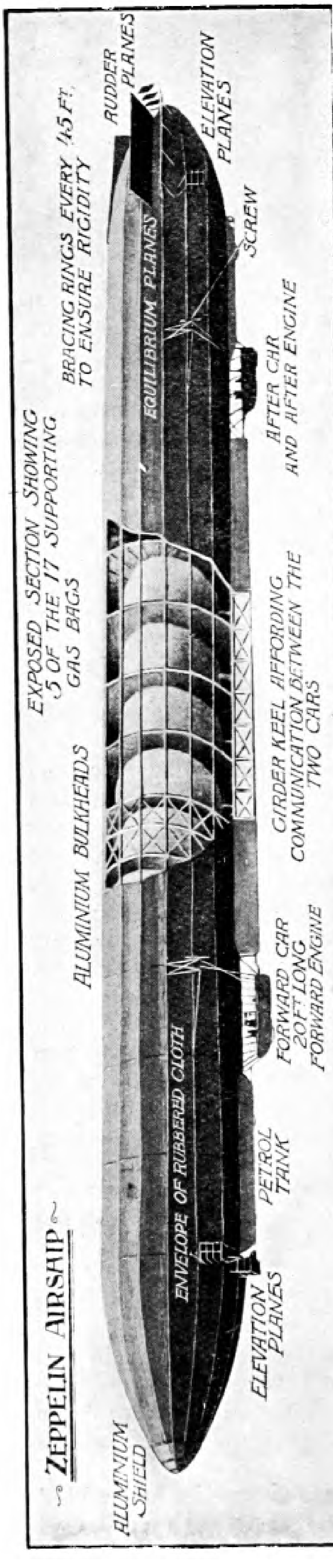
The Zeppelin airship comes within the category of rigid dirigibles. No matter whether deprived of the lifting gas or not, its contour remains unaltered, determined, as it is, by an aluminium framework, or skeleton, covered by an outer skin. Apparently cylindrical in form, with obtuse cones fore and aft, the airship is really a 16-sided prism, the framework consisting of a series of polygon rings, trussed from stem to stern, and kept severally expanded by steel wires, which, starting from each angle of the polygon, converge on a small central ring, just as the spokes of a wheel concentrate in the hub. Each polygonal ring, therefore, possesses 16 converging stays or, to preserve the wheel metaphor, as many spokes. From the inside ends of the longitudinal trusses, which also number 16, cords of ramie stretch from ring to ring, and form a network separating the lifting power from the outer skin.

The source of lifting energy is hydrogen gas, enclosed within 16 separate cells, 12 in the cylindrical section and two in each of the forward and after cones that constitute the stem and stern respectively of the airship. This separate-cell system is a distinctive characteristic of the Zeppelin. The Count, it may be observed, was the first to place separate gas-bags inside a rigid frame. Destruction of any one cell, consequently, does not necessarily involve the collapse of the airship.

Between gas-cells and outer skin there is, as stated above, an air-space, which plays an important part in the system, namely, to counteract the effects of varying temperature on the gas, air, as every student of physics knows, being an extremely poor conductor of heat. Naturally, the counteraction is only one of degree. The Zeppelin, with its metallic framework and more or less rigid skin, always presents a good steering surface, its form being altogether independent of the state of the gas-cells—a point noted in the opening sentence.

The weight of the framework and inter-connections makes it absolutely necessary that the airship should have large dimensions. "Zeppelin I." measures 446 ft. in length, and has a diameter exceeding 38 ft., the volume working out at some 12,000 cubic metres, or 211,900 cubic feet. On the other hand, thanks to the low conductivity of the air-space between the cells and frame-cover, the density of the gas is less affected than in the case of dirigibles constructed on other principles. Hence, the aeronauts need less ballast as such, although this advantage becomes neutralized by the airship's huge dimensions, which necessitate the carrying of more fuel.

With the object of stiffening the frame, Zeppelin has added a keel, of triangular cross-section and covered with rubbered



(From "The Sphere.")

Fig. 83.—The Zeppelin airship and its constructional details.

cloth to reduce resistance. About a fourth of the whole length from each end the keel is interrupted to admit of attachments for two boat-shaped cars of aluminium and steel tubing, connected by a gangway containing, amongst other things, a wagon, which runs on rails and can be hauled to and fro by wire cable, for preserving equilibrium. The cars have pneumatic shock - absorbers underneath. Each car is over 26 ft. in length, and hangs within 7 ft. of the outer skin, a proximity tending to obviate oscillation.

"Zeppelin I." has two sets of horizontal-steering planes, fixed high up, towards the middle of the stern cone, at the rear end of two laterally-placed steadying planes, and operated from the cars through an ingenious arrangement of gear, wire and wheel. Each set consists of three parallel planes of about 43 sq. ft., hanging, like ship's rudders, almost perpendicularly to the large steadying planes, each over 300 sq. ft. in area. The frames of steering sets and other planes are composed of aluminium rods, over which canvas is stretched, wires holding the surfaces in position.

Change of altitude is effected by means of two pairs of plane-sets, the one forward and the other astern, each set being made up of four parallel planes, attached laterally, just over the keel, to the first ring of the cylindrical section. Of course, their planes of position are identical with that of the airship's axis, or at a tangent with the body. As each of the parallel planes terminate outwardly in a line with the others of the same set, they differ in length, being shorter according as they approach the centre of the balloon's transverse curvature. The pairs can be worked alone or together. They have severally an area of about 240 ft. Turned aslant, they act like a kite, the airship gliding upwards or downwards as their position may determine. With these altitudinal planes, in fact, the ship can rise dynamically under the power of its propellers; in other words, it can rise in spite of being at the time somewhat heavier than air, like an aeroplane. Two four-cylinder engines of 85 h.p. each supply the propelling power, which gives the monster an independent velocity of over 30 miles an hour. Its propellers are four in number, resting on supports fixed to the framework of the cylindrical section and high above the two cars, one on each side. They are three-bladed, about 10 ft. in diameter, and act at a point where they can be most effective. Power is transmitted from the motor through bevel gear, propellers and motors corresponding in revolutions per minute.

The French Airships.

The first really successful airship in France was appropriately named " La France," and was designed and constructed by the late Colonel Renard and Commandant Krebs. Starting from the military establishment of Chalais-Meudon, in the suburbs of Paris, on 9th August, 1884, " La France " sailed a distance of several miles to the intersection of the Versailles and Choisy-le-Roi road, described a circle, reversed, and went through various manœuvres, then returned to its starting point in safety, the return journey of five miles being made in 23 minutes.

Santos-Dumont was the first in France to adapt the petrol motor to a balloon. His early attempts may be passed over, for it was not until No. 5 was produced that anything like success was achieved. This was a long, small diameter balloon, 111 ft. in length, but of only 19,000 cubic feet capacity, to which was

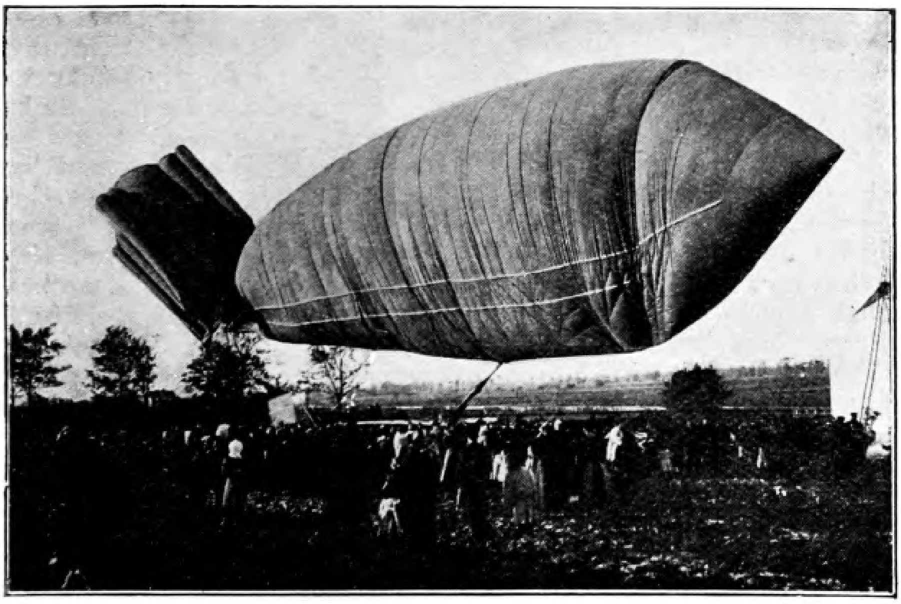


Fig. 84.—A loss of symmetry! Deflation of "La Ville de Paris."

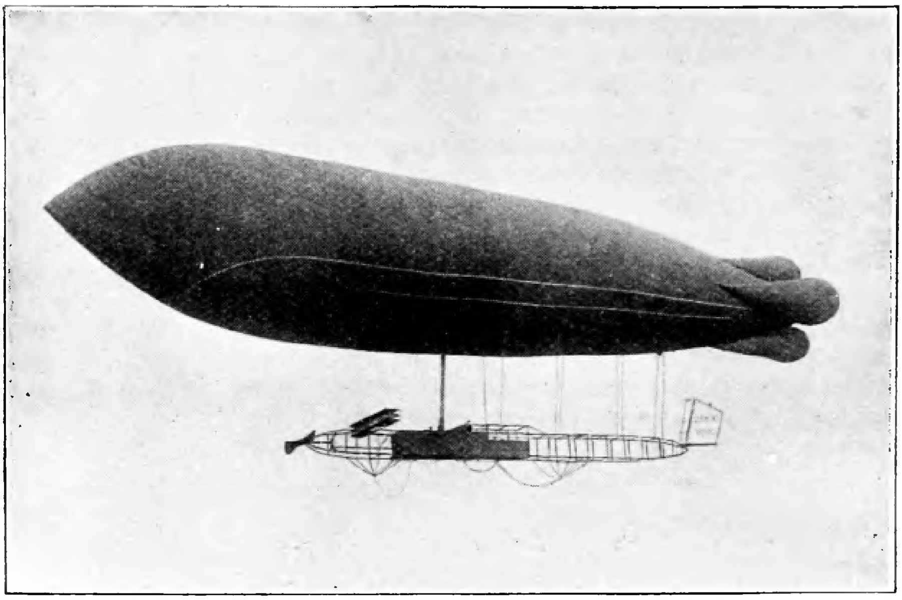


Fig. 85.—"Clement-Bayard," a very successful ship.

attached a rough sort of platform receiving a four-cylinder 16 h.p. petrol motor driving a large propeller. The accommodation for the pilot was very mean, there being no car properly speaking, but merely a bicycle saddle, with two pedals as on a motorcycle, allowing the engine to be started up. It was a delicate construction, and needed the audacity of a Santos-Dumont to mount it.

The first important experiment was made on 12th July, 1901, when the airship went up from St. Cloud, crossed over the Seine, and came down on Longchamps racecourse less than a mile away. On 19th October of the same year Dumont successfully rounded the Eiffel Tower on his No. 6, returning in safety to his starting point at St. Cloud, the winner of the Deutsch de la Meurthe prize of 100,000 francs.

There was a temporary set-back to the airship movement by the fatal accidents the following year to "Pax," piloted by the Brazilian Severo, and to the Bradsky airship. "Pax" was badly designed in respect to the position of its motors, the exhaust valve of the envelope being so near to one of the motors that a mass of gas formed outside the balloon and was fired. Baron Bradsky, who used a non-rigid type of airship, met his death, together with his companion, by the car breaking away from the balloon when sailing over the suburbs of Paris.

Black as was the year 1902, it was nevertheless the starting point of the practical airship movement in France, for at the end of that year the Lebaudy dirigible was produced, and made more than 50 journeys between October, 1902, and November, 1903, when it was wrecked by colliding with a tree during landing operations in a heavy wind. This was followed by "Lebaudy I.," even more successful than the first one, and which served as a model for future military airships, among others the famous

"Patrie." Since the disaster to the airship "Republique," very little has been heard of French dirigible balloons. The huge Clément-Bayard, of 212,000 cubic feet, which was almost ready for inflation at the time of the "Republique" disaster, was immediately modified to such an extent that it had to be practically reconstructed. When it makes its appearance it will have been transformed from a non-rigid to a rigid type, with six distinct compartments, and with a cagework to prevent a propeller blade striking the gas-bag in case of fracture. It will be equipped with two four-cylinder motors, each one developing 200 h.p. and driving a large wooden propeller at the side of the airship. Provision will be made for driving the two propellers by one engine only, in case of necessity, either directly by chain or through a reducing gear set. In all, three balloons of this type are being constructed, one of them being intended for England, another for the Clément-Bayard Co., the destination of the third being unknown.

The "Colonel Renard," which first made its appearance at

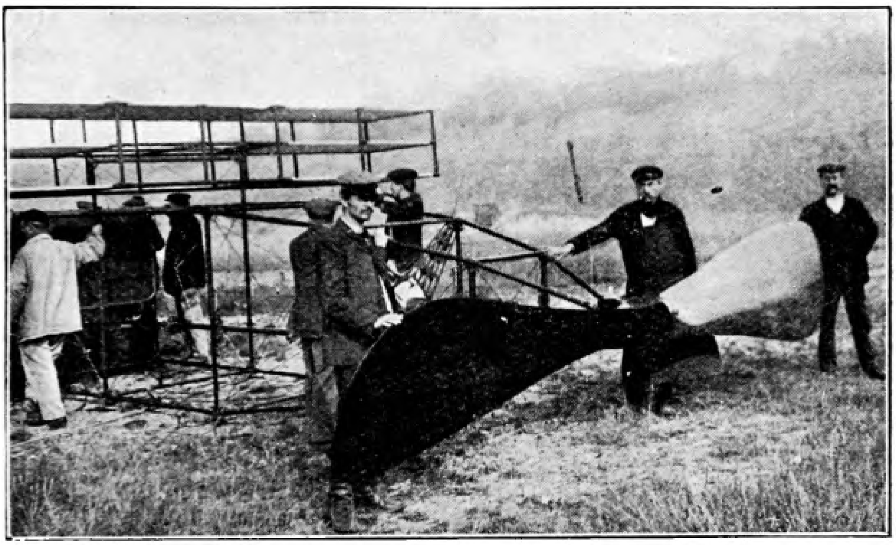


Fig. 86.—Forward framing and tractor screw of "Clement-Bayard."

Rheims in August, 1909, has been undergoing modifications for several months, but may be expected to be put into commission during the present year. It is of the non-rigid type. The "Liberté" is a semi-rigid type of balloon, being constructed by the Lebaudy brothers. It will be brought out during the present year. The "Ville de Paris" is a non-rigid type similar in general features to the "Ville de Nancy," "Ville de Bordeaux," and the "Clément-Bayard," which fell into the Seine in 1909. Other balloons are the "Lebaudy," now an old vessel, the small dismountable "Zodiac" and the rigid "Spiess," the designs for which have been given to the Government, and is now being built at the Mallet factory.

The "Spiess" dirigible, the first rigid airship to be built for the French Army, was patented by its inventor in 1873. The vessel now being built has a cubic capacity of 294,000 ft.; its length is 288 ft., greatest diameter 39 ft., number of compartments 12, weight of the framework $4\frac{1}{4}$ tons, total weight, including the gas-bag and internal balloons, a little over 6 tons. The original design provided for an aluminium framework, but this has been changed in favour of a hollow wood framework, with aluminium joints only. The general form of the balloon is a cylinder terminated by two cones, the rear one being much finer than the front one. Motive power will be two four-cylinder motors of 120 h.p. each, furnished by the Panhard-Levassor Co. It is not expected that this airship will be ready until the spring of 1911.

A type of balloon which has met with considerable success in France is the dismountable "Zodiac." It is made in two sizes, the larger one having a capacity of 35,000 cubic feet, and the smaller one of 25,000 cubic feet. Naturally, the airship is of the non-rigid type, its distinctive feature being the construction of the car in three distinct parts, rapidly assembled or dis-

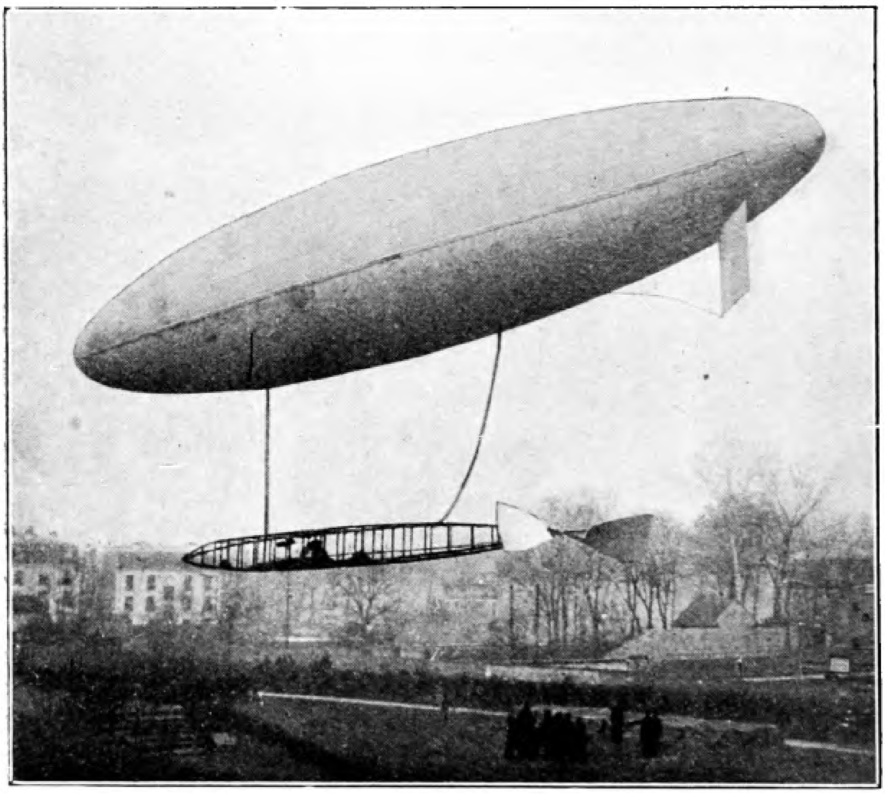


Fig. 87.—An early Deutsch dirigible balloon.

sembled. When it is desired to deflate the airship, the propeller is dismounted, the rear rudder taken off, and the airship placed broadside to the wind, so that, on being deflated, the empty gas-bag falls clear of the car. It only remains to withdraw a series of bolts separating the car into three distinct parts. Mounted on a lorry, together with the gas-bag and fittings, the airship is transported as easily as a spherical balloon, and can be stored in any ordinary coach-house or motor garage.

British Army Dirigibles.

At present the military authorities in this country possess three airships, officially known as " Dirigibles I., II. and III." All three are really experimental, although the latest to make its appearance is a very serviceable little ship.

" Dirigible I.," upon which the Press heaped ridicule by calling it " Nulli Secundus," was built under great difficulties, both time and money for its construction having been begrudged by the War Office. It had a sausage-shaped envelope of goldbeater's skin and was unprovided with balloonets. She attracted considerable attention by her bold flight to London, when exactly what had been feared and had been risked actually did occur. The ship had to descend in the Crystal Palace grounds, where she rode at anchor during an increasing gale.

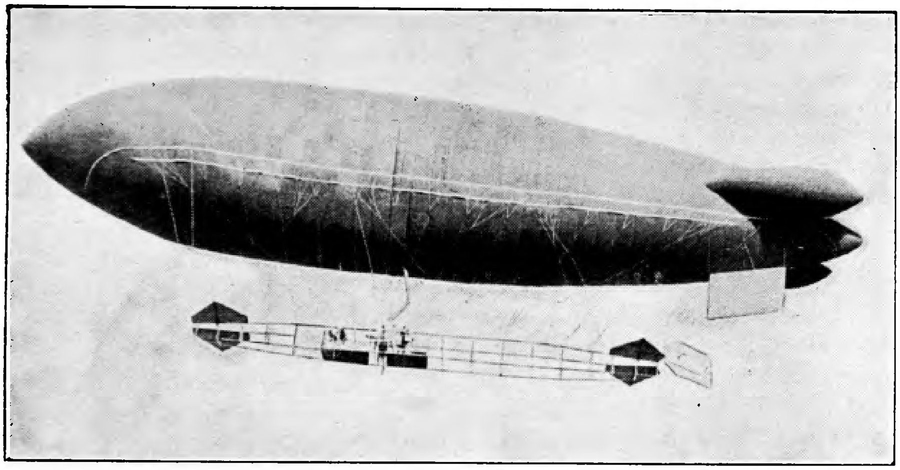


Fig. 88.—The latest British Army airship "Dirigible II."

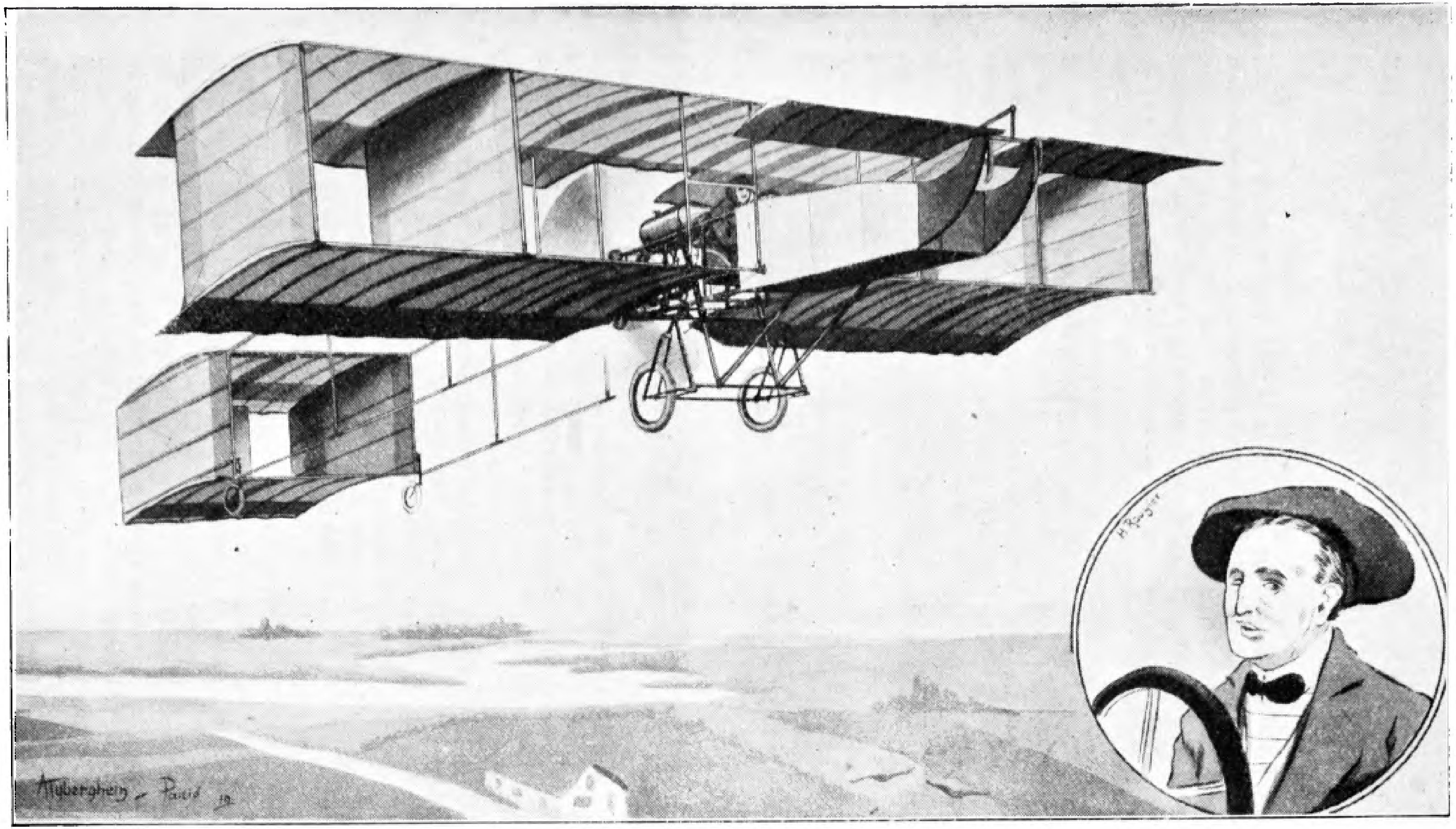
The impression remains amongst most people that she was wrecked there, but nothing of the sort happened. The corporal in charge, afraid that she might be torn away by the wind, took prompt action and ripped the envelope. The gas-bag and car were taken back to Farnborough, where they were reconstructed (being slightly enlarged).

" Dirigible II." made her appearance in February, 1910. She has an envelope of Continental balloon fabric and of 72,000 cubic feet capacity. Overall she is 152 ft. in length, with a major diameter of 30 ft. at a distance of about 45 ft. from the nose. In form, the gas-bag is ichthyoidal, that is, having longitudinal sections of fish shape, the nose, however, being pointed. Right aft at the tail there are two external balloonets, placed horizontally at each side and of reverse ichthyoidal shape. These communicate with the interior of the main envelope through small holes, and at the apex of the fins connecting them to the main gas-bag are holes, evidently designed to prevent the accumulation of water. Under the tail is a short, deep keel, about 14 ft. in length and 8 ft. deep. Two internal balloonets are used, one forward and one aft, with a common connection to the air fan, just above which is fitted a two-way butterfly valve.

At each side of the main envelope, along the line of greatest beam, are attached two strips of material from which depends the rigging that supports the car of the ship. Built of steel tubes fore and aft and of hickory with steel joints amidships, the car frame, which is now somewhat longer than when the ship made its first appearance, is about 90 ft. in length. Right forward and right aft of the car, balanced planes of triangular form are fitted, whilst between the rear pair of elevating planes is a large steering rudder. An 80 h.p. Green engine is fitted athwart the car, somewhat forward of amidships, and drives a pair of double-bladed propellers, 9 ft. in diameter, one on each side. The propellers are built up of metal and are of true helicoidal form. They are mounted on booms at each side of the ship, the booms being tubular and carrying the driving shafts, which are geared by bevels to the propellers. An ingenious mounting of the booms permits them to be turned on their axes, so that the propellers can be used not only for driving ahead, but also for driving upwards or downwards. Several attachments are made to the envelope to permit certain experiments to be made, and, though the size of this dirigible is more imposing than that of the other two, she should be regarded only as an experimental ship.

"Dirigible III." was the second of the ships to make its début. Popularly known as "Baby," she is a small ship of 40,000 cubic feet capacity and with an engine of 30 h.p. The reason why her number is III. is to be found in the fact that she was designed and laid down for construction after "Dirigible II.," the most recent to make its appearance, had already been taken in hand. She was comparatively a cheap ship and not too unwieldy, and from her some very useful results were obtained. At the Army Balloon Factory at Farnborough, progress is being made by small and sure stages, and, before "Dirigible II." was completed, it was thought advisable to build "Baby" as an intermediate stage. "Dirigible II." even is only a step toward bigger ships.

Whilst the work at Farnborough may not appeal to the public mind, it is certain that it is based on an excellent method, and one which, in the long run, will produce the best results. The knowledge which is being obtained from the progressive experiments is exceedingly useful, and will be more useful than ever when big ships are being built. It must not be forgotten that, though other countries possess much larger military airships, they, in reality, are only experimental, although they are not so termed, nor perhaps even so regarded by their builders. But the fact remains that a very big percentage of Continental airships have come to grief, and, though the authorities there have now learned some very useful lessons, they have paid dearly for their knowledge.



AVIATORS AND THEIR MACHINES.
M. Henry Rougier and the Voison biplane.

HOW TO LEARN TO FLY WITH A VOISIN BIPLANE.

After about six months in charge of the Voisin aviation school at Mourmelon, during which time he had trained not less than a score of pupils, M. Edouard Chateau considered that he had obtained sufficiently satisfactory results to enable him to respond to a request to explain in a simple manner for The Aero Manual how to proceed in order to become a successful pilot of the Voisin type of flying machine. While at the head of the aviation school, he says he never found any pupils altogether incapable of learning to fly; but he found considerable differences in the adaptability of the would-be aviators. The Voisin aeroplane, however, is a comparatively easy one to handle, and it is certainly the one with which practical results can be most quickly obtained.

The general education of the pupil is a matter that has considerable bearing on the manner in which he will behave as a pilot. Before settling down to practical work it is necessary first of all to understand at least the elementary theory of the apparatus that is about to be used. The essential qualities, and those which will be of greatest help to the beginner, as well as to the experienced flyer, are calmness under unforeseen circumstances and rapidity of decision. The sports practised before taking up aviation which will be most useful in the new calling are motoring and yachting (sailing yachts).

After having explained to the pupil in language as simple and clear as possible what an aeroplane really is, and how it behaves both on the ground and in the air, he is shown, on the apparatus itself, by what operations of the elevator and vertical rudder it can be maintained in its correct position. Following this, the instructor shows in a practical manner how to operate the single controlling wheel in order to bring about the various desired movements of the machine. These are: (1) To push the steering wheel ahead in order to descend; (2) to pull it towards him in order to rise; (3) to turn the wheel to the left in order to make a left-hand turn or to correct the balance of the machine if it is inclining to the right; and (4) to turn the wheel to the right to make a right-hand turn, or to correct the balance of the machine if it is inclining to the left.

The pupil is then placed in the pilot's seat and the tail of the aeroplane is raised by two workmen until the apparatus is in its correct flying position in relation to the earth. Whilst the tail is held up in this way, the pupil is told in what position to maintain the elevation rudder in order to keep the aeroplane in its correct position while running at speed over the ground. This is a most important point, it being necessary for the pupil to be able to run over the ground in the correct flying position, that is with the tail clear and the main wheels just skimming the surface, before attempting to rise altogether. The instructor also points out very forcibly the danger of allowing the aeroplane to "rear up," and this point is reverted to again and again until it is absolutely certain that the pupil has learned his lesson.

The only condition on which an aeroplane will remain aloft is that it has sufficient horizontal speed. If, by reason of a false movement of the elevator rudder, the angle of incidence is increased too much—that is to say the angle it makes with its horizontal trajectory—if, in other words, it is caused to rear or to dive, its speed is diminished and all power of sustentation is lost or greatly reduced.

From theory the instructor passes to practice. In an almost perfect calm he would mount, with the pupil on his left, and ask him to pay particular attention to the position in which the elevation rudder is kept in order to skim over the surface of the ground. It is necessary for the pupil to train his eye in order to be able later to retain the rudder in this position almost unconsciously. Several rounds of the aerodrome would be made in this way, then, little by little, the pupil would be allowed to take the steering wheel on the straightaway runs, the instructor correcting whatever mistakes might be made, and explaining them to the pupil afterwards. Following this, he is allowed to have control on the turns also. No attempt would be made to rise high. For the greater portion of the time the machine would be just skimming over the surface, getting clear into the air when it came to a dip in the ground, and running on the front wheels only when over rising ground.

Little by little, indeed almost imperceptibly, the aeroplane would rise higher until it was possible to make the turns correctly without danger of the wings touching as it heeled over. Of course, the first turns were made as wide as the nature of the aerodrome would allow. When the pupil and instructor had flown round the field together several times, the pupil holding the wheel, but being subject to the other's corrections, the instructor would give up complete charge whilst he filled the passive rôle of passenger. If all went well, the next step would be for the pupil to go out alone in a dead calm. Generally, he would operate in a correct manner and accomplish a satisfactory flight.

The only duty of the instructor, then, would be to calm the enthusiasm of the pupil by pointing out to him the exceptional conditions under which his flight had been made, and to emphasize the thousand and one treacheries of the air. In aviation, more than in any other calling, the motto should be "slow but sure." A few days alone on the aeroplane and the pupil would be sufficiently advanced to run to the factory—or fly there—in order to take delivery of his own aeroplane, with which, doubtless, he would soon obtain fame and fortune.

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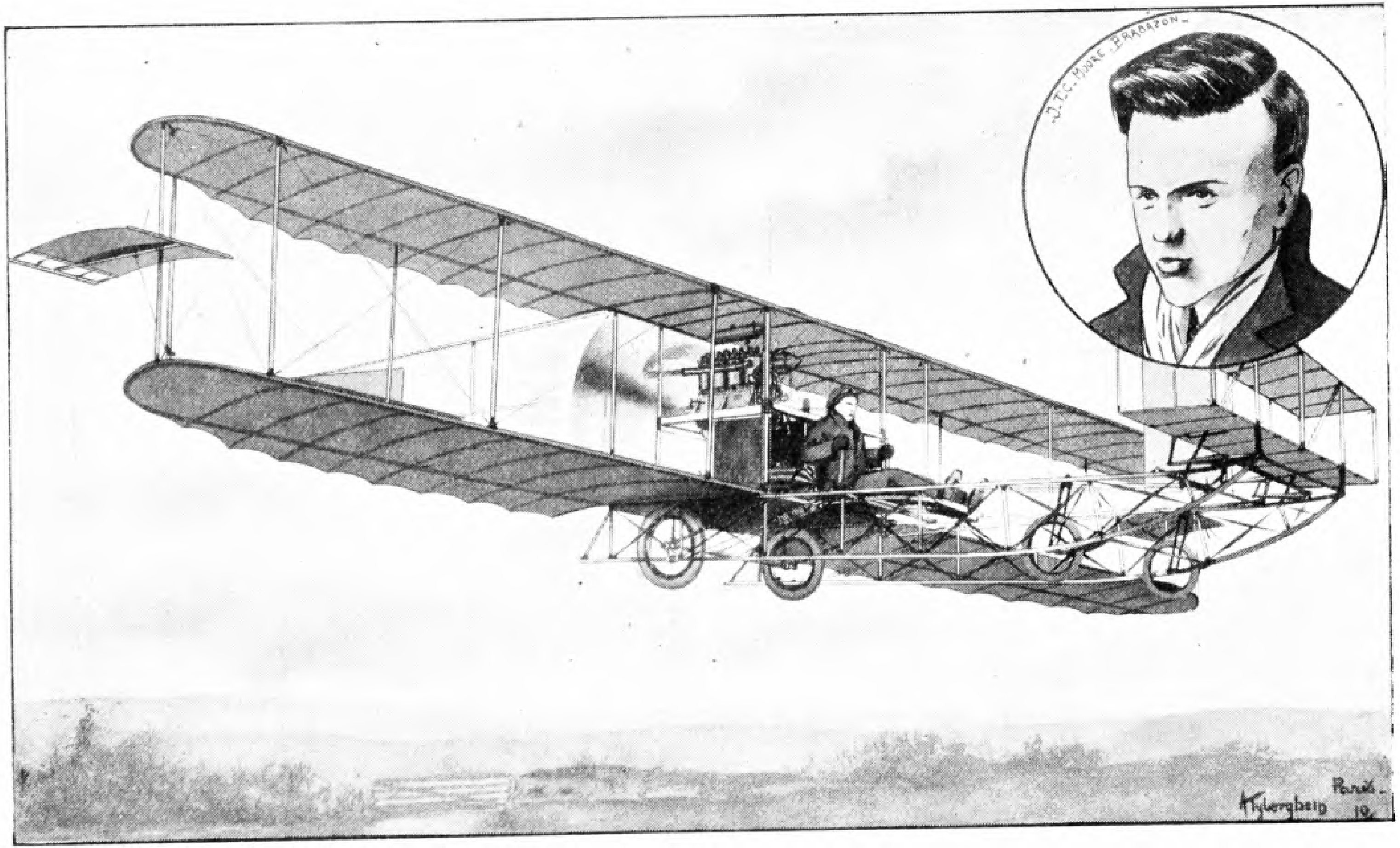


AVIATORS AND THEIR MACHINES.

Mr J. T. C. Moore-Brabazon and the latest Short biplane.

THE MANAGEMENT OF THE SHORT BIPLANE.

Mr. Horace Short, the designer and constructor of Mr. Moore-Brabazon's present machine, is an individual who keeps ahead of the times, and, consequently, before these instructions get into print, he will probably have designed and constructed a machine even better than the present one, although it is only himself who could do such a thing, and, therefore, these remarks may be subject to the reservation that they apply to what is known as the " Short No. 2 " biplane.

Having tuned the engine to run to its full power, and having carefully looked over all joints and moving parts, the machine is placed on the rail as is the case with a Wright machine, but the weight is not necessary for starting, although it, of course, can be used.

The aviator, should he be seated in the seat of Mr. Moore-Brabazon's biplane, would then find, on his right hand, a lever operating the elevating planes in front; on his left a lever controlling a rudder placed in front of the machine, but behind the elevator, and two stirrups, into which his feet slip easily, operating the ailerons for side balance. The engine having been started and fully accelerated, the catch holding the machine back is released, when, behold! with ever-increasing velocity, the aeroplane starts down the rail, at first with dignity, held at each corner by a man, until the rise of speed leaves them behind, and then, with a mad rush, which to the tyro is very terrifying.

The first thing to remember during this mad rush is to keep the elevator depressed, so as to keep the front roller on the rail, or it will buckle over and you will come off; the next thing, and equally important, is to keep lateral balance; this is done by ailerons at the edge of the planes, which are operated by the two stirrups on the feet. If you are leaning to the right, by pressing the right foot equilibrium is restored; similarly with the left.

For the first six times down the rail Mr. Moore-Brabazon considers it prudent not to raise the elevator at all, as confidence is thus gained, which on an aeroplane is everything. You will slide off the rail on to your skids; no damage will result, but you will have learnt quite a lot.

After familiarity with the rail is acquired, actual flight may be tried, but only in a straight line with the rail, which, of course, should be placed in the eye of the wind, of which there should be very little at first.

Actual flight is acquired by raising the elevator about 15 ft. before the end of the rail, when the front trolley will rise off the rail, thus inclining the main planes to the horizontal, when the air, striking them on the underside, will lift the whole machine in the air. You have then reached the state of grace known as " flight," and your future manipulation of the machine comprises various movements of the control levers to maintain the same.

At first, all one's attention will be directed to the management of the front elevator, and, if the machine should wish to lean or turn to the right or left, it is best to descend before making a mistake, as mistakes in control of aeroplanes are liable to be expensive. When the control of the elevating plane has been acquired (it soon becomes automatic), the aviator can try to correct any lateral movements caused by slight side gusts. This is done simply by depressing the foot on whichever side you are leaning down.

By Short's system of ailerons and the control thereof there is no tendency to " rotate about a vertical axis " (as the Patent Office has it), which sounds alarming, but which means simply turning to the right or left. This is done by the balancing of " drift " on either side, a state of affairs which cannot be done in a machine that warps the wing.

Now we pass to turning, and herein lies the charm of flying. The sensation of " wheeling " to the right or left, to use a terrestrial metaphor, must be experienced to be appreciated.

The turn to the left is done as follows:—Having attained a sufficient height, not less than 20 ft., press the right foot slightly; this will incline the machine to the left. After this, pull the left-hand lever, which operates the rudder; this will turn the machine to the left, and continue to do so until brought straight again, when the machine will come back to horizontal by itself, or more quickly by a slight pressure on the left foot.

The reason Mr. Moore-Brabazon advises banking the machine before turning is to obviate those " imperial " sideslips of about 300 yds. one is liable to make in the air, which at first are very alarming unless you know how to correct them.

All machines will land (perhaps we ought to be thankful for this!), but there are many ways of doing it, some of which we need neither describe nor explain, as machines look so undignified when smashed up, with odd ribs poking out of the fabric, the whole resembling nothing so much as the vanquished in a cock-fight!

Landing can always be done, as we have said, but a good return to mother earth is an art, and very pretty to watch. The essence of it is to get the machine flying in the eye of the wind, with no side-slip on her; the beginner may then gradually bring the machine down till touching the ground, when the elevator is pressed hard down and the engine switched off. To glide down is prettier still, but is better left till some proficiency has been attained, as a nasty kick takes place upwards when the engine is switched off, due to the sudden ceasing of thrust, but this is easily provided for by keeping the elevator down, and, consequently, way on the machine.

We may conclude with a few don'ts.

Don't be in a hurry. Better go ten times more down the rail than smash something; it will be quicker in the end.

Don't fly in a wind till you have got thoroughly accustomed to "side drift."

Don't fly too low at the corners, or take them too sharply.

Don't try any tricks till you have steadied yourself off the rail.

Don't frighten yourself; go quietly.

Don't take any risks; it may not much matter your being killed; but it does the whole movement harm.

Don't try experimental machines. Leave them to their inventors. You will be quite busy enough learning to fly a machine which you know can fly, and more profitably engaged than wasting your time on something that never will.

Don't *know* too much till you have got up in the air. After this you will feel inclined to take your hat off to every sparrow you see performing feats we can never even hope to imitate.

HOW TO PILOT THE MAURICE FARMAN BIPLANE.

To become a successful aeroplane pilot in the shortest time and with the fewest accidents, the learner should begin by thoroughly familiarizing himself with the controlling levers before even attempting to run over the ground. On M. Maurice Farman's type of biplane, these organs are only two in number and are reduced to their simplest proportions. A steering wheel, similar to the steering wheel of an automobile, except that it is mounted on a horizontal column, is immediately in front of the pilot. It turns to left and right, in the same way as a motorcar steering wheel, and with exactly the same results. In addition it has a fore and aft motion. If pushed ahead, causing the front elevation rudder to be lowered, the machine is either kept on the ground or caused to descend if in the air. If pulled towards the operator, the machine is made to rise in the air. Lateral stability is secured by the use of ailerons commanded by a horizontal lever worked by the feet. This really reduces itself to the natural swaying of the body, for if the machine heels to the right the pilot naturally leans in the opposite direction, pressing more powerfully on the controlling lever with his left foot than with his right, thus correcting the lateral balance of the machine. When these movements have been repeated until they become instinctive, the motor should be started and the same performance gone through. This is necessary from the fact that such a violent current of air is set up by the propeller that the aviator is apt at first to find the operation of the rear rudder somewhat difficult.

The active stage commences by running the machine over the ground, without any attempt to rise in the air. It is not advisable to run at a very slow speed, unless, indeed, the ground is absolutely smooth, for, unlike the motorcar, inequalities of the ground are felt more at low than at high speed. Further, the rudders are not really effective unless the machine has a certain amount of headway, the analogy with a boat in this respect being complete. In M. Maurice Farman's opinion, the most desirable speed for a learner is half that necessary to leave the ground.

As the learner becomes more skilled and confident in the handling of the machine, he should accelerate the motor for a few seconds only in order to almost attain the speed necessary for flight, and then drop back again to his former speed. After these tests, which should on no account be hurried, and when the learner feels fully confident of his ability to handle the aeroplane, he should start from a given point, accelerate the motor to the speed necessary for flying, and operate the front elevation rudder in order to very slowly leave the ground. Immediately it is felt that contact with the ground has ceased, the steering wheel should be gently pushed ahead to bring about a descent. The first flight should be only a few seconds in duration and should be in a straight line. Continuing the same method, the flights can be gradually lengthened, but without any attempt to make a turning movement. It will doubtless not be found necessary to work the ailerons; thus the entire control will be confined to the fore and aft movement of the steering wheel and the operation of the throttle of the motor.

When flights of several hundred yards in length can be made with ease, at a low altitude and in a straight line, it is necessary to rise higher in order to clear all such obstacles on the ground as telegraph wires, trees, etc., and to attempt very wide turning movements. The attempt should be made very gradually to depart from a straight line, the first trial at a turn being but a portion of a wide curve. The ground over which the attempts are made naturally plays an important part. The greater the surface free from obstacles the easier it will be to attempt turning movements. When a complete turn has been made in a very wide circle the same movements should be repeated until they can be performed with ease, then attempts may be made to gradually lessen the radius of the curve.

THE DIFFERENCES BETWEEN THE MONOPLANE AND THE BIPLANE.

Has the monoplane an inherent stability greater or less than that of the biplane? Is it easier or more difficult to pilot than the two-decker? What are the essential differences between the two types of machines? What are the respective rôles that they seem called upon to fill in aerial navigation. To these questions, so often asked, we will endeavour to give an answer.

Let us go back to the beginning of aviation in France, that is to say, to the year 1907, during which various constructors—Voisin, Blériot, Esnault-Pelterie, and others—produced their first mechanical birds (after Santos-Dumont) and obtained their first results. Public favour veered at once in favour of the monoplane. An endeavour was made to give reasons for this preference, but nothing solid or logical could be advanced. In reality, the favour of the novice (how few were the experienced men at that time!) was naturally given towards the type of machine which was most pleasing to the eye—which satisfied the æsthetic. It is always so: our taste, like matter, possesses a certain inertia. It was believed that flying machines should be modelled on the form of birds, and, in consequence, biplanes were despised.

Nevertheless, the biplanes flew. And the first practical results entirely upset all pre-established judgments. Whilst the monoplanes remained glued to the earth, or only succeeded in making short flights, to clumsily fall to the ground and be broken in their fall, the biplanes—those built by the Voisin brothers—made sure progress. Each day Henry Farman covered a greater distance than that of the succeeding day, and came back to earth in a correct manner. Then the judgment was pronounced, almost unanimously, that the biplane possessed greater stability and was more easy to pilot than the monoplane; but that this latter had certain saving qualities which might be revealed in the future, etc. Then the same biplane, after being judged capable of flying in a straight line only, succeeded in making its first turns; it flew a circular kilometre and won the Deutsch-Archdeacon prize; it remained in the air ten minutes, a quarter of an hour, half an hour. Then Wilbur Wright came to Europe. We witnessed his brilliant success, followed by the more arduous labours of the French aviators. Less than a year after we had Rheims and the magnificent triumph of the flying machine. And now both types of machine—biplanes and monoplanes—have succeeded in making sensational flights. Yet this old idea still remains: the biplane is a machine possessing great stability; the monoplane is a fast-flying machine. We have shown that its origin is entirely of a sentimental and æsthetic character.

But what is the actual fact of the matter? From a purely technical standpoint, the inherent stability of the aeroplane does not, in any way, depend on the number of superimposed planes of which it is composed. Robert Esnault-Pelterie, long ago, explained this in a remarkably elegant manner. Imagine a biplane with a given coefficient of stability. Theoretically, you can always transform its two surfaces into a single resultant surface, giving an equal sustaining speed, having the same head resistance as that of the two surfaces, and with a centre of pressure coinciding with the centre of pressure resulting from the two surfaces.

It is another matter to know if, the first machine having been built, the second will be easier of realization, or even if it will be possible to realize it. If we reduce existing aeroplanes to their essential elements, we can classify them, from the standpoint of longitudinal stability, into three types:—

1. A main bearing surface and a front rudder (Wright).
2. A main bearing surface and a rear rudder, generally with the addition of an empennage or a fixed surface (the monoplanes and the new Voisin).
3. A main bearing surface, a fixed or variable bearing surface at the rear, and an elevation rudder in front (the Voisin, Farman, Curtiss, and Short biplanes, etc.).

In this classification they are placed in inverse order of the inherent stability which they possess.

Without entering into detailed explications, it is easy to understand that the Wright machine possesses little inherent stability, and that the control of machines of the third class is easier than those of the second, if their individual stability is comparable. Naturally, the biplane and the monoplane can each be placed in these three categories.

We purposely leave on one side transverse stability, with regard to which, however, the same reasoning can be applied. At present, it is obtained in three different manners: by vertical planes (Voisin); by flexing wing tips or ailerons, the action of which sets up rotation in a horizontal plane (Wright, Farman, etc.); balanced ailerons (Curtiss and Short).

It is worth while pointing out, however, that there are grounds for affirming, as does Wilbur Wright, that, in order to be on guard against the perpetual central movement, a good aeroplane should not possess inherent stability, and that, on this condition only, does it constantly remain under the efficient control of the pilot. The experience that has recently been obtained is of a nature to weaken this argument.

To sum up, an attempt should not be made—in fact, it is impossible—to classify existing aeroplanes into monoplanes and biplanes from the standpoint of their stability. From a structural standpoint, however, it is much easier, with an equivalent stability, to produce a *safe* apparatus by building a biplane than a monoplane. In our present state of knowledge, it would appear that, although the biplanes of Curtiss and Henry Farman have recently shown themselves to be the fastest, it is with the monoplane that constructors hope to obtain constantly-increased speed. It is the biplane—or the multiplane—that will be called upon to carry increasingly heavy loads by the aerial way, and that will become the touring machine of the skies.

STREAMLINE FORM.

All bodies that are to be called upon to move through the air should take a form which should prevent, as far as possible, the multilation of the stream lines. It has been shown by a

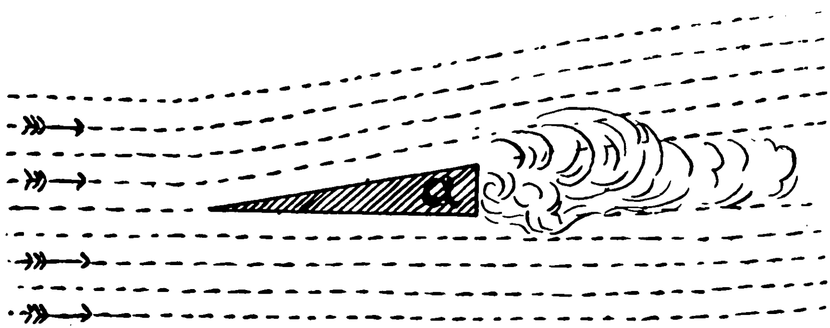


Fig. 89.—Discontinuity of flow due to the shoulder (a).

study of the form suitable for bullets and for torpedoes and submarines (although information about the latter is not readily

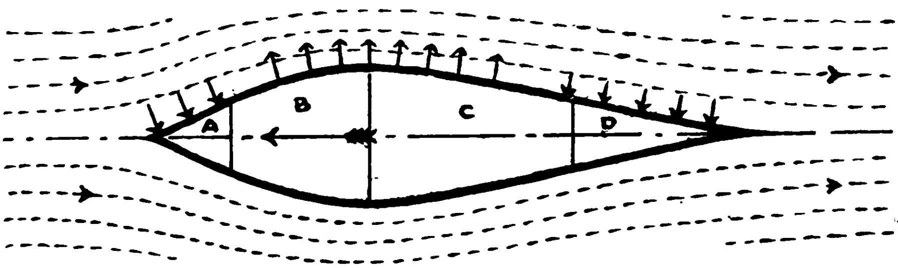


Fig. 90.—The pressures showing the forces acting on and outward from a streamline body.

A is the head of the body, B the shoulder, C the buttock, and D the tail.

available) that a discontinuous flow of the fluid in which the body is moving must be avoided if that motion is not to be

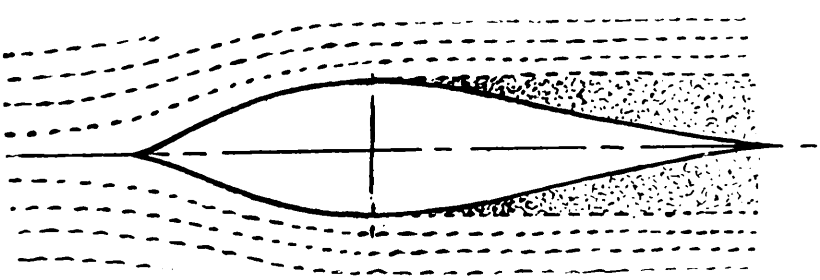


Fig. 91.—Discontinuity caused by removal of buttock and tail portions.

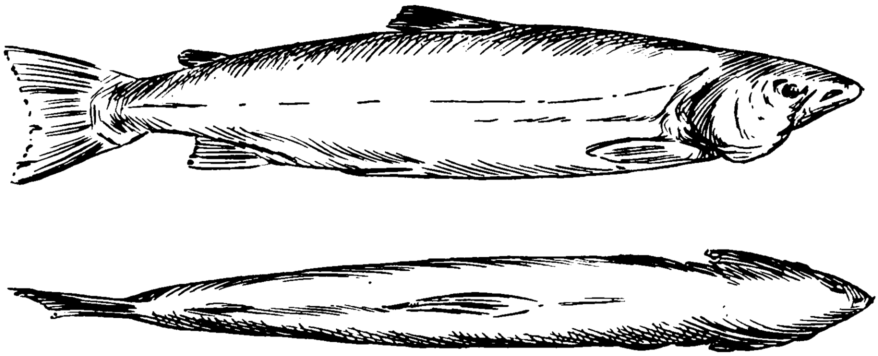


Fig. 92.—The salmon, a fish with typical streamline body.

affected by undue resistance. If a cylindrical body (say, for instance, a round stay or strut) be moved rapidly through a fluid—the air, for example—there will be an excessive pressure on the surface presented to the direction of motion, and, as the air has not time to close in round the rear portion or run, there is a diminished pressure in that region. If the body takes the form of a cone (Fig. 89) the air will shoot off past the sharp edge at the shoulder at (*a*), and, behind the shoulder, the fluid will break up into a vortex of small eddies. Maxim has found that the air in this case will have a tendency to press the body at (*a*) downwards. If, however, the body in motion be of perfect streamline form there is no resistance due to work done upon the fluid, for the late Mr. W. Froude has shown that the applied forces—the pressure inward at the head and at the tail and the pressure outward at the fullest part of the body—balance each other (Fig. 90), and there will be no resistance to its motion through the fluid. The viscosity of the fluid must, however, be allowed for, and it may approximately be represented by the tangential resistance of the exposed area as determined for a flat plate of the same general proportions. If the perfect streamline body be cut in half at the beginning of the run (shown by the vertical line on the body in Fig. 91) the flow of the fluid will again be discontinuous, and a void will be formed behind the moving body, as indicated by the stippling in the figure. It is highly important in the case of a propeller blade, for example, that the cavitation, as it is termed in that

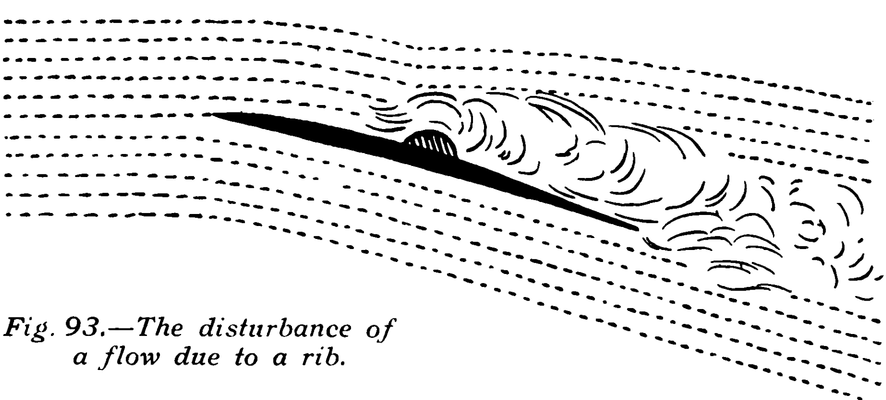


Fig. 93.—The disturbance of a flow due to a rib.

case, should be reduced to a minimum, for the fluid becoming discontinuous, ceases to follow the surface of the blade. The bodies of fishes and birds provide a means of studying the practical aspect of streamline form, and the salmon (shown in Fig. 92) is an excellent example of what Mr. Lanchester terms the "fish-shaped fish." It will be observed that, whilst the entrance (from the nose to the shoulders) is full, the run (from the shoulders to the tail) is fine, Mr. Froude's assertion being that "blunt tails rather than blunt noses cause eddies," thereby involving a loss of power. Losses can also accrue from the use of ribs across the surface of a plane, Fig. 93 showing how the air is disturbed behind a cross rib.

An accurate streamline form should, therefore, be adopted in connection with each constructional detail of an aeroplane. The form of the machine as a whole should be based upon this requirement, and every item in its construction should be considered with the same end in view—that of offering as little resistance as possible to the air. The section of the approximately-perfect plane offers a streamline aspect, the nose being blunt and the tail end fine. Stays and struts require the fullest care in designing, not only in order that head resistance shall be reduced to a minimum, but that the effect of a side wind upon them shall also be minimised. The body of an aeroplane generally presents a number of small surfaces to the direction of motion in the shape of struts, stays, and mechanical details, and considerable advantage can be gained by closing in a body of that character, although care must be taken not to allow the covering to form a scoop, or it will be ripped from its, generally, insecure fastenings.

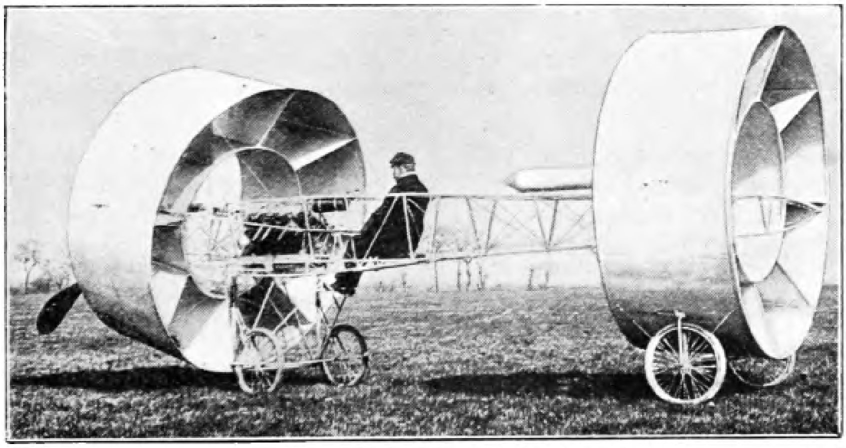


Fig. 94.—The Givaudan aeroplane, having the same area of sustaining surface at any lateral angle.

THE DIPPING FRONT EDGE.

A fact that seems to have escaped observation until within the last quarter of a century is that the front edge of a bird's wing is of arched form or dipped. This dipped front edge is, according to those who have of recent years closely studied this peculiarity, characteristic of the wing form of all birds that

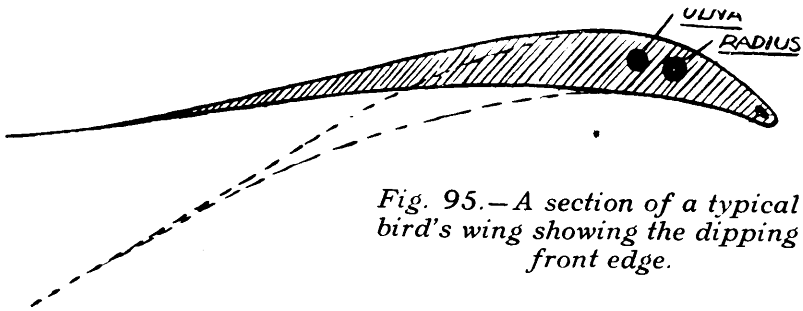


Fig. 95.—A section of a typical bird's wing showing the dipping front edge.

are able to sustain a flight. As an example of this dipped front edge, Lanchester gives a section of the wing of the herring gull (Fig. 95), and, assuming that the bird is making a horizontal flight, the wing would take the form shown by the full lines, whilst the dotted line gives the form shortly after the bird has been killed.

Fig. 96.—The arched wing sections discovered by Horatio F. Phillips and patented by him in 1884.

The dipping edge was, so far as all records show, first discovered by Mr. Horatio F. Phillips, who patented his discovery in 1884 (patent No. 13,768), and the wing sections which he showed in his specification are reproduced in Fig. 96, whilst his later patent of 1891 (No. 13,311) gives the modified form

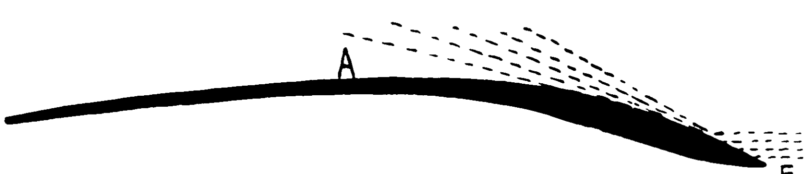


Fig. 97.—Phillips's modified wing form patented in 1891.

shown in Fig. 97. It is considered likely that Lilienthal, who used an arched wing section in his experiments commencing in 1890 and continuing until 1894, did not know of Phillips's work, whilst at about the same time Lanchester evolved the arched form, as he says, from theoretical considerations and without any knowledge of the work of either Phillips or Lilienthal. Phillips assumed that a current of air striking the forward edge (E) (Fig. 97) at an acute angle would be deflected upwards by the forward part of the surface creating a vacuum (or partial vacuum) over the greater part of the upper surface (A), but Lanchester considers that this theory is inadequate. Maxim explains that when a plane is curved so that it is convex on the top and concave on the underside, it encounters, as it advances, stationary air, which divides into two streams. The top stream is not able to fly off at a tangent when turning over the top curve, so it flows down the incline and joins the

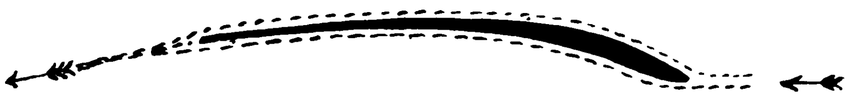


Fig. 98.—Maxim believes that the air follows both surfaces.

current which is flowing over the lower horizontal surface. The angle at which the combined stream of air leaves the plane is the resultant of these two angles. Thus, the plane finds the air in a stationary condition and leaves it with a downward motion, so that the plane itself must be lifted.

But there is some evidence to support the theory of Horatio Phillips that a partial vacuum is created above the upper surface of a curved plane. If a piece of writing paper be held by the finger and thumb of each hand so that the arched edge is presented towards the holder, and he blows horizontally on the edge and along the upper face, the rear of the plane will be found to rise. Blowing along the under surface will be found to have a much less steady effect in lifting the rear end of the plane. If the rear end of the sheet of paper be hinged for about a quarter of its length and the end be curved downwards, blowing along the upper face of the plane will be found to lift the rear hinged portion almost vertically in the air and

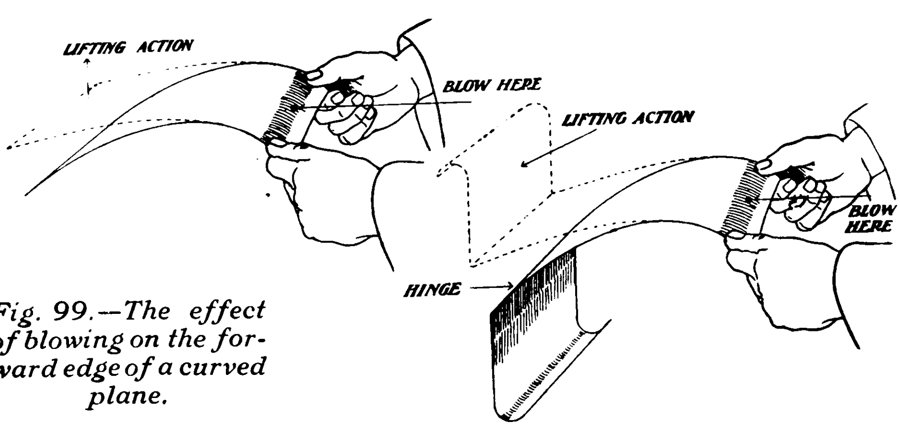


Fig. 99.—The effect of blowing on the forward edge of a curved plane.

seemingly right in the face of the current of air, whereas if the hinged portion be kept flat it will not lift, and if its rear end be curved upward it will merely vibrate and act as a drag upon the lifting of the plane forward of the hinge.

Whatever may be the real explanation, however, there is no question about the superiority of a curved plane. Maxim has found in the course of a long series of experiments that if a

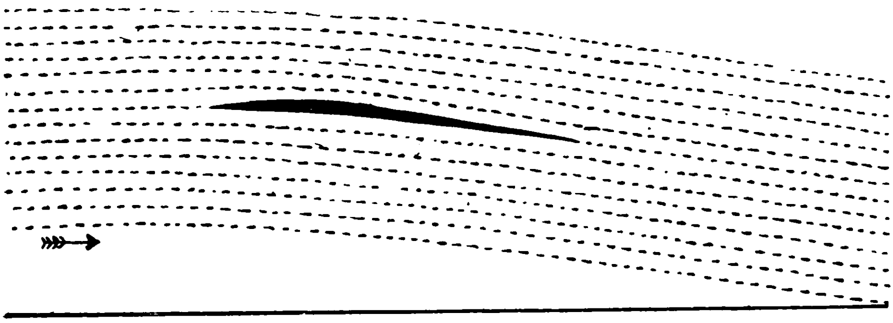


Fig. 100.—The air leaving both sides of a plane in a downward direction exerts a lifting effect on the plane.

plane, convex on the top and perfectly flat on the bottom side, be mounted in the air so that the bottom side is perfectly horizontal, it will, if a current of air be passed over it, produce a lifting effect, no matter in which way it may be run. Maxim's experiments led him to assert that the practical shape and the practical angle, 1 in 10, of an aeroplane are as set out in Fig. 100, and he thinks that the air striking the underside of the plane will not move forward and curl over the top of the

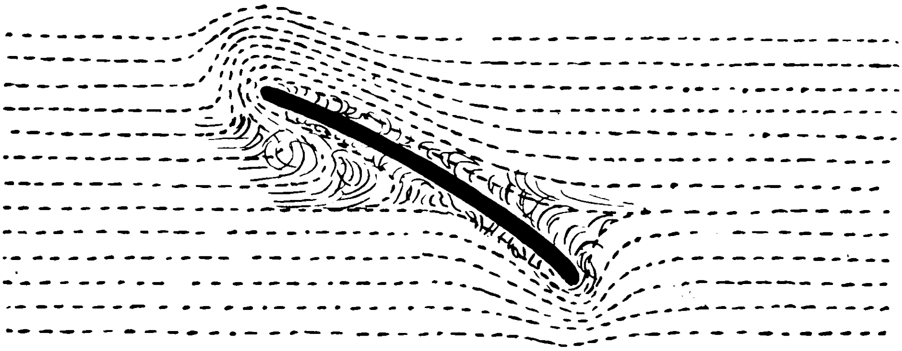


Fig. 101.—The disturbance in the vicinity of a moving plane according to some experimenters.

plane, or be compressed and leave a large eddy in the rear as in Fig. 101. He points out that the theory upon which this diagram was based does not provide that the air travels downwards after the passage of the plane, and that the lifting effect upon a plane is, therefore, not explained by this theory. Lanchester points out that, if the dip of the front edge be insufficient, the upward current will not strike the edge conformably, and the result will be a small pocket of dead air just above the forward edge, whilst if the insufficiency of the dip be serious, then a very large pocket, practically extending over the whole of the upper surface of the plane, will occur. If the dip be too great, the pocket of dead air will be below the plane, and the pressure region occupying the upper surface, a condition of instability arises and the new system of flow inaugurated produces a downward instead of an upward reaction.

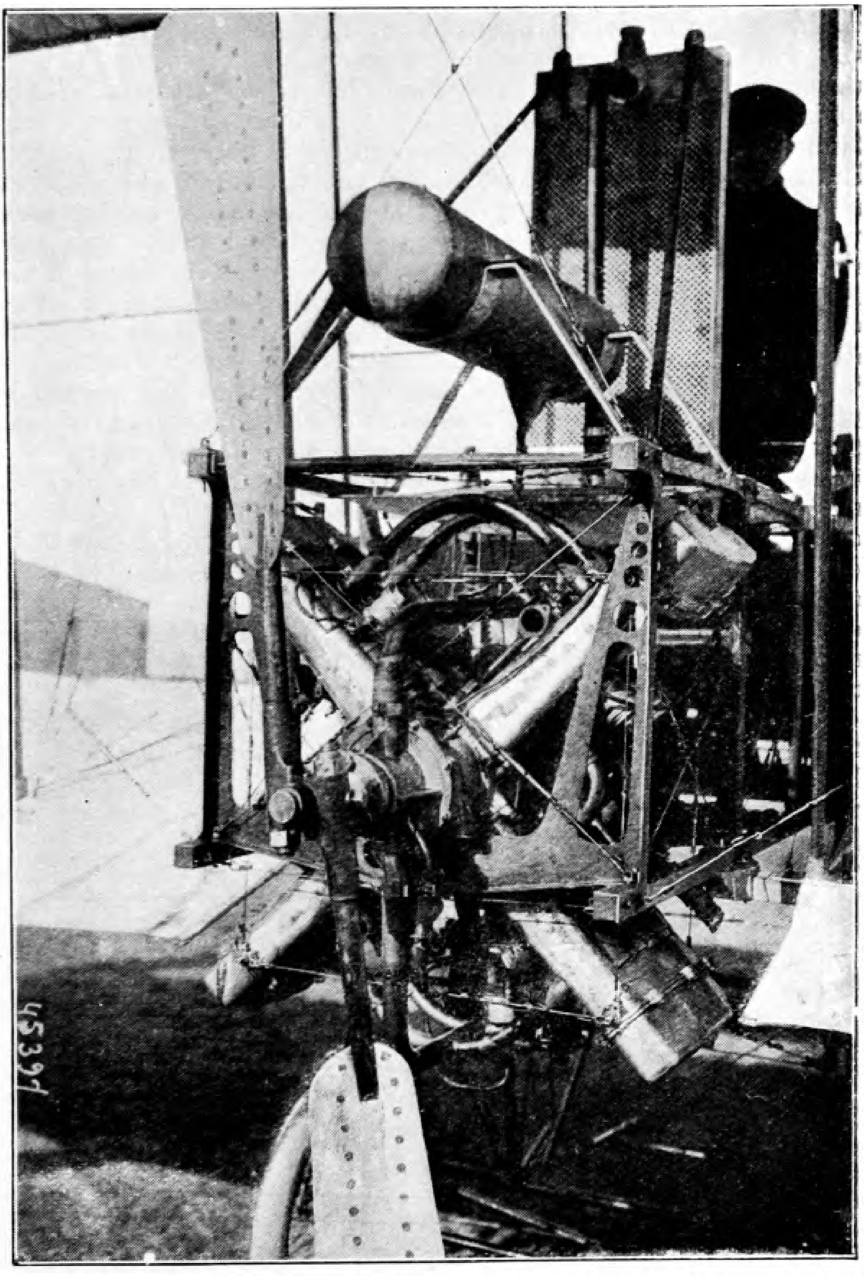


Fig. 102.—The installation of the Gobron engine and the propeller on Baron de Caters's aeroplane.

THE GLIDING ANGLE OF AEROPLANES.

There is, perhaps, no more important point to be considered in the design of aeroplanes than that of the "gliding angle," for, whilst the smallness of that angle, to some extent, measures the efficiency of the machine, too steep a gliding angle may result in the death of the aeronaut. Unfortunately, the information available on this subject is exceedingly scanty. The reason for this is that, whilst the action of gliding itself is simple and its laws may be more or less easily determined, yet, in order to apply these laws to practical cases, constants must be introduced to make corrections for the influence of the shape and surface friction of the planes, and, before these constants can be known, a large amount of careful research will need to be carried out. The gliding angle may be defined as the angle at which an aeroplane will descend to the ground in still air with no other forces at work than those of gravity and air resistance—that is to say, with the propellers at rest.

In considering the movement of an aeroplane in the air, one must, of course, always remember that its motion is relative to the air and not to the ground. This point, which should be obvious enough, has been insisted upon, ad nauseum, in aeronautical literature during the last twelve months, with regard to horizontal movement and the effects of wind, but the point is sometimes lost sight of when dealing with the vertical movement of an aeroplane.

An aeroplane, travelling horizontally under the influence of its propellers, is in reality continuously falling, relatively to the air through which it moves, the distance fallen vertically, in a given horizontal distance, depending, of course, on the gliding angle.

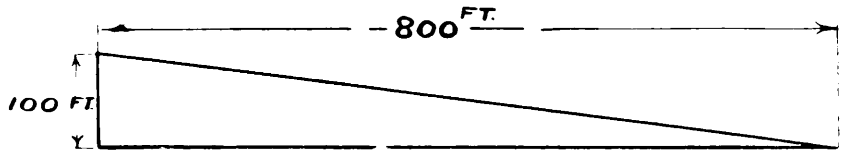


Fig. 103.

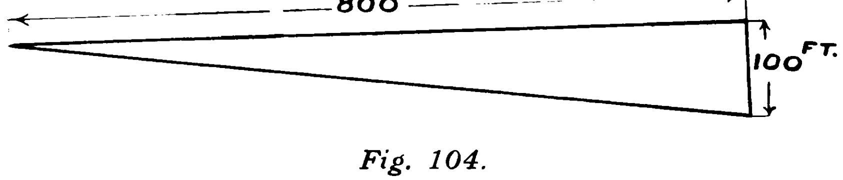
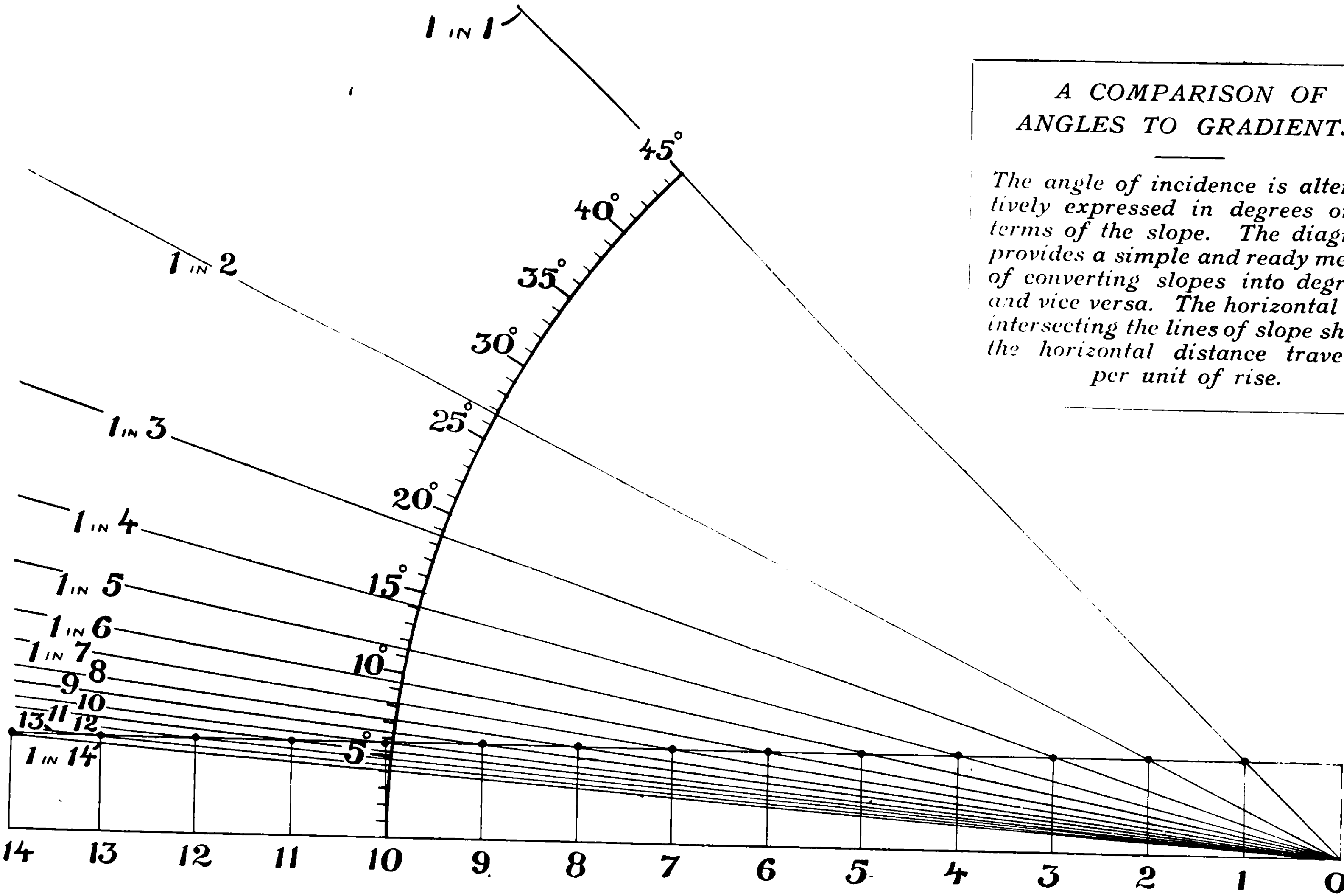


Fig. 104.

A COMPARISON OF ANGLES TO GRADIENTS.

The angle of incidence is alternatively expressed in degrees or in terms of the slope. The diagram provides a simple and ready means of converting slopes into degrees, and vice versa. The horizontal line intersecting the lines of slope shows the horizontal distance travelled per unit of rise.



Thus, supposing a machine to have a gliding angle of 1 in 8 or 7 degrees, as shown in the diagram (Fig. 103). That is to say, if the machine starts gliding from a height of 100 ft. with the engine stopped, it will reach the ground at a horizontal distance of 800 ft. ahead. Now, if this same aeroplane travels horizontally under the influence of its propellers, it will have pressed down, after travelling a distance of 800 ft., an amount of air which is represented by a similar triangle to Fig. 103, but inverted as in Fig. 104. In this case the angle of incidence represents the gliding angle.

If the efficiency of the planes were 100 per cent. the weight per unit area would have no effect whatever upon the gliding angle, but would simply increase the speed of the sloping descent, and this, of course, means that a corresponding increase in speed is necessary to maintain a horizontal course. In practice, however, the efficiency can never possibly be as high as 100 per cent., or anything like it.

In the first place, there is always some slip, that is, vertical drop through the air as distinguished from gliding over it. The amount of this slip will depend, principally, on the shape of the planes, and is, therefore, a criterion of the correctness or otherwise of design. In the second place, there is friction, which, by decreasing horizontal speed, tends to increase the vertical slip.

Concerning the second of these two factors, a fair amount of data is available, but, with regard to the first, some information as to the constants determining it is most urgently needed. The Wright Brothers claimed a gliding angle of 9 degrees for their own machine which they had constructed themselves, but even this was doubtful. At the present moment, not a single maker of aeroplanes can give an approximate gliding angle for his machines, for the simple reason that each individual machine of the same make will behave in a different manner. Mr. Cody's mishap, when his engine stopped at the end of his first long flight over Aldershot, is an example of the necessity for knowing the gliding angle of an aeroplane; he attributed his accident to the angle being too steep and, after making various alterations in the disposition of weight, he has been able to cut off power and glide down without difficulty.

It is to be hoped that some of the Government investigators, who are working at the National Physical Laboratory, will make this question of the gliding angle one of their earliest subjects for practical experiment.

GLIDING AS A SPORT.

How to Construct a Glider. Instructions for Learning to Glide.

There is an exhilaration about gliding which cannot be obtained in any other sport. The sense of floating through the air, of being of the earth but above it, of conquering a barrier that Nature had for centuries drawn against man, gives a feeling of exultation and delight that can be found in no other pursuit of pleasure. There is also in gliding a splendid school for the training of quick judgment, of calm reflection but rapid decision, and of precision of movement, which stimulate the brain and develop those qualities which flag in our modern life. And with the work that comes from the necessity of carrying the machine again and again to the top of the hill, or, as Chanute once put it, winding up the gravity spring, there is all the exercise associated with other out-door sports.

In gliding there is no danger, if one be not ridiculously imprudent, and provided one is strong enough to suffer a few shocks without hurt. The art must be learnt in easy stages, caution being the insurance against harm. And who, in trusting himself to the element which since the beginning of the world has seemed, and even now seems, to defy man's skill and ingenuity, will not proceed warily? No man who cannot swim would throw himself into an unfordable stream, expecting to reach the other side. He would first set himself to master the ability to progress a few feet through the water, and by gradual stages learn to swim. So must it be with gliding. A few feet at first; then further and gradually further; until, with intelligent and capable control of the machine a glide of a hundred feet or more can be taken. From Wilbur Wright's lecture of 1901 and from the later one of 1903, both read before the Western Society of Engineers, let a lesson be taken in caution. If ever there were men who exercised patience and self-restraint they were the Wright Brothers during the experiments that led them to the conquest of the air by mechanical flight. Impatience, rashness, and precipitation are of the very essence of peril, whilst, on the other hand, calmness, self-possession, patience and self-restraint will carry the gliding devotee safely and unscathed through thousands of flights.

Beyond those who will indulge in gliding as the nearest approach that their purse permits to controlled flight, everyone who takes to aeroplaning should previously indulge in a course of glides. The present-day great masters of flight, the Wrights, Farman and the Voisins, have learnt their elementary notions of equilibrium in the air from gliding experiments. Chanute, with his assistant, Herring (whose work has not yet been accomplished), Capt. Ferber, Archdeacon, and others have practised the art, not primarily for sport sake, though enjoying the sport, but for education and instruction.

The first and ruling qualification for the sport of gliding is the accessibility to a suitable slope. The ground should be open

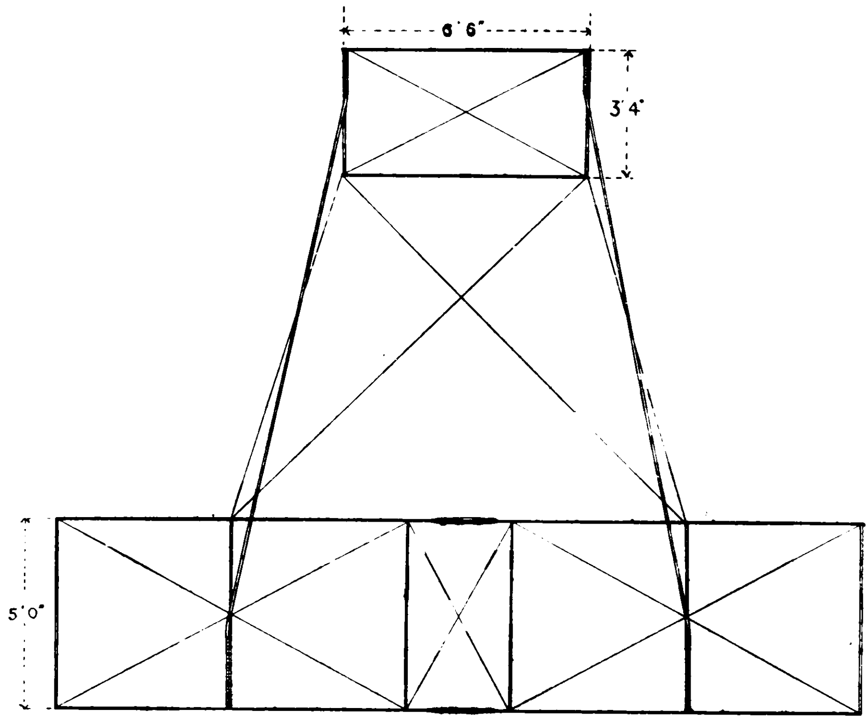
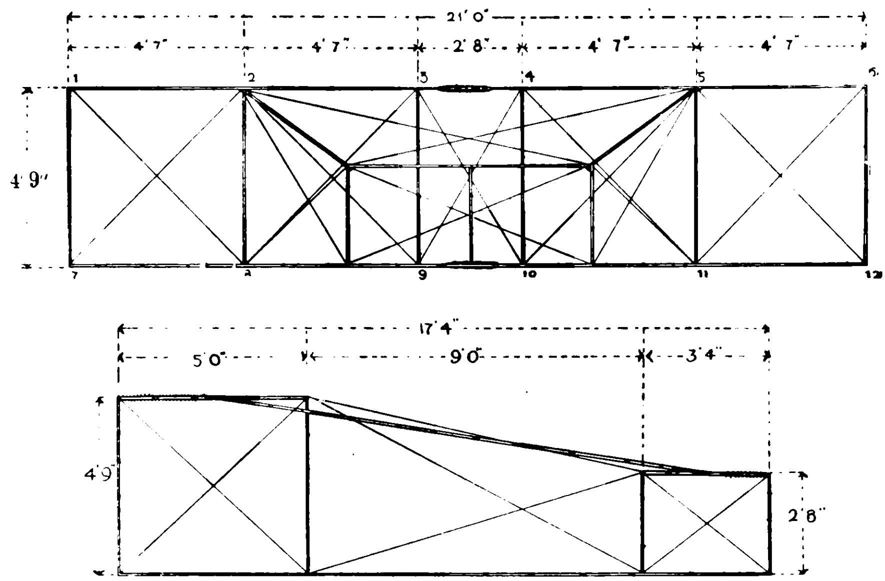


Fig. 105.—Plan of glider, giving dimensions of tail and width of main planes.

and free from trees, with no bushes or gorse—heather does not matter—to cause obstruction when alighting. Heather, in fact, is an advantage, just as sand is, because of the "cushioning" it affords should a glide be prematurely terminated. How smoothly the glider comes to ground at the natural termination of a flight can be gathered from the fact that the Wrights assumed a prone position during all their gliding trials. The slope should be from 1 in 10 to 1 in 7, and should be from 150 ft. to 300 ft. or 400 ft. long. Such slopes are not to be found in many parts, and it should therefore be the first concern of the would-be gliding exponent to discover a suitable ground, which should also be at least 150 ft. wide. Trees in the proximity do not matter, if they are planted in regular order, and if the machine does not approach them too closely.

For the novice no better material will be found for the framework than bamboo, which can be obtained selected for the job. In respect of its section, it is not all that can be desired for the reduction of wind resistance, but this is not of much importance at the speeds which the glider attains. Providing strength with lightness, bamboo possesses the additional advantage that it requires no working. It is ready for use in the state in which it is bought, only a saw being required to cut it to the correct length. Owing to the fractures that are sure to occur during the initial glides, it will be useful to lay in some spare lengths



Figs. 106 and 107 Dimensioned elevation plans of glider.

over and above those actually required for the frame in the first instance.

The quantities and materials that must be taken into stock for the construction of the glider are:—

1. Bamboo: 135 yds., in lengths of $6\frac{1}{2}$ ft., 14 ft., and 18 ft., and of $1\frac{1}{4}$ in. diameter.
2. Piano wire: 175 yds. of silver-plated .056 in. dia. (No. 17 S.W.G.).
3. Nine dozen Hope rigging eyes or about 7 ft. of No. 20 Imperial wire gauge copper tubing (3-16 in. external diam.).
4. Calico: 25 yds. of double width.
5. Brass sheet: 1 sq. yd. of 24 B.W. gauge.
6. Screws and nuts: a gross of 3-16 in. (1 in. long).
7. A ball of cord.

Though variations in prices will be found in different localities, especially with the bamboo, it may be taken that the average cost of the materials will accord with the following estimate:—

	£	s.	d.
1. Bamboo	1	12	0
2. Piano wire		12	6
3. Copper tubing		2	0
4. Calico...		14	0
5. Brass sheet		9	0
6. Screws and nuts		6	9
7. Cord		1	0
Total	3	17	3

No account is taken of the cost of labour, nor are the necessary hand tools priced, the assumption being that the glider is to be made by an amateur already possessed of the pliers, hacksaw, and wood saw that form the small outfit required.

Before the construction of the frame can be undertaken, a number of joint-holders must be made. The simple pattern shown in Fig. 108 and used as in Fig. 109 will be found quite serviceable, and lends itself well to the variations in the section of the bamboo. Since three dozen of them are required, the labour of cutting them out from the brass sheet may well be deputed to a local engineer. It is not likely that their production will appeal to the amateur.

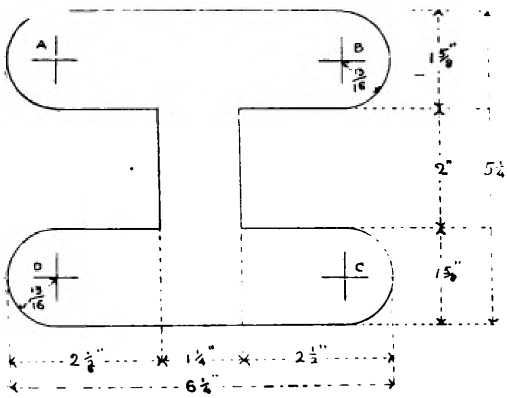


Fig. 108.– Sheet metal as cut for making joint-holders.

In the views of the glider shown in Figs. 105-107, the thick lines indicate the wood structure, the thin lines representing the wire rigging. To make a start with the job, take two lengths of bamboo each 11 ft. 6 in. long and well matched. Cut a plug to fit the ends, and, dipping this in white lead or varnish, use it as a dowel for the butt ends of the bamboo (see Fig. 111). Although the joint could then be bound up, a better job can be made if some bamboo splints are laid along the butted ends. These splints can be obtained by splitting a short piece of bamboo and tapering off the edges. Using three of these, bind the joint up with wire at four points, as illustrated in the diagram on next page. The ends of each binding wire should be crossed under the turns of wire in the spacing between two splints and twisted on each other above. The binding can then be tightened by driving wedges into the spacing between the splints, means being employed to fasten the wedges. This will make a strong and workmanlike joint, neat and tidy. If desired, the joints in the bamboos can be rasped down nearly flush without weakening the sticks. Lay out another 21 ft. length in the same manner, and bend a half-dozen joint-holders over each at intervals corresponding to the positions of 1, 2, 3 . . . . . . 11, 12 in the drawings, remembering to turn the lap of the joint towards the inside. Cut a dozen lengths of 5 ft., and, laying the two 21 ft. poles on the ground, fit the short pieces horizontally into the joint-holders. This will give a stiffened

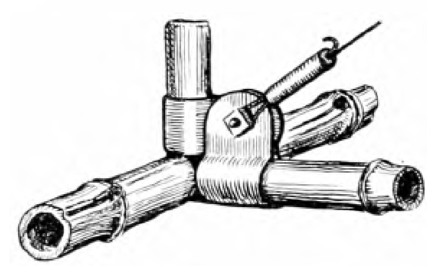


Fig. 109.—A joint-holder bent to shape and placed in position.

rectangle, which will form one of the main planes. Into the tops of the joint-holders should next be fitted a dozen lengths of 4 ft. 9 in., on the free ends of which must be placed the upper main frame, constructed in the manner just described for the lower one. At this stage the frame will present the appearance of a cage, as shown herewith; though possessing the elements of rigidity, it will need bracing.

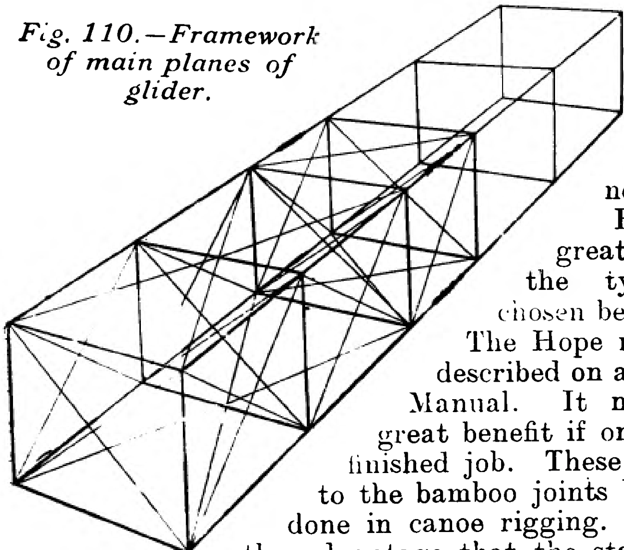


Fig. 110.—Framework of main planes of glider.

Even for this no great skill is required, the type of fastening chosen being of the simplest. The Hope rigging eye is fully described on another page in this Manual. It may be used with great benefit if one desires a neatly-finished job. These eyes can be lashed to the bamboo joints by light wire, as is done in canoe rigging. This method has the advantage that the stays will seldom require to be tautened, but there is the disadvantage that to haul all the lashings up taut, when they have slackened, takes a considerable time.

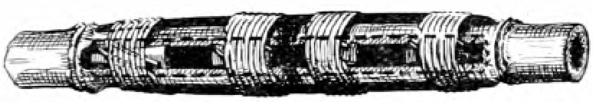


Fig. 111.—Method of making butt joints with bamboos

Fig. 112.—The general method of making eyes by passing the end of the wire twice through a piece of copper tube, leaving an eye, and bending the end of the wire over.

An alternative method is to adopt the Voisin style of rigging. Take the copper tube, and cut it into short pieces about $\frac{1}{2}$ in. or $\frac{3}{4}$ in. long. Through each of these a piece of the piano wire must be threaded and bent back, so that the tube may be pushed over a double thickness of the wire (see Fig. 112). Twist the end over and snip the wire off short. This will give a good eye fastening which cannot slip, and which is small enough to be clamped by the nut of the joint clip whilst being amply strong. A similar eye must be lashed at the other end of the length of wire necessary for the diagonal. It is not of the greatest importance to have a strong tension on the wire, but it is very advisable to have the tension of all the wires uniform. Straining screws can be regarded as refinements for gliders. There may be a little difficulty at first, but after a few attempts one can become quite an adept at getting the proper length of wire. The extent of the bracing can be gathered from Figs. 106, 107 and 110, each cell being braced along all diagonals, and the frames of the main planes stiffened, as shown in the plan view. If supported at its outer ends, this skeleton structure is capable of supporting a load of about 3 cwt. in the centre.

In the construction of the tail, exactly the same procedure is to be followed. The spread being 6 ft. 6 in., four pieces of this length must be sawn off, and there will also be required six lengths of 2 ft. 8 in. for the vertical members and six lengths of 3 ft. 4 in. to serve as fore-and-aft members. The same pattern of joint-holder being available as in the building of the main planes, the completion of the tail will offer no difficulties. For its attachment to the supporting planes, four rods, 18 ft. in length, must be used. These are laced between the bamboo struts of the main planes and tail, as depicted in Fig. 107, and are then lashed with wire drawn tightly round the struts and main poles. By rigging diagonal wires across top and bottom and across both sides, the entire frame of the glider will be rendered quite rigid.

Both the main planes have to be covered completely with calico, except for the space between the points 9 and 10 (see Fig. 106) on the lower plane. This space, which corresponds to the joints in the main poles, is required for the aviator, who supports himself on two bearers set at the most convenient distance apart and lashed at both ends to the main poles. The calico must be turned over the bamboo members and stitched in place after it has been drawn up as tightly as possible. The tail also needs to be covered with the same material, but in this case there are also three vertical panels to be added, as shown in the rear elevation of the glider. If necessary, the calico can be shrunk by one or two coats of starch paste.

Trials can be made in a steady wind, that is strong enough to lift the glider when it is held by one of the front cross-poles.

In the initial glides it is essential to have the assistance of two men. For this purpose two cords, about 6 ft. in length, should be attached to the forward extremities of the lower main plane, and these should be held by the assistants, one at each end. Having determined the direction of the wind, face it, place yourself in the glider, with the supports under your arms, and give the order to start down the slope at a moderate pace. At the end of a few steps the glider will lift the passenger from the ground, but the assistants should continue to run right down the slope, keeping the cords in their hands. Caution is most advisable, and it should not be until at least a dozen captive glides have been made that an aviator should attempt a free glide, and even then only if he feels perfect confidence in his ability to control the machine.

To steer to the right, throw the legs to the right; to steer to the left, throw them to the left; to alight, bring the weight of the body further forward. At first there will be a tendency to keep the body too far back. This must be strongly combated, for it is the only position that is dangerous. During the captive glides, the effect of various movements of the body must be closely watched, for upon them depends the control of the machine. When these details have been mastered, a short free glide can be attempted, the order to cast off being given to the assistants almost as soon as one's feet have left the ground. The cords should be released by the assistants simultaneously, otherwise the machine will not glide straight and evenly. The great thing to master is to bring the machine smoothly to the ground by stretching the legs forward. With these hints, it must be left to each one's practice to obtain the skill which renders long glides in even fairly strong winds quite safe. A few minutes in the air is worth more than the same number of weeks of theoretical study.

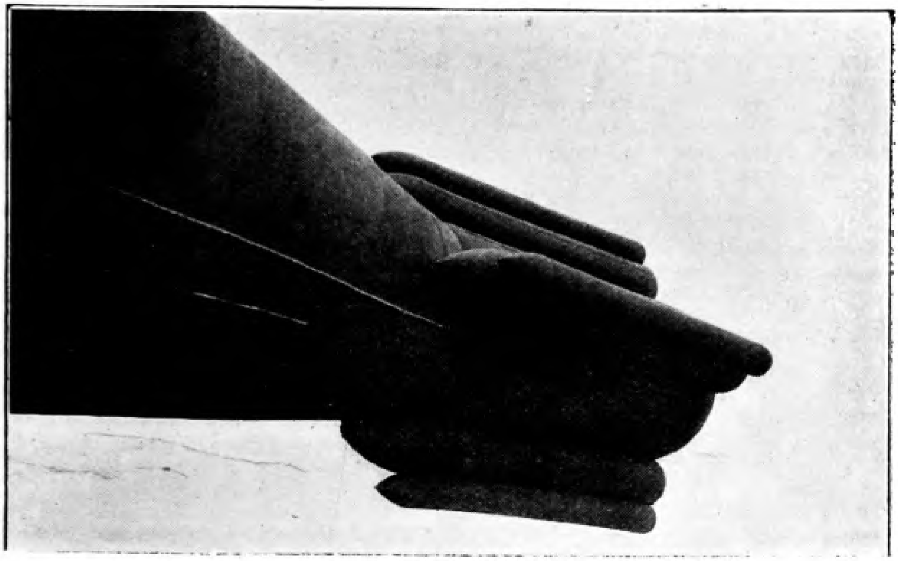


Fig. 113.—Stern view of "La.Ville de Paris."

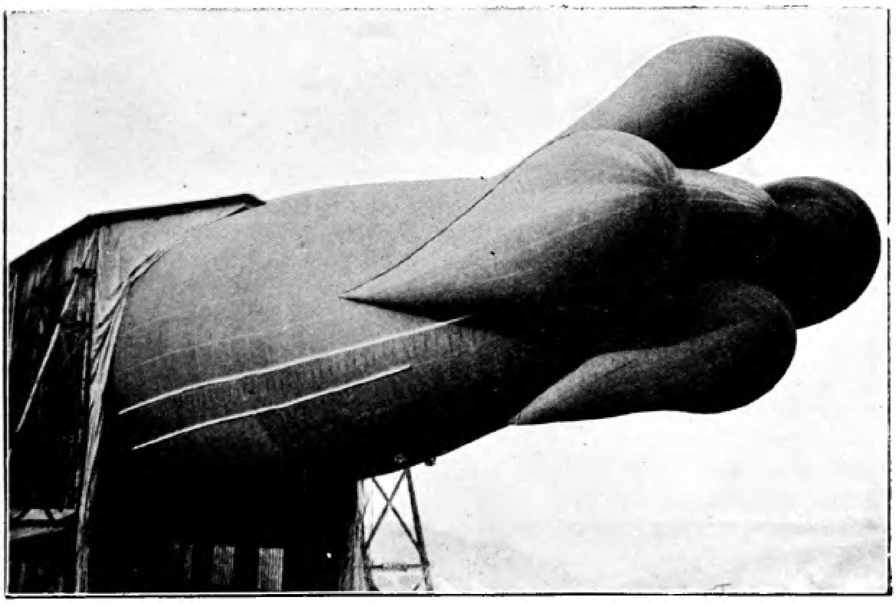


Fig. 114.—Stern view of "Clement-Bayard."

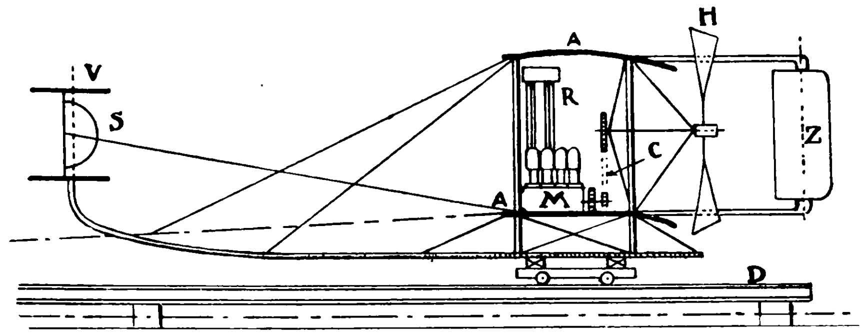
AEROPLANES OF 1908 AND 1909.

The Wright Aeroplane.

The Wright aeroplane is an exceedingly simple apparatus, the main features of which are two large superimposed planes or sustaining surfaces; two similar planes, but of much smaller dimensions, carried in front, and pivoted to form an elevation rudder; and, at the rear, two vertical planes or rudders, operating in exactly the same way as the rudder of a ship. Near the forward edge of the main lower plane, slightly out of the centre line, is a four-cylinder petrol motor, driving, by means of chains, a couple of propellers in the rear, both chains running in tubes, and one of them being crossed in order that the propellers shall turn in opposite directions. The operator sits to the left of the engine, counterbalancing its weight, and has a wooden lever in each hand, the left-hand lever raising or lowering the forward elevation planes, and the right-hand lever having a double movement, forward and rearward, to turn the rear vertical rudder, thus giving lateral movement to the machine, and to left and right in order to bend the wing tips to facilitate turning and maintain lateral balance. The apparatus is mounted on long wooden runners, which slide over the ground on a descent being made and, by their friction, bring the apparatus to a stop. Starting is generally accomplished by a catapult system, the aeroplane being mounted on a bogey running on a long rail and shot down it by means of falling weights, a cord and suitable arrangement of pulleys.

Each wing of the Wright aeroplane measures 41 ft. from tip to tip, and is 6 ft. 6 in. from front to rear, thus giving a total bearing surface of approximately 538 sq. ft. The two main sustaining surfaces are united by nine pairs of stanchions, each 5 ft. 10 in. in height. The sustaining surfaces are composed of a wooden frame built up of two main members of American spruce each 41 ft. in length, the front member having a thickness of about 2 in., with its fore edge rounded off to offer less resistance. The main frame members are distant one from the other 4 ft. 3 in., and are united at their extremities by two cross members of the same thickness, and also rounded. Across the frame thus formed are placed 32 curved ribs (with a curve of 1 in 20). each one flush with the front frame member, but overhanging the rear one. The ribs, which have a total length of 6 ft. 6 in., are constructed as shown in Fig. 121, namely, of two curved members separated by wooden blocks gradually tapering towards the rear, where they are all united by a steel cable. Each of the curved frames thus formed is covered on both its upper and lower surface by rubber-cloth nailed at the front edge and sewn at the rear.

The 19 wooden uprights uniting the two bearing surfaces are not all rigidly fixed. All the front ones and the middle rear ones are secured in aluminium sockets to the main frame members, but six of the rear ones—three at each end—are attached by a system of hook and eye illustrated in Fig. 125. The eye bolt is secured to the extremity of the stanchion, fits on the hook of the frame, and is prevented from slipping off by means of a split pin. These hooks at the same time serve to receive the ends of the wire stays with which the structure is strengthened. A feature of the staying of the Wright aeroplane is that there is no provision for regulating the tension of the wires. The end of the wire is doubled back to pass into a copper tube, the whole being soldered, and the loop thus formed fitting on to the



hook of the frame member. The reason for this pivoting structure is to allow of bending the rear extremities of the wing tips in a manner and for a purpose that will be explained later.

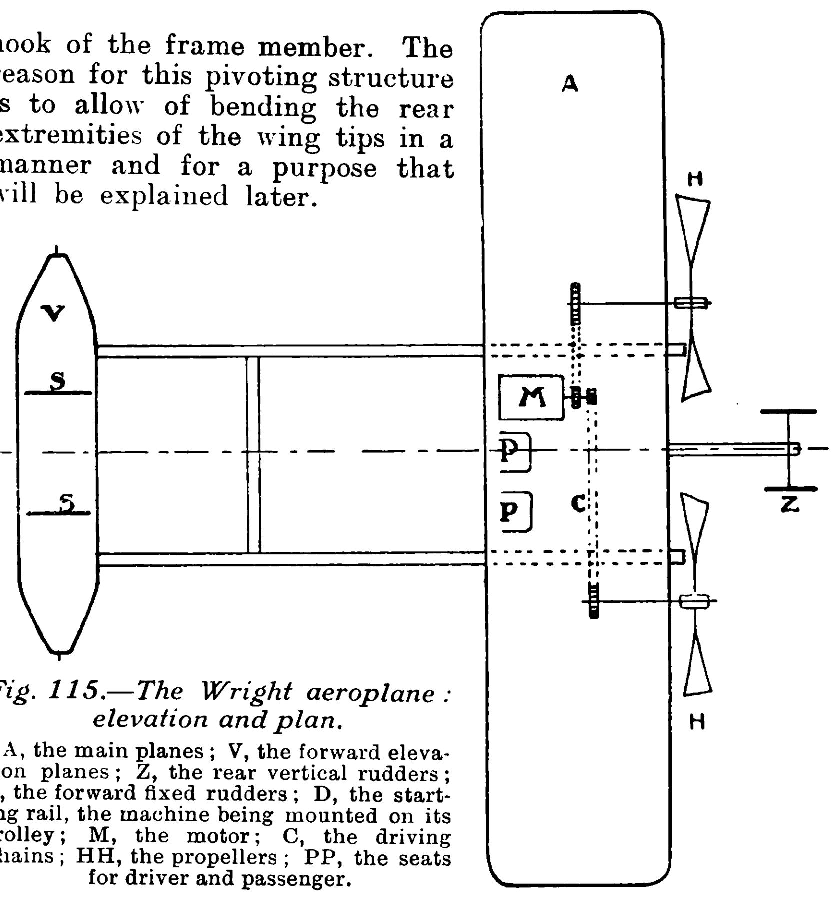


Fig. 115.—The Wright aeroplane: elevation and plan.

AA, the main planes; V, the forward elevation planes; Z, the rear vertical rudders; S, the forward fixed rudders; D, the starting rail, the machine being mounted on its trolley; M, the motor; C, the driving chains; HH, the propellers; PP, the seats for driver and passenger.

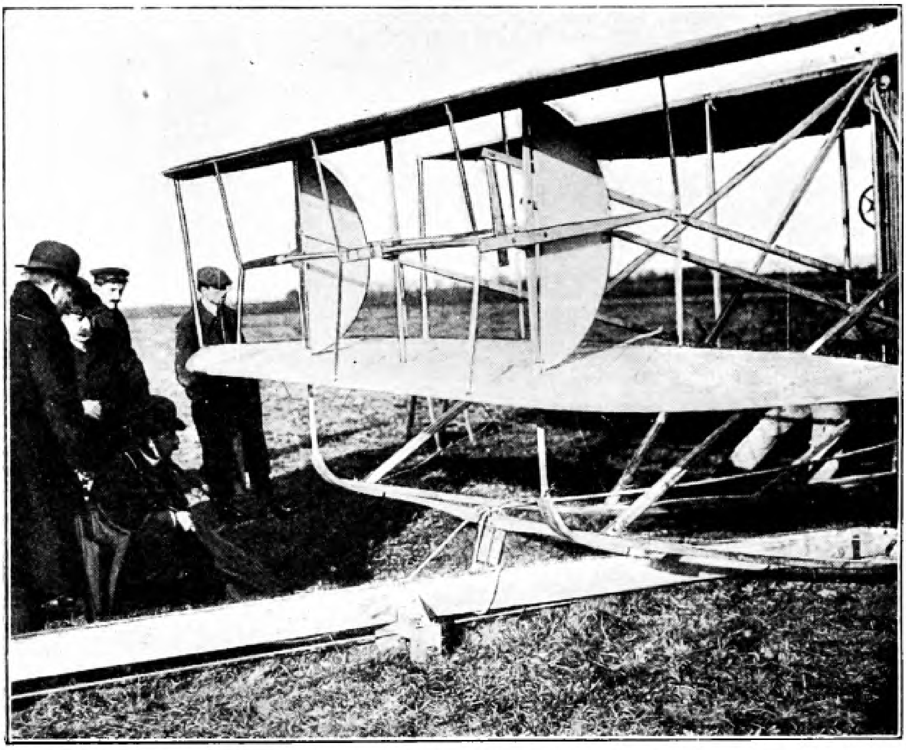


Fig. 116.—The forward elevation planes and the fixed vertical rudders. The machine on its starting rail.

About 10 ft. ahead of the main wings is the elevation rudder, which may be roughly considered as a reduction of the main bearing surfaces. The elevation rudder is composed of two superimposed horizontal planes, each 14 ft. 10 in. from tip to tip, 2 ft. 5 in. in depth, and 2 ft. 7 in. apart. Between the two surfaces, and 6 ft. apart, are a couple of half-moon-shaped vertical planes, free to pivot slightly on their axes.

At the rear, and distant 8 ft. 6 in. from the main planes, is the lateral rudder, composed of two vertical planes 5 ft. 10 in. in height and 2 ft. in width. The two planes are united by cross members and are distant from one another 19 in. The entire apparatus is mounted on two long wooden skates which commence a little to the rear of the main plane, and at their forward end are curved up to attach to the elevation rudder. Two sets of wooden stays connect the forward end of the skates to the fore edge of the upper plane, thereby considerably strengthening it. On a descent being made the skates come in contact with the ground, and by their friction bring the apparatus to a stop. Under favourable circumstances, as, for instance, on smooth, wet grass, the apparatus can be driven over the ground on its skates and made to rise in the air without any external aid. The more common way of starting, however, is by the use of the catapult.

The mechanical portion of the Wright aeroplane consists of a four-cylinder motor built by Leon Bollée, of Le Mans, from the Wright Brothers' own designs. It is what may be designated a medium-weight motor: not so light as the special aeroplane engines recently developed in France, but considerably lighter than the standard car engine, which it resembles in all main features of design. The engine is carried near the forward edge of the lower plane, but about 2 ft. to the right of the longitudinal centre. The pilot occupies a seat to the left of the engine, thus counterbalancing its weight; the passenger's seat is between the pilot and the engine and almost in the centre line of the plane. Thus, whether a passenger is carried or not, the lateral

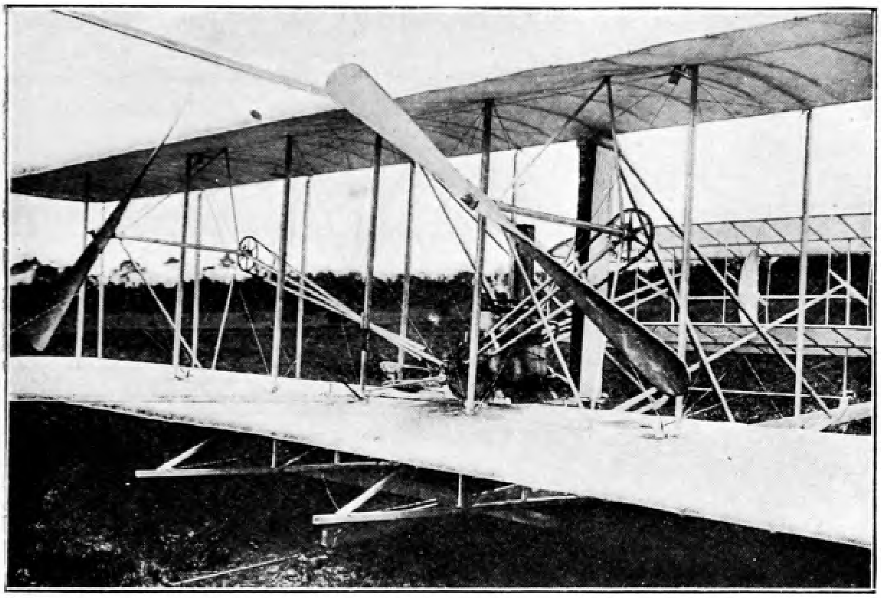


Fig. 117 —Rear view showing engine, propellers, and transmission. The skates are also clearly seen.

balance of the aeroplane is not disturbed. The engine drives a couple of wooden propellers in the rear; those generally employed have a diameter of 8 ft. 3 in., and are geared 33 to 9, giving 450 propeller revolutions a minute. In this respect the Wright machine differs from most of the French machines, where the propeller is mounted direct on the engine shaft, and turns at from 1,100 to 1,500 revolutions a minute. During the 1908 trials in France, the propellers and the gearing were frequently changed, the longest flights being made with propellers of 9 ft. 2 in. diameter.

The supply of cooling water for the engine is contained in a radiator composed of plain, flat copper tubes attached to one of the forward stanchions of the aeroplanes. The quantity of water carried is a little over two gallons. The petrol supply is contained in a cylindrical reservoir, at first placed horizontally, but now hung vertically between the two main planes. The flow is by gravity to the petrol pump within the crankcase, from which the petrol is directly injected into the cylinders.

It has already been stated that, under favourable circumstances, the aeroplane can be started from the ground on its runners. The general method of getting into the air, however, is by the use of a rail and falling weights. It is a method that has been much criticised, the critics maintaining that, so long as this apparatus was necessary, the Wright aeroplane could never be employed for cross-country flights. The catapult sys-

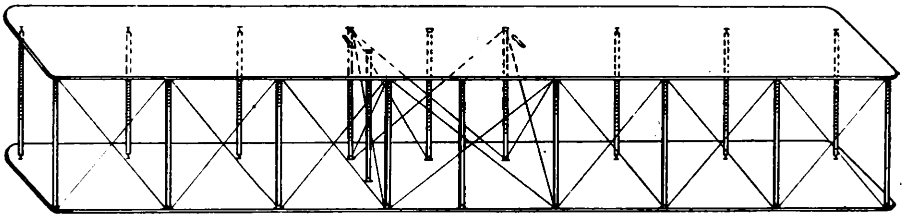


Fig. 118.—The struts and stays of the latest form.

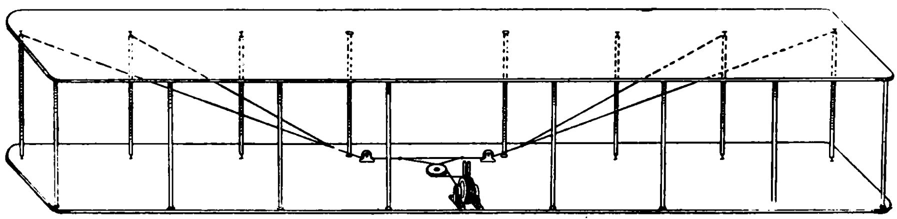


Fig. 119.—The primary warping mechanism with its lever to warp the upper plane.

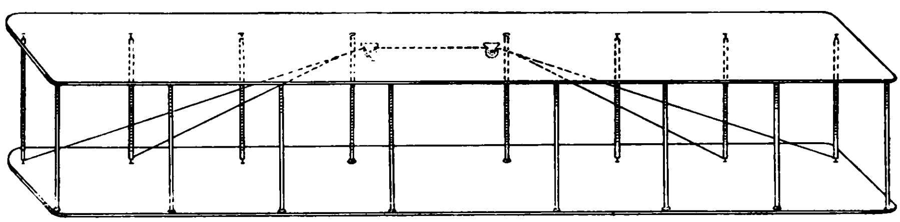


Fig. 120.—The secondary warping mechanism to warp the lower plane.

tem, however, is only a means for getting into the air, and, so long as operations are confined to flights over a specially-prepared ground, it is a most convenient method, and one that is successful in 99 starts out of a hundred. It will be soon enough to burden the apparatus with wheels when cross-country flights are attempted.

The wooden starting rail, the upper face of which is bound with metal, is 68 ft. in length. A two-wheel wooden bogey, formed of two lengths of wood placed at right angles, is laid on it and receives the aeroplane, which, immediately before the start, is supported at the right-hand tip by a trestle; this side, of course, being heavier by reason of the motor being out of centre. To the rear of the aeroplane, as it rests on the starting rail, is a pylone, to the summit of which are hoisted a number of metal discs weighing about 14 cwt. The rope securing the discs passes over a pulley at the summit of the pylone, under another pulley at the base, then travels forward underneath the

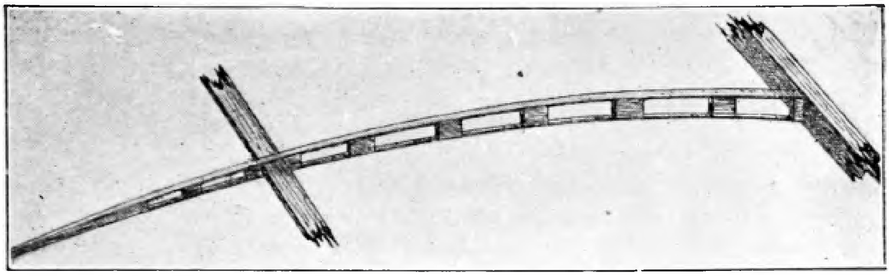


Fig. 121.—Showing construction of one of the curved ribs forming framework of the main wings to be covered with rubbered cloth on both surfaces.

aeroplane to a pulley at the extremity of the rail, returning along the rail to the aeroplane, to which it is attached by means of a hook.

When the aeroplane has been placed in position on its rail, and the weights mounted, it is temporarily attached in the manner shown in Fig. 122. Here the pilot's seat is shown at S; beneath him is a bar (A), hinged at B, and secured in a notch of the plate (P). Around the bar (A) is a short wire cable secured to the starting rail.

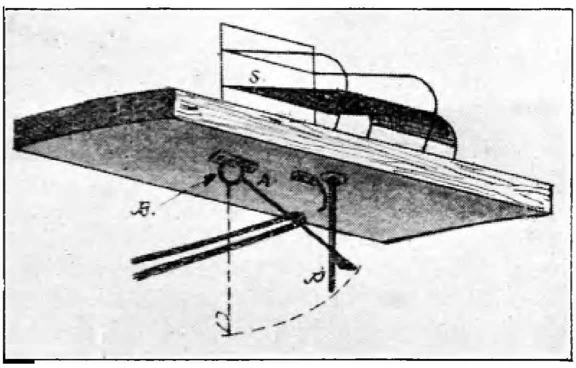


Fig. 122.—The method of attaching the aeroplane to the starting rail, and of releasing it.

The engine having been started and the trestle under the extremity of the wing replaced by an attendant, the pilot leans forward and pulls the bar (P) out of engagement with A, with the result that this latter falls, the cable (C) slips over its end, and the aeroplane is free to shoot down the rail. Under the combined influence of the falling weights and the revolving propellers, the 68 ft. of the rail are covered in $3\frac{2}{5}$ sec., which gives a speed at the end of the rail which may be estimated at 35 miles an hour. While running down the rail, the front elevation rudder has been kept in a position to hold the aeroplane down, and it is only as the end of the rail is reached that it is raised and the apparatus rises somewhat rapidly into the air to perform its wonderful evolutions.

The pilot has to operate two different steering levers in order to preserve the machine at the right altitude, to maintain longitudinal and lateral balance and to make his turns. He has, in no way, to occupy himself with the engine, which is indeed unprovided with any other control than an appliance for relieving the compression, and so stopping, when it is desired to descend. The point of ignition is fixed, the throttle does not exist, for the supply of petrol is mechanical, and lubrication is assured by a pump.

The lever in the pilot's left hand has a simple movement forward and backward. If pulled towards the pilot, the front elevation planes are slightly raised, and the tendency of the aeroplane is to rise to a higher altitude. If pushed ahead, the two planes are made to point towards the ground, and the direction of the aeroplane is then downwards. Reference to

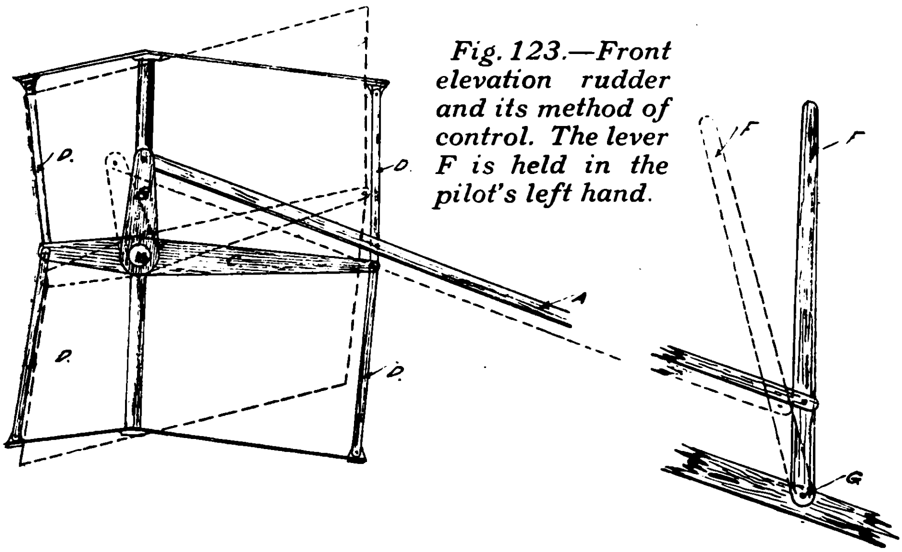


Fig. 123.—Front elevation rudder and its method of control. The lever F is held in the pilot's left hand.

Fig. 123 shows how these movements are obtained. F is the elevation lever pivoting at G, and having attached to it, by a bolt, the bar (A), connected up to the short lever (B) and controlling three connecting rods (C), operating on the tubes (D) and inclining the planes. When the operating lever (F) is in its normal position the elevation planes have a slight curve, but by reason of the difference of length between the front and the rear portions of the connecting rod (C), as well as the front and the rear portions of the planes, when the lever is carried full ahead the rear of the planes are carried upwards, as shown in the dotted line. When the lever is brought to the rear the forward edge of the planes is raised but slightly and the rear is fully lowered. The control of this elevation rudder is first given to pupils learning to handle the machine. Whenever the aeroplane has a tendency to dive the lever is pulled back; if the machine is going too high the rudder is pushed forward. The movement is only slight, and is very difficult to follow by an observer on land.

The right-hand lever is more complicated in its operation, and more difficult to manœuvre than the one just described. It has two distinct movements—forward and backward and to left and right. If the lever is merely carried ahead it will direct the vertical rudder over to the left, and cause the aeroplane to turn to the left. How this is accomplished will be immediately understood by reference to Fig. 124, in which A is the right-hand lever, B the forked end connecting rod, C the pivoting crossbar, and

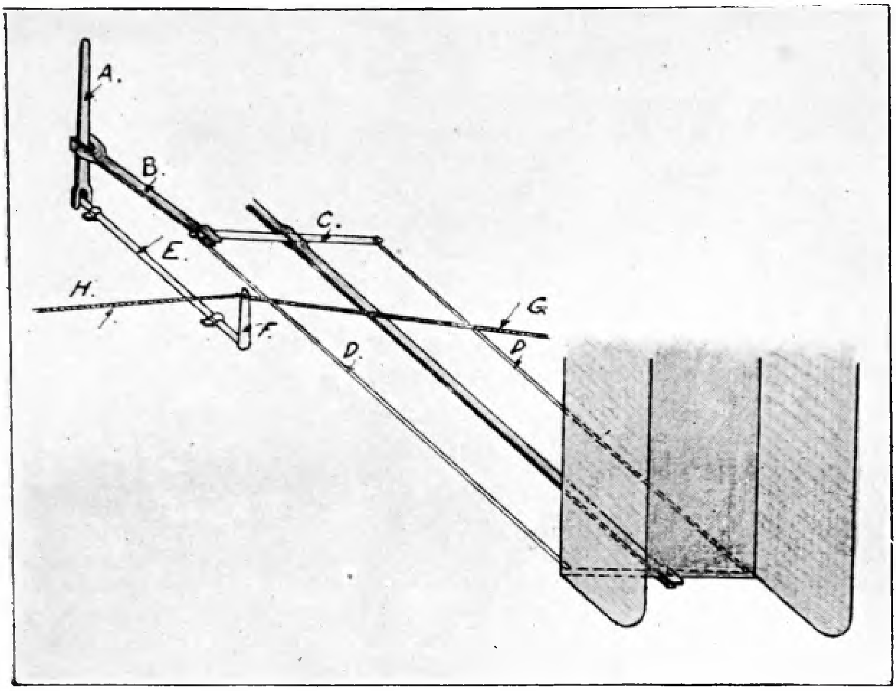


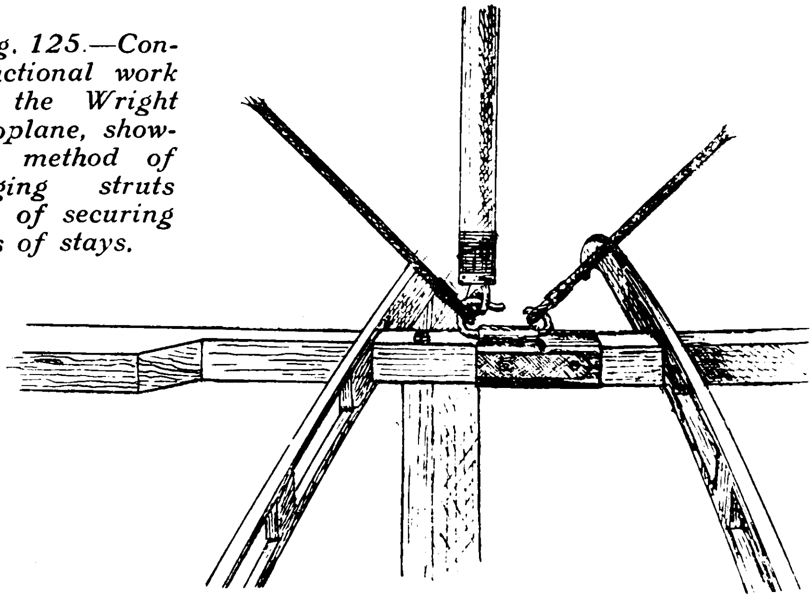
Fig 124.—The combined rudder control and wing-warping mechanism.

DD the two cables connecting to the two extremities of the vertical rudder.

If, instead of being carried forward, the lever (A) is moved over to the left, it will naturally at the same time shift the short lever (F) in the same direction, tightening the cable (G), and slackening the cable (H), with the result, as shown in Fig. 13 (p. 21), of lowering the right-hand wing tips, and the two being inter-connected, as shown, raising the left-hand tips. This, of course, is made possible by reason of the pivoting joints of the rear stanchions already described, and gives the helicoidal torsion necessary for modifying the angles of incidence at which the ends of the wings are presented to the atmosphere.

The outcome of the movements of the rudders and of the warping of the planes requires to be carefully studied, because of the conflicting forces at work. When the wings are so warped at their rear corners (for the front edges remain always undeformed) that the left-hand end—assuming that the spectator is standing behind the machine and looking in the direction of travel—is depressed and the right-hand end is raised, the left-hand end presents the greater angle of incidence to the atmosphere and will rise because the pressure of the atmospheric action on this part is increased. The right-hand side offering a lesser angle of incidence will tend to fall. This permits the lateral balance to be maintained, whilst, in making a turn, it would seem that the action of flexing the wings is mainly employed for righting the machine. Assuming that a turn to the left is to be made, the rudder is put over in the required direction, and the machine at once commences to describe a circle. The effect of the increased volume of air passing under the outer tip (that describing the larger circle) is to elevate that side and so create a " banking " that assists the turning movement. But when the turn is completed, the aeroplane will still be heeling over, and it is then that the wings are flexed so that the angle of incidence at the inner tip is increased to lift that side. The machine is thus brought into a horizontal position, but, as lift on one side is gained at the expense of forward speed on that side, the rudder has to be put over to the opposite direction simultaneously with the wing-flexing, in order to counteract the effort of the machine to continue the turning

Fig. 125.—Constructional work on the Wright aeroplane, showing method of hinging struts and of securing eyes of stays.



movement. Thus the order of the motions for a turn to the left is as follows: (1) rudder is brought over to left, (2) aeroplane then makes turn and its outer tip rises, (3) wings are flexed so that inner tip is depressed (in other words, the angle of incidence is increased) and rudder is put over to the right, (4) inner tip then lifts and tries to slow down, but as the rudder opposes this tendency, the machine is kept on its course. Naturally, with experience, these movements can be co-ordinated and each individual movement of wing or rudder reduced to the minimum, whilst the wings can be flexed to a slight degree to increase the turning movements, the result being that the Wright aeroplane possesses, as one of its distinctive features, a quick-turning movement, in strong contrast to the slow-turning ability of almost all French machines.

In reality, turning is only a secondary object of the flexing of the wing tips, the most important being to maintain lateral balance. In such an unstable element as the air the aeroplane has a constant tendency to oscillate in all directions. The tendency to plunge or rear is corrected by the manipulation of the elevation rudder through the left-hand lever; the tendency to roll is overcome by the flexing of the wing tips. Should the aeroplane take a list towards the left, the vertical rudder would at the same time be inclined; if it is brought back to a vertical position this tendency would be corrected. The contrary, of course, applies if the heeling movement of the aeroplane is towards the right.

It will be noticed that, with the exception of the operation of the vertical rudder, which requires the lever to be pushed ahead for a left turn and rearwards for a right turn, all the controlling movements are natural. Thus, to descend, the operator leans forward and carries his left-hand lever with him; to ascend, he pulls on the same lever. To make a sharp turn to the left, he carries his right-hand lever in that direction (at the same time, of course, moving it forward). If the machine is inclined towards the left, he leans over with his right-hand lever in the opposite direction, thus causing the aeroplane to right itself.

During the past season several private owners have added starting wheels to the Wright machine to work in conjunction with the skids. In most cases the wheels are so arranged that they are automatically raised as soon as the aeroplane leaves the ground, thus allowing the skids to come into full use on a landing being made. The wheels have proved specially advantageous to learners, allowing them to master the machine without an instructor in a much shorter time than would be possible with the starting rail.

It is also interesting to note that Comte de Lambert is now fitting a Wright machine with two horizontal superimposed tail members, to be operated in conjunction with the front elevation rudder. The work is not sufficiently advanced to say whether this will be a success or not.

Voisin Biplane.

In its main features, the Voisin biplane is based on the simple lines of the Hargreave box kite, to which has been added an elevation and a lateral rudder. When first produced as a glider, in 1900, it consisted of a couple of superimposed planes with an elevation rudder in front and a vertical rudder in the rear. About 1905 the cellular tail was added and vertical planes placed between the main horizontal bearing surfaces. Although these latter were removed on the first aeroplane used by Henry Farman, they were fitted again a little later, the present type of machine differing from the 1905 model only in details and improved methods of construction.

The aeroplane may be divided into five distinct parts: the chassis, or running gear, an all-metal structure carrying the wheels, by means of which the aeroplane runs over the ground prior to taking the air; the fuselage, or main framework, to which is attached the chassis and wings, and on which is mounted the motor and pilot's seat; the main forward planes, divided vertically into three distinct cells; the tail, or rear cell, containing the vertical rudder giving lateral direction; and the framework uniting the tail to the main planes.

Wings with plane surfaces, although possessing remarkable stability when towed as a kite, altogether lack this quality when built to travel through the air under power. The surfaces were, therefore, given a slight curvature.

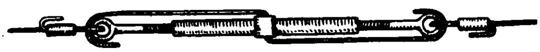


Fig. 126.—The Voisin straining screw with wire loops to prevent turning.

The framework of each wing is composed of two parallel ash members 32 ft. 9 in. in length, united by a series of slightly curved poplar and ash ribs, flush with the wooden frame member at the front, but slightly exceeding the one at the rear, thus giving a rigidity to the entering edge and a certain amount of flexibility to the rear. The depth of the main plane is 6 ft. 8 in. On the upper face of the lower transverse members, and on the lower face of the corresponding upper members, are a series of aluminium sockets receiving eight pairs of vertical stanchions separating the two planes. The stanchions are of ash, have an oval section to diminish wind resistance, and are supplemented by piano cord stays. The ends are enclosed by a canvas covering, stretching from frame to frame and from stanchion to stanchion, and two other vertical divisions are fitted, dividing the structure into three distinct cells, the central one being the largest. The horizontal planes are

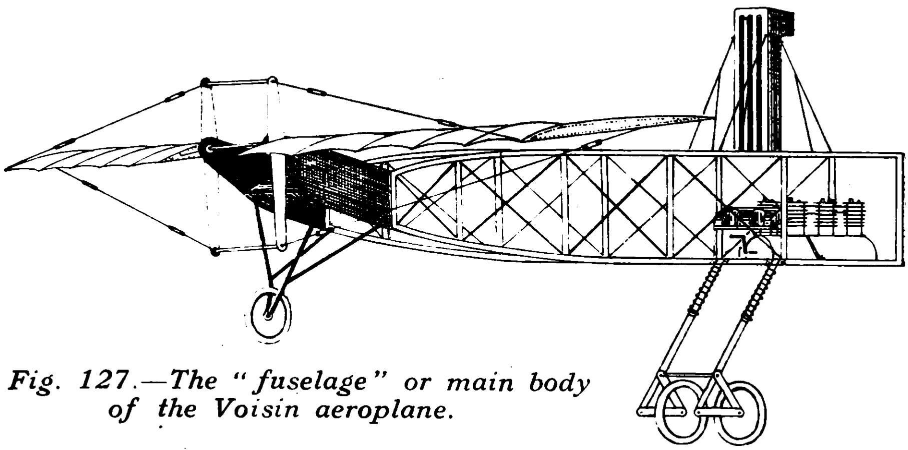


Fig. 127.—The "fuselage" or main body of the Voisin aeroplane.

deeper than the vertical planes, these latter stretching from stanchion to stanchion only.

The rear cell, or tail, designed to fulfil the same functions as the tail of a kite, namely, to give stability to the main member, is much smaller than this latter, the measurements from side to side being 8 ft. 9 in. It is constructed, like the forward cells, of a wooden framework covered with canvas and strengthened by wire stays, but its two ends are completely closed in. Between the two horizontal planes is a vertical rudder, the size of which has been increased one-quarter on the latest models, operated at will by the pilot, and pivotable in a manner that will be described later. The Voisin is one of the few aeroplanes built without wing flexing, lateral stability being secured by the use of the vertical planes. A tendency to too great an inclination is automatically corrected with the vertical planes by bringing the nose of the machine into the wind.

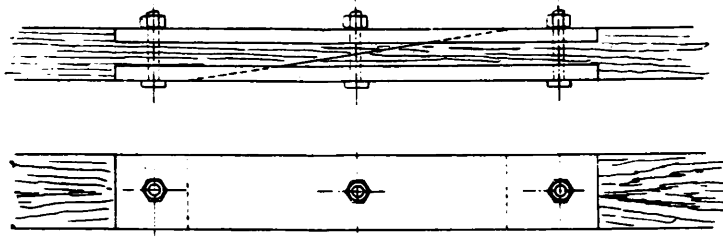


Fig. 128.—The **C** *shaped plate for fastening together the longitudinal frame members of the Voisin biplane.*

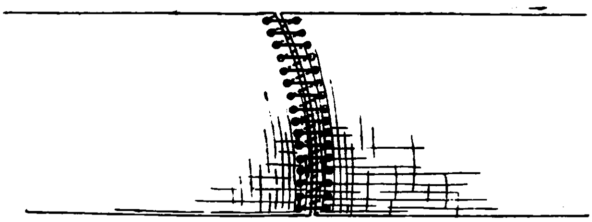


Fig. 129.—The mode of lacing the canvas on the upper plane.

All Voisin aeroplanes are now made to carry two persons and to be rapidly dismounted. The longitudinal frame members, instead of being in one piece, are in two portions united by a steel U plate and three bolts, as shown in Fig. 128. The canvas of the upper plane is broken in the centre and laced together through eyelets. By slackening off the wire stays the eight pairs of stanchions can be lifted out of their sockets and replaced by special stanchions about 4 in. in height, which merely serve to prevent the two canvas planes from rubbing together when packed. By this arrangement, instead of a surface 39 ft. 9 in. in length, 6 ft. 8 in. in depth, and the same in height, the greatest dimension is only slightly over 16 ft.

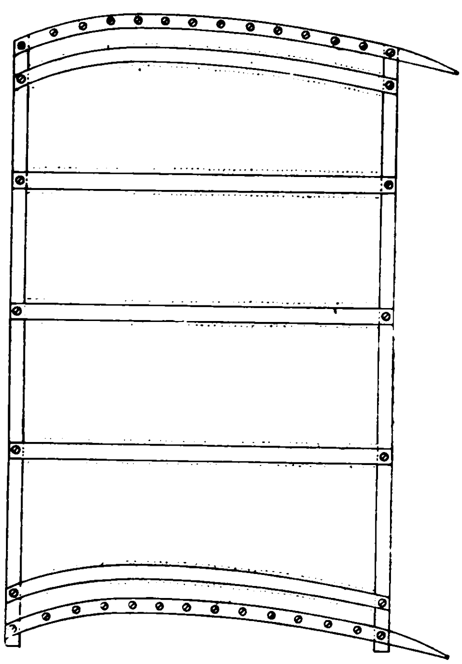


Fig. 130.—The screwed-on vertical planes on the Voisin aeroplane.

Provision has also been made for the rapid dismounting of the vertical planes. Instead of being nailed, as formerly, these are now screwed to the end of the upper and lower horizontal planes, and are attached rigidly to the stanchions by five laths, three of them straight and two curved, passing through a sleeve in the canvas and secured by a single screw at each end. The method of dismounting is shown in Fig. 130. The same construction has been adopted for the rear tail, thus allowing the large wood and canvas box to be reduced to a couple of plane surfaces and two small rolls of canvas in a few minutes.

The special framework known as the fuselage has been redesigned to allow the carrying of a passenger. Roughly, the fuselage has the form of a flat-bottomed hydroplane boat, and is formed of four longitudinal members united by vertical members carried in aluminium sockets and suitably trussed. In order to decrease resistance, the forward portion of this framework is covered with rubbered cloth. Formerly the fuselage was just sufficiently wide to carry the motor and one seat for the pilot. On the latest models its width has been increased to 36 inches, thus allowing of two bucket seats being placed side by side.

The motor is generally bolted to a light steel chassis and carried at the rear of the fuselage, the rear extremity of the main shaft projecting beyond the frame members. Just ahead of the motor, and carried on the upper members of the fuselage is the radiator, bolted to a transverse plank, and further secured by steel tube stays. The pilot and passenger sit side by side, just ahead of the radiator, and with their backs to this latter. The seat is placed midway in the fuselage, and is hinged at one end, while the two aluminium bucket seats are also hinged, allowing the seat to be folded up against the side members. This has been done in order to allow the pilot to start the motor himself, a starting handle being fitted, as on motorcars. Starting by swinging the propeller is not only

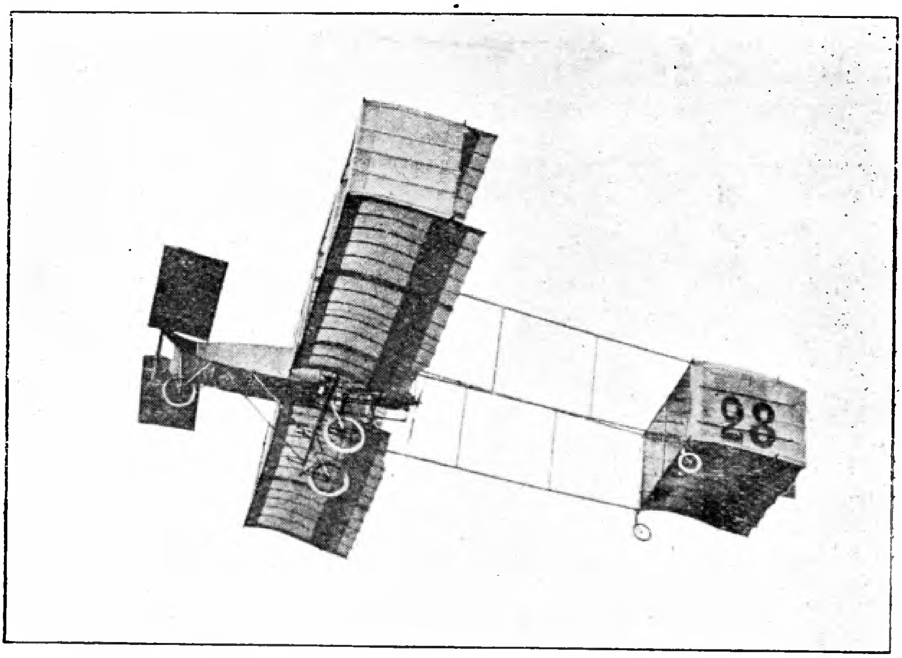


Fig. 131.—The Voisin biplane with forward elevation planes.

inconvenient, but very dangerous. Although the Voisin brothers now make their own motor, any type of engine may be fitted, according to customers' ideas. Normally, the petrol tank is suspended above the engine, the flow to the carburetter being by gravity. When very long flights are attempted a large petrol tank is carried below the fuselage, immediately beneath the motor, and the fuel pumped to the upper tank, from which it is fed to the motor in the usual way. The standard propeller supplied with the aeroplane is a two-bladed metal one, having a diameter of 8 ft. 8 in.

At the forward end of the fuselage is mounted the elevation rudder, consisting of a couple of pivoting planes, each 6 ft. 6 in. by 3 ft., one at each side of the fuselage, as shown in Fig. 127. They are pivotable so as to vary the angle of inclination and determine the rise and fall of the aeroplane. The entire control of the aeroplane is united in a single steering wheel, similar to the steering wheel of an automobile, but mounted on a horizontal column. The steering wheel has two

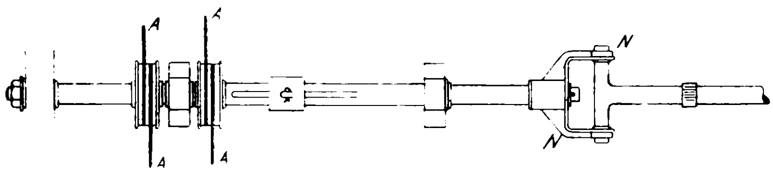


Fig. 132. —The steering shaft of the Voisin aeroplane.

distinct motions: it can be moved in a horizontal direction and also made to turn on its axis, the same as a motorcar steering wheel, the two movements being made together or independently. If pushed ahead, the front elevation rudder is depressed, bringing the machine down or holding it to the ground. If pulled towards the pilot the elevation rudder is raised and the entire aeroplane caused to rise. The steering shaft carries a couple of aluminium drums (AA), Fig. 132, around each of which is wound a flexible wire cable carried along the frame members of the rear vertical rudder within the tail. Thus a turn of the steering wheel to the right will shift the vertical rudder to the right and cause the aeroplane to turn in the same direction. A turn of the wheel to the left will have the contrary effect. Two pulleys and two independent cables have been fitted merely as additional security.

What is technically known as the " chassis " is really the running gear and suspension (see Fig. 127). It is an all-metal structure mounted on 90 mm. pneumatic-tyred wheels and secured to the fuselage. On the earlier models the shock-absorbing springs were of considerable length, reaching from near the wheels to the upper portion of the fuselage. It was found that even under the most violent shock the full length of the spring was never required, and on the latest models the attachment is made to the lower portion of the fuselage. This, together with a few other detail improvements, has allowed a saving in weight of about 60 lb. The wheels are what the French term " orientable," or of the castor type, being free to turn in any

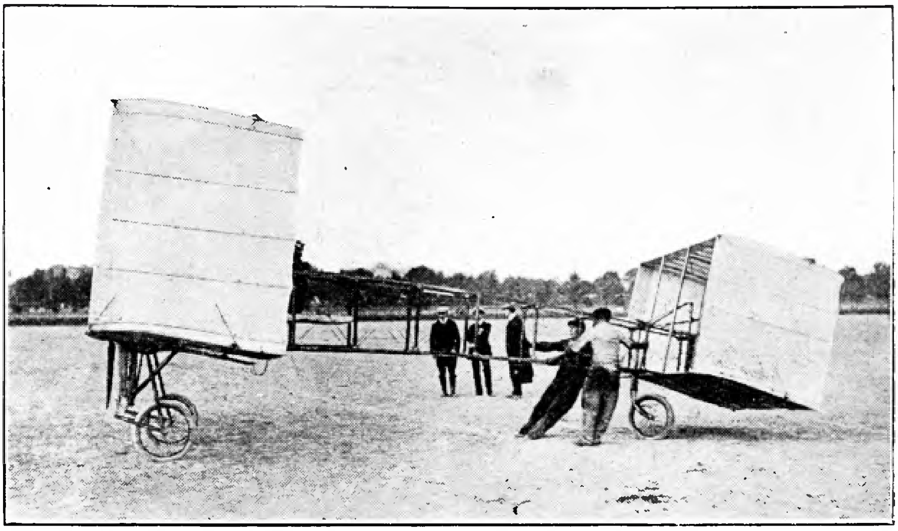
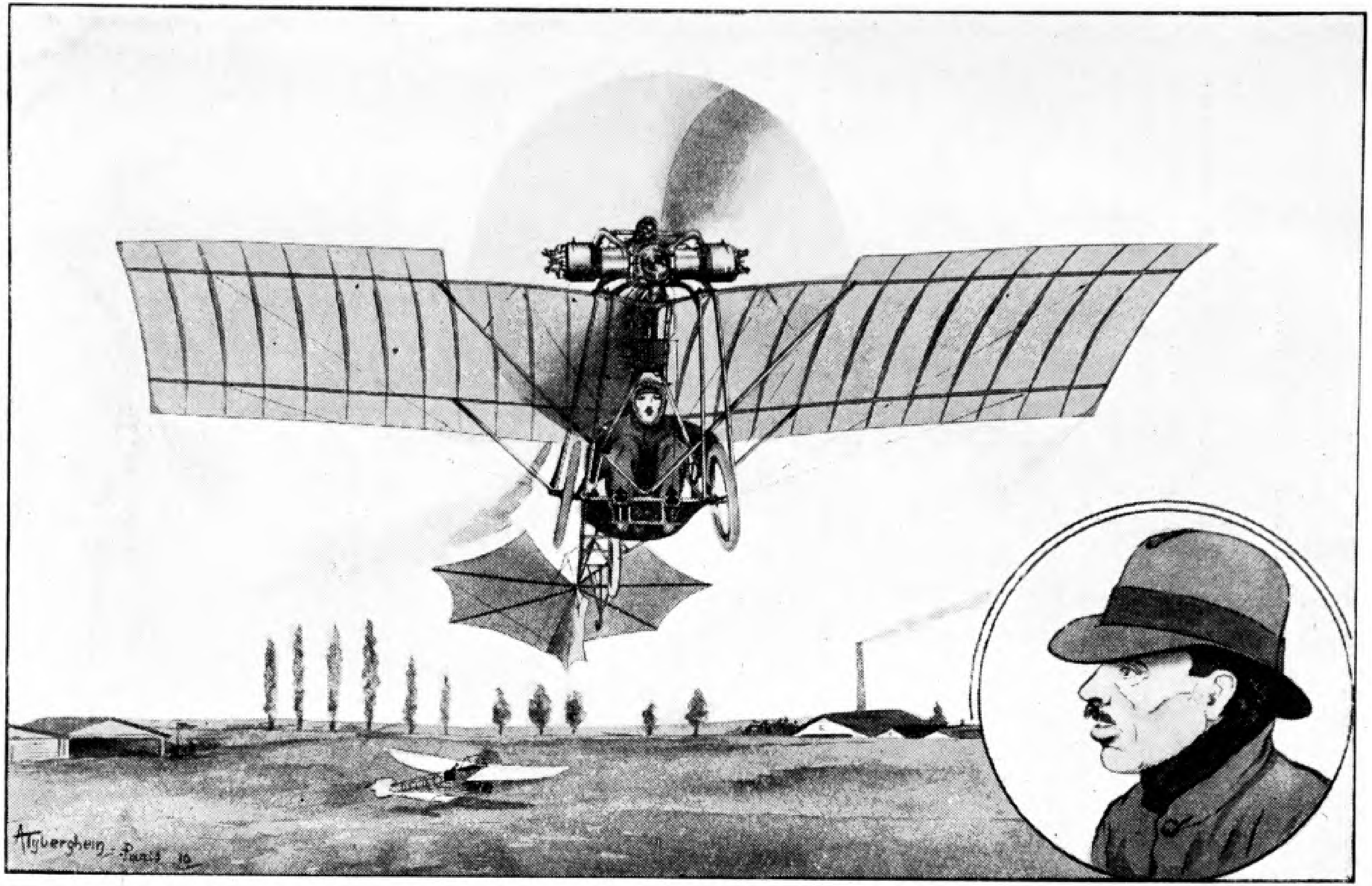


Fig. 133.—The latest type (1909-10) Voisin biplane.

direction. The rear cell is carried on two smaller pneumatic-tyred wheels, also free to turn in any direction. As these have merely to carry the weight of the tail, and, indeed, are chiefly employed to prevent the tail dragging on the ground, only light coil springs are used as shock absorbers. On all new machines a fifth wheel is carried under the forward extremity of the fuselage. When running over soft ground there is a tendency for the main wheels to bury themselves, causing the tail to lift and the nose of the machine to dive, as happened in the fatal accident to Capt. Ferber. The front wheel effectively prevents this. Many skilled pilots remove the forward wheel as unnecessary weight, but its use is recommended by the constructors. Completely fitted, but without motor, the weight of the Voisin biplane is 504 lb.

During the present season the Voisin brothers will doubtless put on the market a new type of biplane, with which experiments have been made for the last six months. Its features are the abolition of the front elevation rudder, together with the fuselage, and the transforming of the rear cell into a combined elevation and lateral rudder. Dimensions are the same as on the standard type of Voisin biplane, while the construction is also of the dismountable type. Instead of a special fuselage to carry the motor and pilot's seat, there is what is known as a false fuselage, forming part of the backbone uniting the two cells. The motor is mounted on the forward portion of this, with the pilot behind it, a tractor screw, of course, being employed. The rear cell differs from the standard type in the absence of a vertical rudder between its two horizontal planes, and from the fact that it is mounted on a universal joint, allowing it to be moved in any direction. Though a biplane in construction, the new machine flies and is operated in the same way as a monoplane. In other words, the original machine is in permanent disequilibrium, and is only maintained in



AVIATORS AND THEIR MACHINES.

M. Santos-Dumont and "La Demoiselle."

equilibrium by the constant use of the elevation rudder, while the new model is in constant longitudinal equilibrium. Owing to the abolition of the forward fuselage, head resistance is considerably reduced, and, at the same time, the total weight is somewhat diminished.

Santos-Dumont Monoplane.

Santos-Dumont's latest type of aeroplane, known as the "Demoiselle," is now built in series by the Clément-Bayard Co., under the supervision of the inventor. It is a monoplane having a wing spread of 18 ft., the measurement from front to rear, along the surface, being 6 ft. 6 in. The wing tips are flexible. At the rear is a combined elevation and lateral rudder, consisting of a horizontal plane carrying a vertical fin above and below. The aeroplane is mounted on two light bicycle wheels under the wings and just ahead of the pilot's seat, a third wheel being fixed near the tail for the use of learners only. The motor, a special two-cylinder double opposed, is mounted above the wings, with a wooden propeller mounted directly on the forward extremity of the main shaft, whilst the pilot's seat is on the framework beneath the wings.

In general design the aeroplane has not been changed since the successful model was produced by M. Santos-Dumont. Many structural modifications have, however, been made by the Clément-Bayard Co. The main framework is built up entirely of light steel tubing. It consists of three main members placed in a triangle, the three gradually tapering together until they almost meet at the tail. The two lower tubes are attached at their forward ends to the tubular axle carrying the running wheels, and from this axle a couple of tubes form a triangle, the apex of which is the forward extremity of the upper tube. Two pairs of vertical tubes, one at each side of the road wheels, and two inclined tubes, attached to the outer extremity of the axles of the road wheels, form a substantial support for the central portion of the wings. This construction is shown in Fig. 134.

An all-metal framework, comprising the backbone of the machine and carrying the running wheels and the pilot's seat and controlling gear, having been formed, it is only necessary

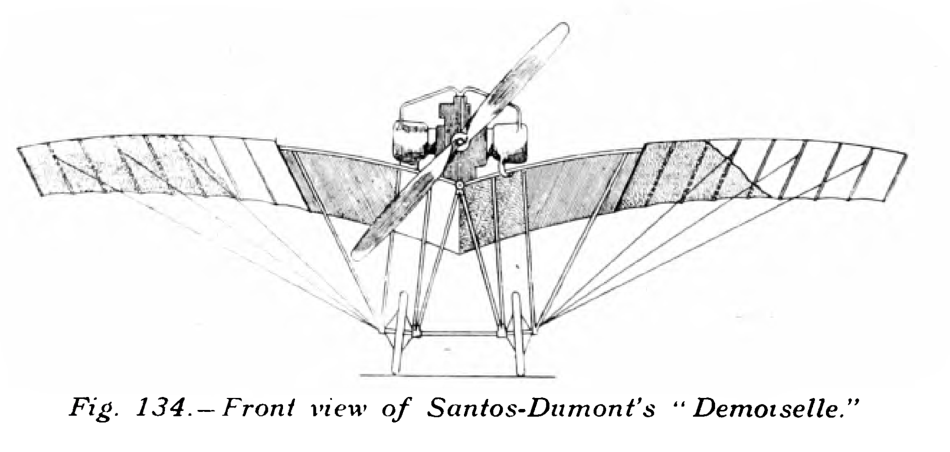


Fig. 134.—Front view of Santos-Dumont's "Demoiselle."

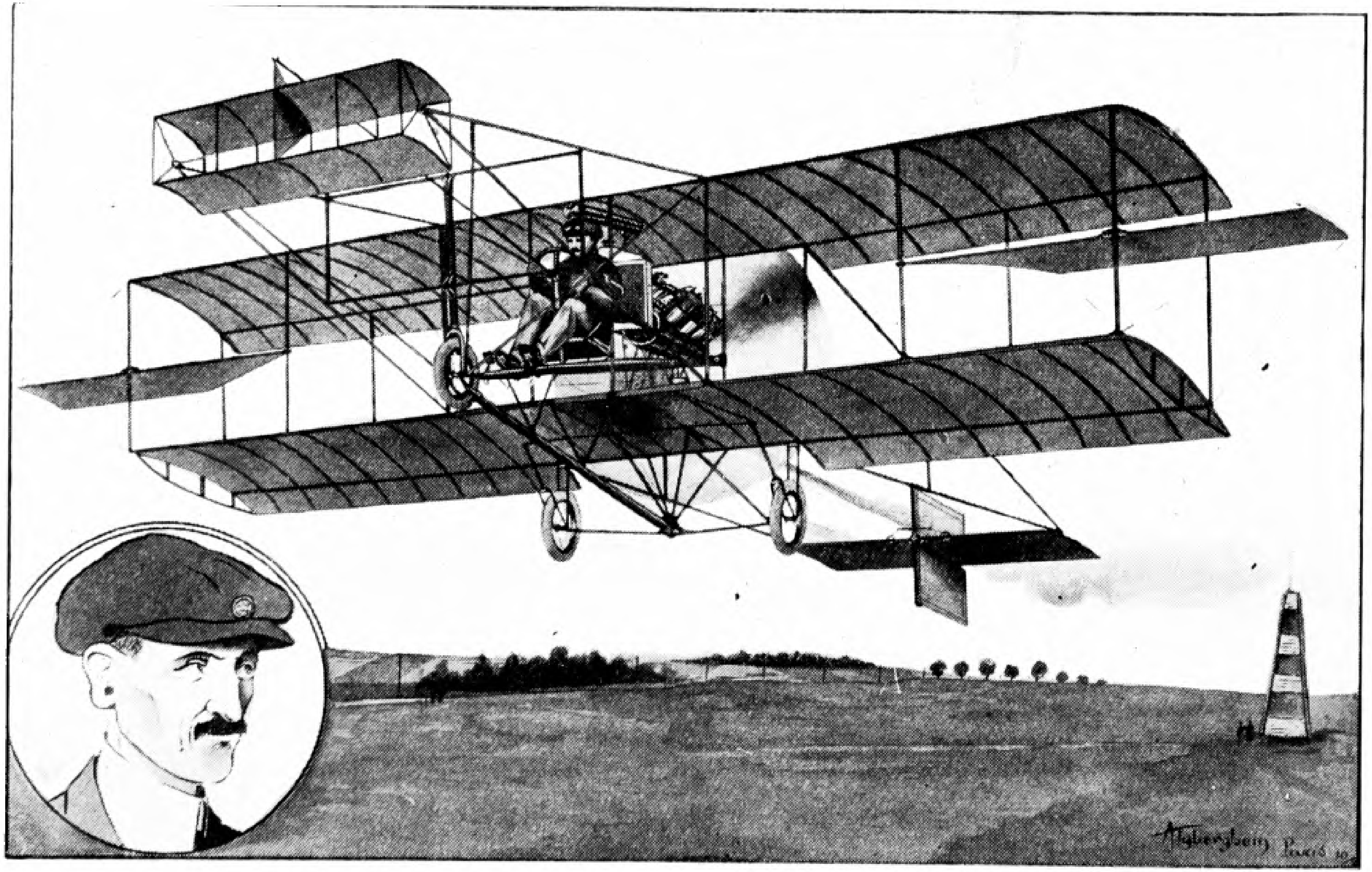
to attach the wings to it. These are in three distinct parts, each part composed of two wooden transverse members, united by built-up curved ribs. The central portion is permanently bolted to the steel fuselage, for it is this section which receives the motor and the radiator, this latter consisting of two sets of light copper tubes soldered front and rear into a brass collector forming the extreme edges of the main plane. The left and right extremities of the wings are composed entirely of wood, with their main transverse members projecting and dovetailing into a socket at the extremity of the central wing members. A couple of bolts hold them in position, and they are further strengthened at the front by three wire stays passing through the hollow front axle, and provided with strainers. At the rear are two stays, one of them being fixed, while the other connects up to a controlling lever, allowing the wing tips to be warped. The wing covering consists of a light rubber-faced fabric placed over the upper and lower surfaces of the wings. The front edge is brought to a fine taper; the rear is composed of a wire connected from rib to rib, with the canvas laced to it.

The pilot's seat is, as usual, under the main wings, and consists merely of a piece of canvas stretched from one to the other of the lower frame members. There are five distinct controls. Through a seam sewn in the back of the pilot's coat a light vertical lever operating the wing tips is passed. By the swaying of the body lateral stability is maintained unconsciously. A lever conveniently placed to the pilot's right hand controls the vertical movement of the rear rudder, downward direction being obtained by pushing the lever ahead, and upward direction by pulling the lever to the rear. On the left is a wheel controlling the lateral movement of the rudder. The pilot's feet rest on a transverse member of the main framework, within which is a kind of toe-clip operating the throttle. In addition, a ring hanging from the wing surface allows him to retard the magneto if necessary.

On the standard machine a two-cylinder double opposed water-cooled motor is employed. It has a bore of 130 mm. and a stroke of 120 mm., and is declared to develop not less than 30 h.p. The wooden propeller of 6 ft. 6 in. diameter by 34 in. pitch is mounted directly on the propeller shaft. Petrol and water tanks are mounted immediately above the engine crankcase, the two reposing on a very light metal framework, and the water tank being just ahead of the petrol vessel; the two are made out of one piece of metal, with a double division and air holes between them. One of the wing stays passes through these holes. If desired, a 45 h.p. four-cylinder motor is mounted on the same aeroplane; this, however, gives a surplus of power that can only be recommended for racing, the machine with this engine being too fast for safe handling by an amateur.

The Curtiss Biplane.

Having been built specially for the Gordon-Bennett speed test, the Curtiss biplane best known to Europe is a model described by its pilot, Glenn H. Curtiss, as having just the same



AVIATORS AND THEIR MACHINES.

Mr. Glenn H. Curtiss and the Curtiss biplane.

difference to the standard model as a racing motorcycle has to a touring machine. The bearing surface has been reduced as much as possible, power has been increased to the utmost limits, and many little conveniences which went for comfort on the first Curtiss biplane have been sacrificed for speed on the second machine. It is this combination of high power and low weight which makes it the fastest machine in existence at the present time. Experiments have shown that the machine will fly, and prove a much better glider, with an engine of half the power now employed; its speed, however, would be considerably diminished.

The two curved, superimposed surfaces measure 28 ft. 9 in. from tip to tip, are 4 ft. 6 in. from front to rear, and 5 ft. apart. The main surfaces are made up of 24 light laminated spruce ribs, attached flush to the front transverse member, but

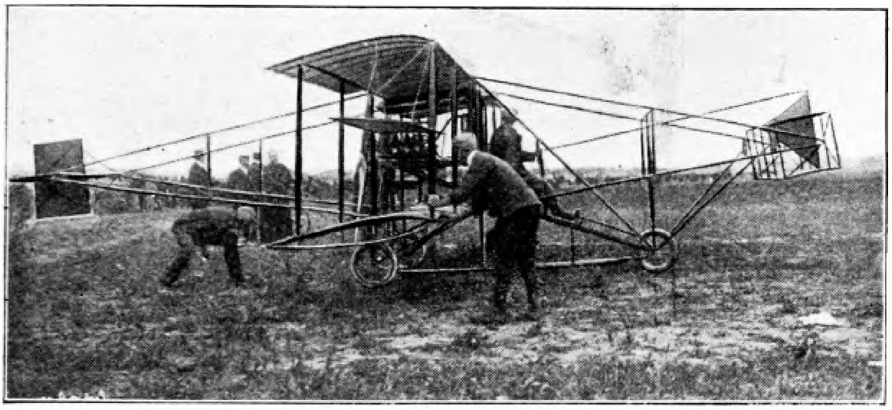


Fig. 135.—The Curtiss biplane.

overhanging the rear one. The covering is a single layer of rubber-faced silk, fastened round the entering edge and kept taut at the rear by wire edgings drawn tight over each rib end. In front of the main planes, and carried at the extremity of a triangular bamboo framework, is the elevation rudder, composed of two superimposed planes with a jib in their centre. A similar structure rearwards carries the lateral rudder, divided into two portions, but controlled together, by a fixed horizontal plane. Lateral stability is assured by two ailerons carried between the main wings, and pivoted to the extreme left and right front stanchions: thus one half of the aileron is between the main surfaces, and the other half extends beyond the wings.

Unlike most biplanes, the motor is mounted on two stout wooden members attached to two pairs of stanchions, and midway between the planes. A honeycomb radiator is placed at the forward extremity of this framework, and immediately behind it is the motor, with its wooden propeller carried directly on the mainshaft.

The running gear consists of three light bicycle wheels, which are not free to swing as on most French biplanes. Two of them are placed under the main wings in bicycle forks and stayed laterally and fore and aft by light steel tubing. From the centre of this tubing a wooden bar runs forward to the single front wheel, also carried in bicycle forks and having no lateral movement.

Commencing at a point under the rear of the engine frame members, and running forward and downward until they meet the forward end of the horizontal bar uniting front and rear wheels, are two stout spruce members, to which most of the controlling gear is attached. The pilot's seat is built ahead of the main wings, and about a foot above the lower plane. At the rear it is attached to the two main stanchions, and at the forward end is connected by steel tubing to the spruce members just mentioned. Immediately in front of the pilot is the steering wheel, having a fore and aft motion to control the front elevation rudder, and turning to left and right to control the

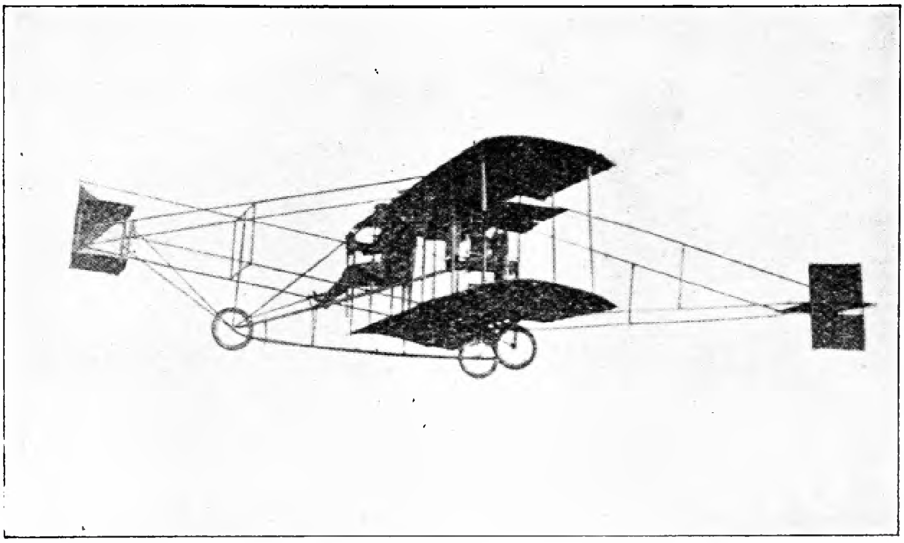
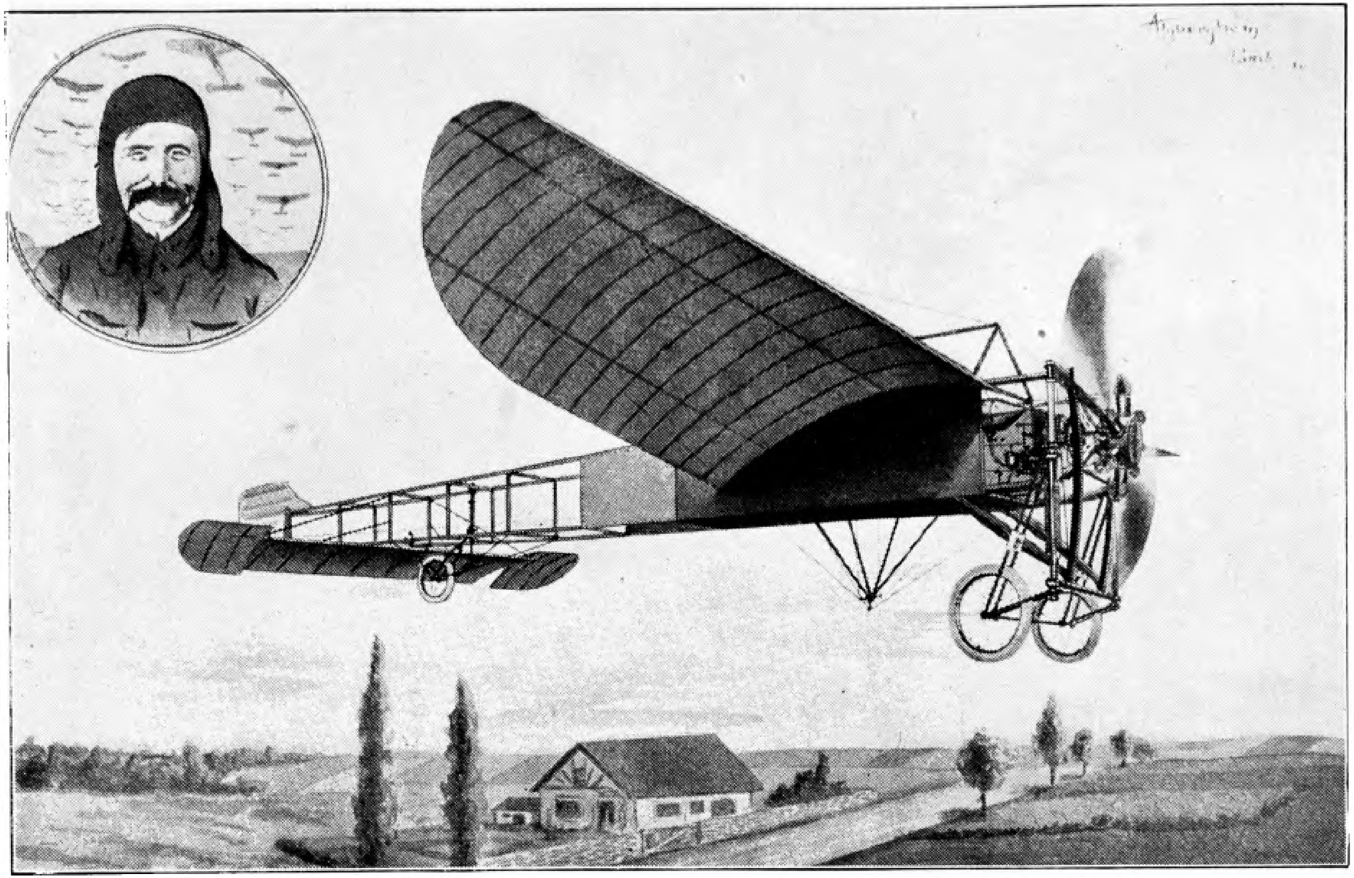


Fig. 136.—The Curtiss biplane in flight.

rear lateral rudder. The ailerons are operated by shoulder control, or, more correctly, by the swaying of the body, the seat having a light steel-tube back to which the control wires are attached. Natural swaying of the body corrects the balance. Ignition advance is obtained by means of a lever convenient to the pilot's left hand. There are three foot controls, one allowing an extra charge of oil to be pumped to the engine as required, and another short circuiting the motor, and, if pushed to its extreme limit, applying a brake to the front running wheel; the third controls the throttle. The front-wheel brake was found necessary when landing on smooth racecourses.

Oregon spruce is employed almost exclusively for the main framework of the machine and bamboo for the triangular structures carrying the front and rear rudders. All the operating cables are passed within the bamboo tubes, precautions, of course,



AVIATORS AND THEIR MACHINES.

M. Louis Blériot and his cross-Channel type of Blériot monoplane.

being taken to prevent them chafing at the extremities. It is believed that this offers a greater amount of security than exposed wires. The motor used on the Gordon-Bennett racing model is an eight-cylinder water-cooled engine of $4\frac{1}{4}$ in. bore and stroke, developing 50 h.p. Lubricating oil is carried in a light metal tank under the motor and pumped up to the crankcase. Petrol is carried in a long, pointed-end racing motorcycle type of tank immediately under the upper frame; the size of the tank varies with the flight about to be attempted.

The Bleriot Monoplanes.

M. Louis Blériot's best-known aeroplane is No. XI., or cross-Channel type, first produced in February, 1909, after several years spent in experiments with various monoplanes. The Blériot No. XI. is a small machine, having a wingspread of 25 ft. 6 in., and a total bearing surface of 150 square feet. It is supplied by the maker with an Anzani three-cylinder air-cooled motor of 22-25 h.p., weighing only 132 lb. in full running order, and driving a two-bladed Chauviere propeller of 6 ft. 10 in. diameter. Fully complete, with M. Blériot as pilot, and sufficient oil and fuel for two hours, the machine weighs just under 6 cwt. It carries practically $4\frac{3}{5}$ lb. per square foot, at a speed of 34 miles an hour in still air. The angle of incidence is seven degrees. The body, or fuselage, of the machine is an all-wood structure, 26 ft. in length, of quadrangular section in front and triangular in the rear. It is mounted at the forward end on a metallic chassis with two bicycle wheels and coil spring shock absorbers, while the rear is kept off the ground by a smaller bicycle wheel. The motor is carried in the forward end of the framework, with the propeller mounted directly on its mainshaft, and the pilot is seated within the body of the machine, a little to the rear. All except the rearmost portion of the body is enclosed with canvas.

The wings, which are separate and attached to the left and right of the main body, have their under surface concave, their angles rounded off, and are covered with rubbered cloth. The method of attachment has been so designed as to allow of rapid dismounting, making it possible to fasten the wings alongside the body for convenience in transport either by road or rail.

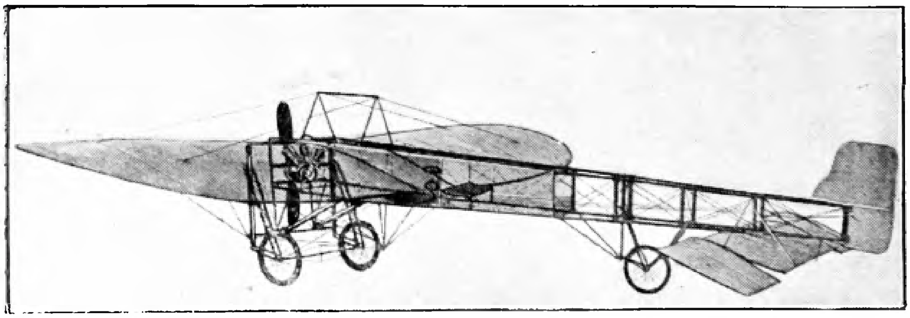


Fig. 137.--Bleriot XI., which crossed the English Channel 25th July, 1909.

The wings are built flexibly to allow the rear extremities to be warped. In addition to their main attachment to the body, they are stayed above and below by piano wire. At the rear, and under the fuselage, is a stabilizing tail, the two extremities of which are pivotable to form an elevation rudder. Hinged to the extreme end of the body is a single vertical rudder, giving lateral direction. The complete control is combined in a single organ, consisting of an automobile type of steering wheel and column, mounted on a universal joint; a bell or dome at the base of the column receives all the operating cables for wing flexing and movements of lateral rudder and elevation planes.

A modified type of the No. XI. has just been produced, in which the fuselage has been shortened to 21 ft. 6 in., the vertical rudder made slightly larger, and the tail redesigned so that the whole of the rear portion is pivotable, and the fixed portion consists of two horizontal fins projecting from the sides of the frame, starting from a point at the front and gradually widening as they extend rearwards. When in its neutral position the elevation rudder forms a continuation of these fins. The entire frame is covered with light, rubbered cloth. Although the first flights have proved satisfactory, these will be continued before the new model is definitely adopted.

Several of the Blériot No. XI. machines have been fitted with Gnome seven-cylinder motors in place of the Anzani. The change, however, is made entirely on the responsibility of the owners, M. Blériot never having flown this machine with any other motor than the Anzani. To accommodate the Gnome, the forward portion of the framework has to be modified, and, as experience has shown, the framework and wing attachments need strengthening for the increased strain thrown upon them.

Bleriot No. XII.

Blériot's racing and passenger-carrying type of aeroplane, with which the world's 10-kilometre speed record was established at Rheims, is the No. XII. monoplane. It has a wing-spread of 29 ft. 6 in., a total bearing surface of 236 square feet, is usually equipped with a 35 h.p. eight-cylinder E.N.V. motor, and weighs complete, without pilot and fuel, only 7 cwt. In this condition it has carried the pilot and two persons, being a useful load of about 2 cwt. For racing purposes it is generally equipped with a 50 h.p. motor, and sometimes with an E.N.V. of 80 h.p. There are considerable structural differences between the No. XI. and the No. XII. types of aeroplanes. The framework of the latter consists of four longitudinal members, the two lower ones being horizontal and the two upper ones gradually curving from the rear upwards until, at the front, they are about 4 ft. from the lower pair. They are untied by verticals and cross members and suitably trussed. The chassis is the same in general features as that used on the smaller machine. The two lower frame members carry the motor the pilot's seat and all controlling gear, while the wings are mounted above the upper members. The wings have thus an unbroken surface from tip to tip, and the pilot and motor

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are carried below them. Another distinctive feature is that the wings on this machine are rigid, lateral stability being obtained by two smaller wings or ailerons attached to left and right of the lower frame members, level with the pilot's feet. After various experiments of covering in the framework, it has finally been left entirely open, and the aeroplane fitted with a long central fin, above the fuselage, the extremity forming a lateral rudder. Almost at the rear, and carried above the upper longitudinal frame members, is a fixed plane to assure longitudinal stability. A little to the rear, and slightly lower than this plane, is the elevation rudder, consisting of two pivotable planes to the left and right of the fuselage.

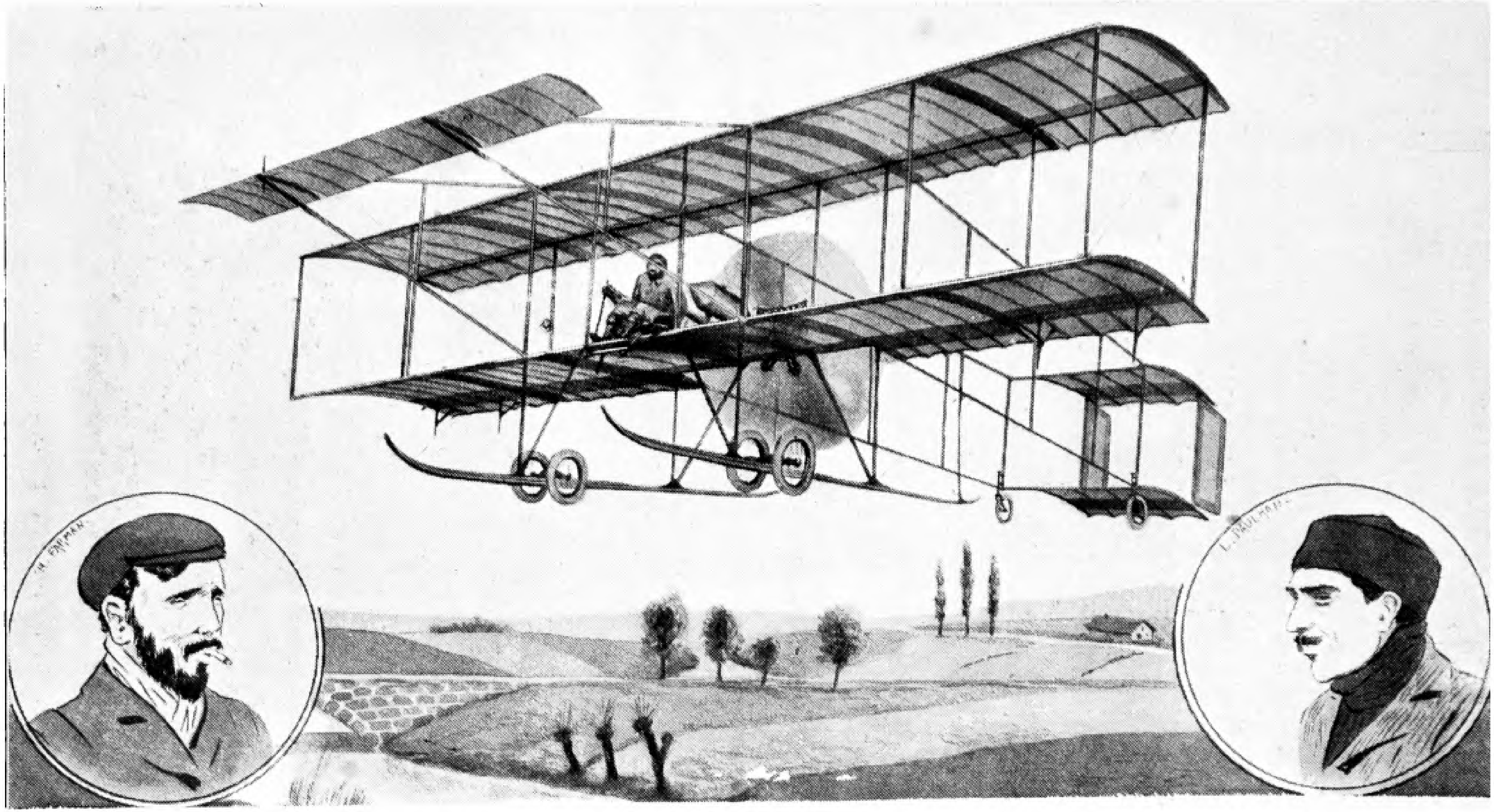
With a view to diminishing resistance, the petrol and water tanks are built within the wing and between the two layers of canvas covering. This, of course, allows the flow of petrol to be by gravity to the carburetter. When long-distance flights are attempted, this tank has to be supplemented by another one under the pilot's seat. The motor, mounted on a steel girder chassis, secured to the lower portion of the frame, drives the propeller by chain, the driving pinion being mounted on the forward extension of the crankshaft, and the driven pinion just ahead of and below the forward edge of the wing. A two-bladed Chauviere propeller is generally employed, geared down to about 900 revolutions a minute.

Henry Farman's Biplanes.

Henry Farman's aeroplane No. 3, designed and built by himself, is similar in general features to the Voisin biplane he formerly piloted. The two main planes measure 34 ft. 6 in. from tip to tip, and the length of the apparatus from front to rear is 42 ft. 6 in. The two planes are united by eight pairs of stanchions strengthened by wire stays, and, as on the first biplane used by Farman, are without vertical planes. Ailerons are fitted to the rear of each wing, a suitable arrangement allowing of their manipulation at the will of the pilot. The peculiarity of the rear cell is that it does not contain a lateral rudder, movement to left and right being obtained by warping the extremities of the two vertical planes. In front is a single elevation rudder in place of the two separate rudders on the Voisin machine.

The framework known as the "fuselage" on the Voisin machine has been abolished on the new Farman. In its place is a false fuselage receiving the pilot's seat and controlling levers, and at the rear a seven-cylinder Gnome motor of 50 h.p. A one-piece, two-bladed propeller is mounted on the crankcase of the motor and revolves with it.

A combination of skates and wheels has been employed for starting the machine and settling down to earth. Under the forward planes are two pairs of pneumatic-shod wire wheels, the inner one of each pair being slightly smaller than the outer one. Between the two is a long wooden skate stoutly attached to the planes, just clearing the ground at the front, but in contact with it at the rear. The tail is prevented from touching the ground by a couple of small wheels free to turn in any direction.



AVIATORS AND THEIR MACHINES.

MM. H. Farman and L. Paulhan, and the Farman biplane.

A triplane is A. V. Roe's latest type of avroplane (A. V. Roe plane). It is equipped with a two-cylinder 10 h.p. J.A.P. air-cooled engine, which drives a four-bladed propeller of 7 ft. diameter. The machine weighs no more than 300 lb., which, with 150 lb. for the aviator, makes a total weight of 450 lb. This works out at 45 lb. per h.p., which is in excess of the 25 lb. per h.p. usually carried by the successful French aviators.

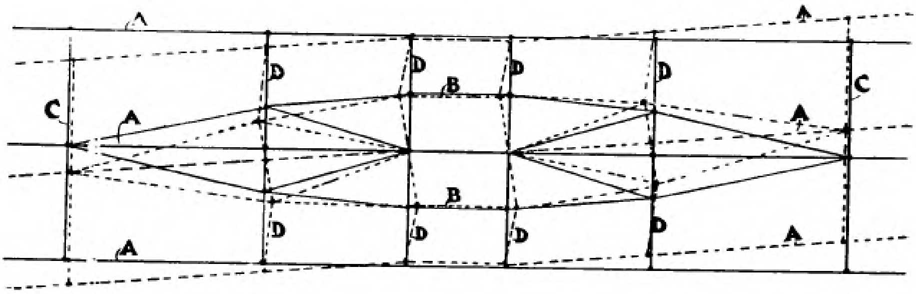


Fig. 138.—The system of warping the wings of the Roe avroplane.

From tip to tip the main planes measure 20 ft., and they are 3 ft. 7 in. deep. The tail is 10 ft. wide and of the same depth as the main planes. The planes are set 3 ft. 2 in. apart. The overall length of the machine is 23 ft. The total surface is 320 sq. ft., which works out at just $1\frac{1}{4}$ lb. per sq. ft.

The machine has several novelties, of which the chief are the steering gear and the method of bracing and twisting the main planes to control the vertical and lateral course of the machine. The rear vertical rudder is turned by a rotary movement of the wheel, the rear planes or tail being fixed firmly to the body of machine.

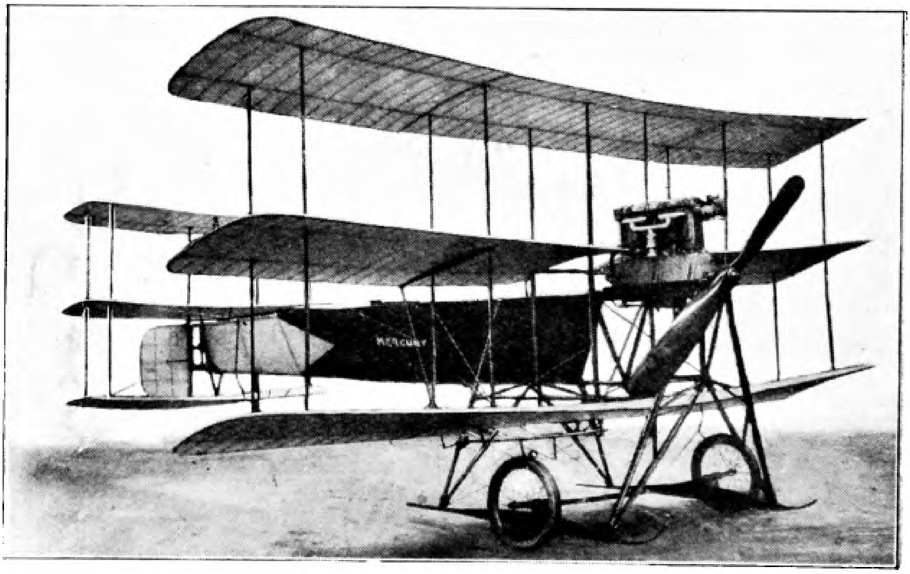


Fig. 139.—The latest A. V. Roe aeroplane or "Avroplane."

The tilting and twisting of the main planes is carried out entirely through levers and rods.

The central main plane (A) (Fig. 138) is braced from end to end by the wire braces (B), so that a girder unalterable in shape is secured. Vertical struts (C and D) carry the upper and lower planes and cause them to be warped similarly to the main central plane. To permit this movement (which would not be possible with stiff struts forming part of the girder), the struts marked D are all thinned in the middle so that they may bend as indicated by the dotted lines. The struts C, of course, do not require to be otherwise than stiff. Connections are made between the middle plane at its rear edge, through rods and levers, to the column of the steering wheel. The rocking up and down of this column moves the main planes and alters the angle of incidence; turning the steering wheel twists the main planes and moves the rudder at the same time.

The latest aeroplane, illustrated on page 150, has a 35 h.p. Green engine, and a propeller 8 ft. diameter and 3 ft. pitch. The total area is 320 sq. ft., the span being 26 ft. and chord 3 ft. 6 in. The total weight is 550 lb.

The Clement-Bayard Biplane.

The Clément aeroplane, built by the Clément-Bayard Co., of Paris, is a biplane without vertical divisions and with a balancing tail. The two superimposed main bearing surfaces are each 37 ft. from tip to tip, and 6 ft. 6 in. from front to rear. Their rigid framework is composed of two hollow white pine transverse members, united by curved ribs, strengthened by wire stays and covered above and below by rubbered cloth. The total bearing surface is practically 485 sq. ft.

Eight pairs of uprights, also of hollow pine, and 5 ft. 10 in. in length, separate the two planes. No arrangement is made for dismounting the aeroplanes into sections, and the wings are entirely rigid. A distance of 8 ft. 6 in. ahead of the main plane is a single-piece elevation rudder mounted on light curved-wood frame members, strengthened by triangular stays to the upper and lower planes. The dimensions of the elevation rudder are 13 ft. by 3 ft. Its angles, like those of the main planes, are widely rounded off.

At the rear is a tail secured to the main planes by four hollow longitudinal members united by uprights and strengthened by

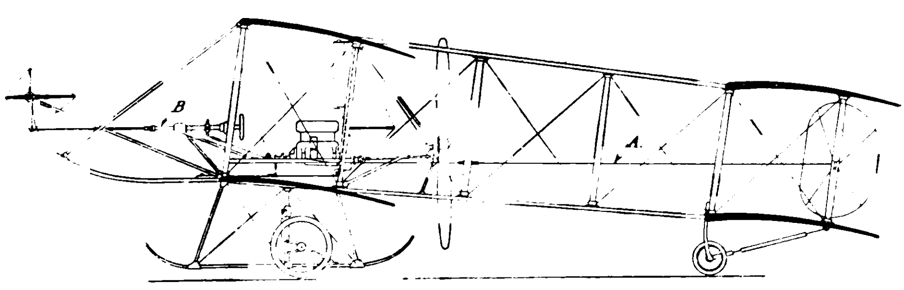


Fig. 140.—The Clement-Bayard biplane.

A, cable operating rear rudder; B, rod operating elevation planes.

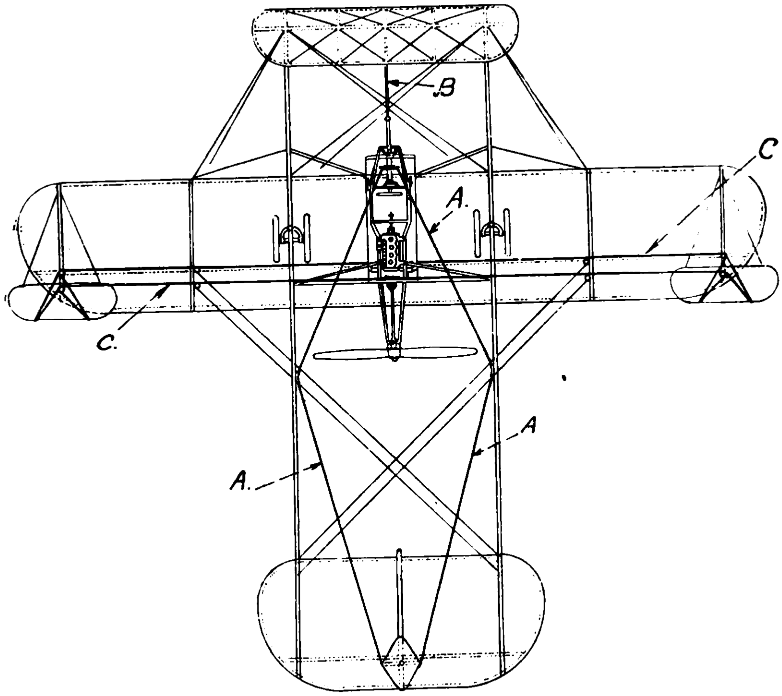


Fig. 141.—Plan of Clement-Bayard biplane showing control.

A, rudder cables; B, rod controlling elevation planes; C, cables to operate ailerons.

wire stays. The distance between the rear of the main wing and the fore edge of the tail is 12 ft. 10 in. The dimensions of the tail are 13 ft. across and 6 ft. 6 in. from front to rear. The two planes are 5 ft. apart, and in the centre of this space is a single vertical rudder almost oval in shape.

There being no vertical planes to secure lateral stability, and the wing surfaces being rigid, two special ailerons are used to correct the lateral roll of the aeroplane. They are mounted at the extremities of the main cell and between the two planes, their dimensions being 5 ft. 3 in. by 2 ft. There are two distinct controls, one by means of a steering wheel mounted on a horizontal column, which on being pushed ahead or pulled to the rear operates the front elevation rudder, and on being turned to left and right controls the rear vertical rudder. The two ailerons are connected by wire cables to a horizontal bar immediately in front of the pilot and worked by his feet. The two methods of control are shown in Figs. 140 and 141, A being the flexible cable operating the rear rudder, B the connecting rod for the front elevation rudder, and C the cables to the ailerons.

A four-cylinder 40 h.p. Clément-Bayard motor, described in another section of this book, is employed on the aeroplane. It is mounted on a wooden framework in the centre of the lower plane, with the pilot's seat and controlling gear just ahead of it. A distinctive feature of this machine is a band clutch within the external flywheel of the motor and operated by a lever on the right-hand side of the pilot. The two-bladed wooden propeller of 8 ft. 6 in. diameter and 6 ft. 6 in. pitch is not mounted directly on the extremity of the main shaft, as is usually the case, but some distance to the rear, the connection to it being by a horizontal shaft with two universal joints and a reducing gear contained in a light gearcase. The propeller is geared down to turn at 900 revolutions a minute. The gearbox is suspended to the main wings by four steel tubes forming a pyramid. The attachment of the reducing gear is intentionally flexible, but in order to reduce the oscillation a spring-mounted lever is fitted from one of the frame members to the gearbox.

The running gear consists of two spring-mounted wheels fitted with pneumatic tyres, immediately under the main planes, and working in conjunction with long wooden skids. The wheels are so mounted that they will rise if the ground is struck with force, thus allowing the skids to take the shock. The rear cell is carried by a single wheel with a coil spring shock absorber.

The Maurice Farman Biplane.

The Maurice Farman machine is a biplane having a certain general resemblance to that of his brother Henry's, although distinctive in details and method of construction. The two superimposed surfaces are each 35 ft. 6 in. from tip to tip, the total bearing surface of the machine being 440 sq. ft. The two planes are united by eight pairs of stanchions, the central ones being placed closer together than those near the extremities. For convenience in transport the main cells are built in three distinct sections, consisting of the central one with the motor and all controlling gear, and two flanking cells, to left and right, bolted to the main one. When bolted together all signs of division are removed by a narrow canvas strip glued over the joining. The method of wing construction is the usual one of two parallel longitudinal members united by curved ribs flush in front and overhanging at the rear. The rearmost extremities of the main planes form ailerons hinged to the transverse member. Thus the ailerons form a part of the main bearing surface and are not a projection, as on the Henry Farman and Sommer biplanes and on one of the Antoinette models.

Placed a considerable distance ahead of the main plane is a one-piece front elevation rudder having the unusual length of 16 ft. 6 in. To the rear of the main plane is a tail composed of two superimposed planes with an elevation rudder pivoted to each of the rear external stanchions, and, of course,

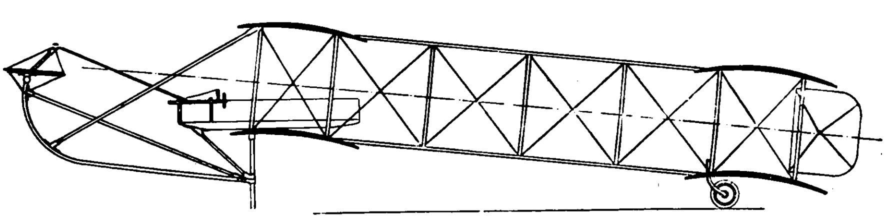


Fig. 142.—Elevation of latest type of Maurice Farman's biplane.

projecting beyond the planes. The total overall length of the machine is 46 ft.

Unlike the Voisin biplane, the lower main plane of the Maurice Farman machine is not broken to receive a fuselage, but is continuous as in the Wright and Henry Farman fliers. The motor, however, is not mounted directly on the wings, but on what is known as a false fuselage, consisting of two ash members laid parallel on the top of the plane, but projecting beyond its forward edge for about 3 ft. and curving inwards until their extremities meet. This structure forms a solid base for the motor, as well as for the pilot's seat.

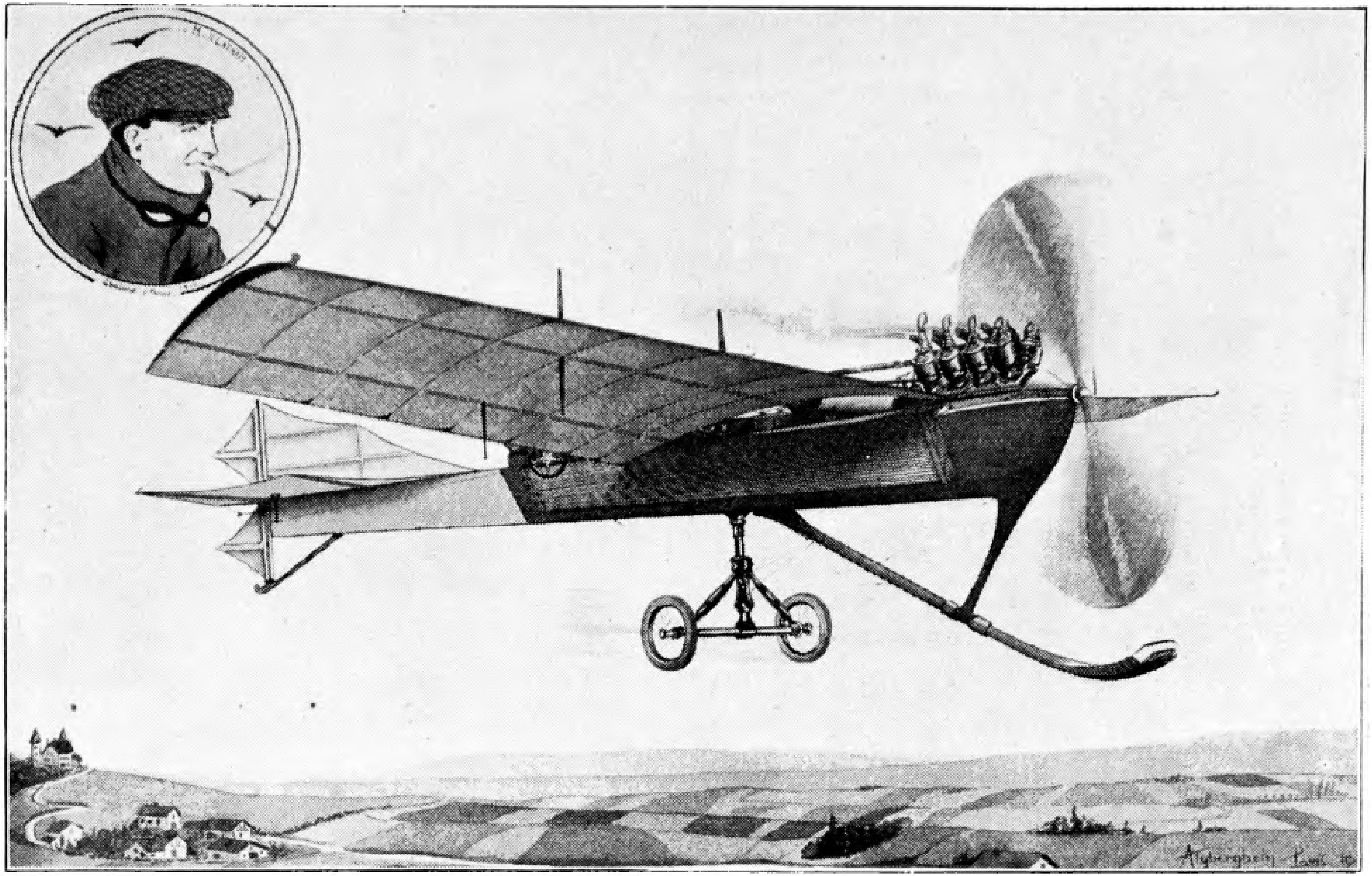
Control of the front elevation rudder is obtained by means of a steering wheel having a fore and aft motion. The same wheel, on being turned to left and right, operates the ailerons. The rear vertical rudders, giving lateral direction, are controlled by a pedal. In all the flights made by Maurice Farman with this aeroplane, a Renault eight-cylinder 50 h.p. motor has been employed, the camshaft carrying the propeller, a Chauviere of 8 ft. 2 in. diameter revolving at 800 revolutions a minute, without the use of any external reducing gear.

The aeroplane is mounted on steel running gear with coil spring shock absorbers and two wheels of 24 in. diameter shod with 100 mm. pneumatic tyres. The rear cell is carried on two smaller castor wheels.

A remarkable feature of the machine is the almost entire absence of right angles. The main planes have their angles widely rounded off; the rear cell is almost oval shaped; the vertical rudders have their corners rounded off, and the front elevation rudder is treated in the same way. Even the frame members uniting the tail to the main surfaces are widely curved. They are set about 16 ft. apart at the point where they are attached to the planes, and sweep together until they are only 9 ft. apart, where they are secured to the rear cell. Hollow white pine is used almost exclusively in the construction of the framework of the aeroplane. The main transverse and longitudinal members, as well as the uprights, are all split, hollowed out and joined together by a special process which makes them impervious to heat or damp. In addition, the main members are bound at intervals by what are technically known as "bracelets." The front entering edge of the elevation rudder is particularly blunt, its section being over 3 in. As it is completely hollowed out, however, with the rear left open, its weight is very much less than would appear at first sight. It is claimed for this method of construction that a great saving of weight is obtained. The weight of the complete apparatus, without motor, is given as 500 lb.

Antoinette Monoplane.

The body of the Antoinette very closely follows the lines of a boat, the transverse section of which is triangular, and the planking replaced by a light canvas covering. The boat has a fine bow, and even at its greatest section is only sufficiently wide to allow of a narrow cockpit for the pilot, about one-third



AVIATORS AND THEIR MACHINES.

M. Hubert Latham and his Antoinette monoplane.

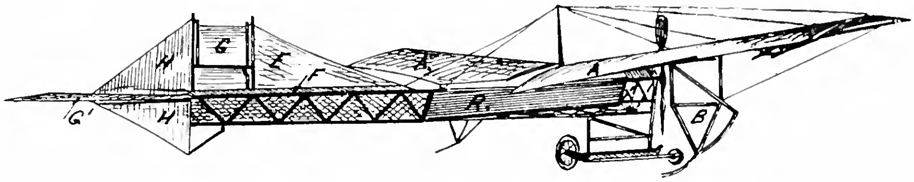


Fig. 143.—The Antoinette monoplane used by M. Hubert Latham.

from the bow; the rear gradually narrows to a fine taper. The bearing surface consists of two wings to left and right of the boat-shaped body, and slightly raised so as to form a very open V, 42 ft. from tip to tip. The surface of the wing is slightly curved, the exact form having been decided upon after numerous experiments with a view to determining the greatest sustaining power with the least resistance. Both surfaces of the wings are covered with fine varnished silk.

At the rear extremity of each wing are carried what are known as ailerons, or supplementary bearing surfaces, pivoted to the rear of the main wing with the object of assuring transverse stability when making turns or when flying in a wind. In their normal position the ailerons are a prolongation of the main wing surface. They are connected together, and by means of a suitable lever can be made to occupy a position perpendicular to the wings, one of the ailerons being raised while the other is lowered. The same effects are procured with this system as with the flexing of the wing tips on the Wright type of aeroplane.

On the machine which made the second attempt to fly the English Channel ailerons were replaced for the first time by a system allowing the entire wing to be pivoted, and not merely warped, as on other aeroplanes. Instead of attaching the transverse girders of the wings rigidly to the bodywork of the machine, they are hinged to allow them to be pivoted in opposite directions. This gives a shoulder movement, as it may be termed, which can be made much more effective in maintaining lateral stability than the pivoting of a square yard of plane at each wing tip. All the new machines are built with pivoting wings; a number of the aeroplanes with ailerons are still in use.

On the Antoinette monoplane all the rudders are at the rear. For the purpose of turning, the fin E, Fig. 144, is prolonged by another vertical plane pivoting round this latter, and in the illustration shown slightly to the right, this being the position it would occupy when about to make a turn to the right. This vertical rudder (H) is duplicated by one in the same plane, but separated from it by the elevation rudder (G), being a prolongation of the fin (F), when in a horizontal position.

The driver's position has been selected to give the maximum security. It is a small cockpit within the frame, and level with the rear of the wing tips; in case of accident it would be necessary for the whole forepart of the apparatus to be demolished before the pilot could be reached. To his right and left, and mounted on a horizontal axis, the pilot has an ordinary

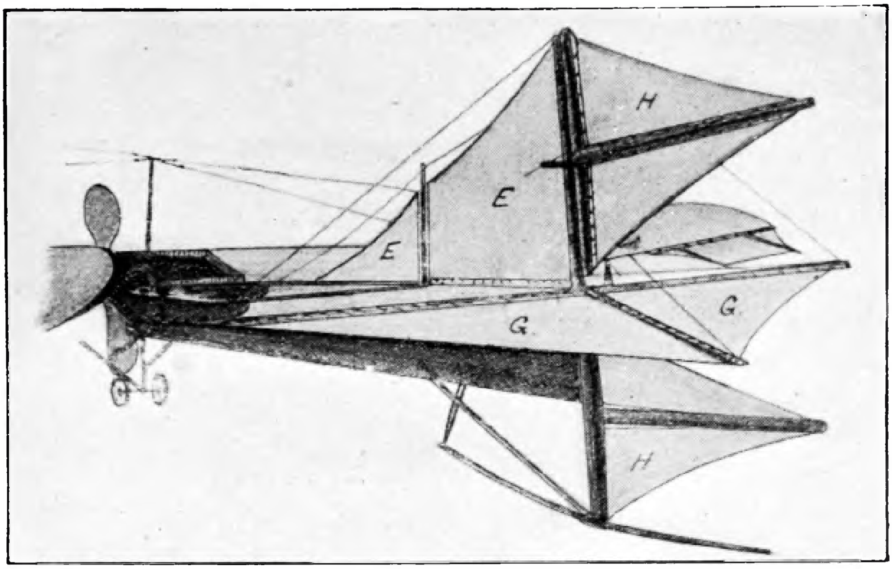


Fig. 144.—Vertical and horizontal rudders of Antoinette machines.

type of motorcar steering wheel. The one on the right controls the rear horizontal plane forming the elevation rudder; thus if the wheel is turned ahead the plane is lowered and the aeroplane descends. A similar wheel on the left controls the ailerons, raising one and lowering the other, thus giving lateral stability in winds and assisting in making turns. The vertical rudder at the rear is operated by a horizontal foot lever and connecting cables. The pilot has a smaller wheel mounted on the end of a horizontal shaft running forward, immediately in front of him, this controlling both the petrol pump regulating the supply of fuel to the engine, and the position of the spark when running on accumulators. The engine, naturally an Antoinette, is carried in the bow of the apparatus, with its two-bladed steel and aluminium propeller mounted direct on the forward end of the main shaft. The radiator for the 50 h.p. engine only weighs 26 lb., and has a cooling surface of 130 square feet. It is composed of a number of long, fine section aluminium tubes placed on the side of the boat-shaped hull, as shown at R in Fig. 143, in which position the tubes receive a strong current of air while offering practically no resistance to advancement.

The Antoinette monoplane is mounted on a skate, with a couple of struts under the centre of each wing, and a strut under the tail. The skate extends about 3 ft. ahead of the apparatus in order to protect the engine from shock in case of a violent descent. It is connected to the body of the aeroplane by two shock absorbers, one of them being placed exactly under the centre of gravity and the other further forward.

The Cody Aeroplane.

The Cody aeroplane is the result of the designer's experience in kite work embodied in a design on accepted lines. The Cody

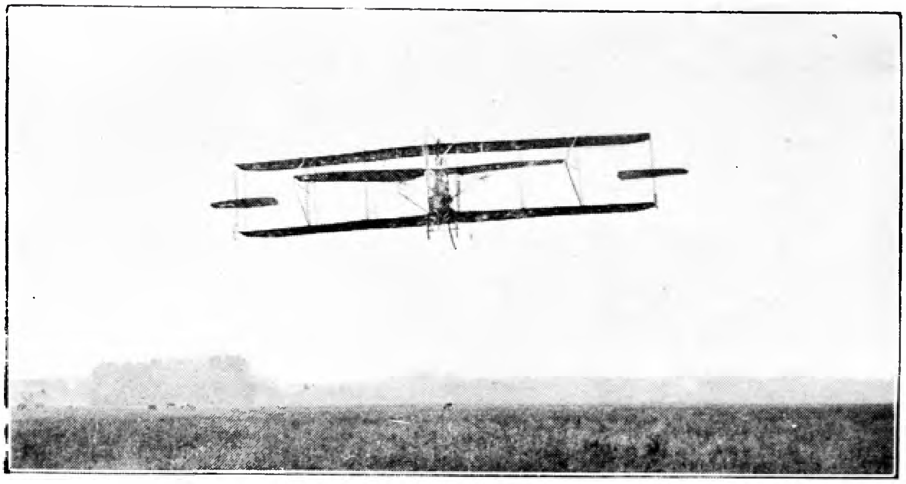


Fig. 145. –The Cody aeroplane in flight.

is a biplane, each plane being 52 ft. long and about 7 ft. 6 in. wide, and presenting a sustaining surface of approximately 1,000 ft. super. The framework is largely tubular. The two planes are set 9 ft. apart and are cambered. The elevator is placed forward, being supported by triangular framework projecting from the main framework of the machine. The elevator is a monoplane divided, the two parts being capable of being worked in unison or in opposition. They operate in unison as an elevator and in opposition to counteract any canting of the machine. At the ends of the planes and midway between them are small planes, which are intended to assist in maintaining equilibrium, although it has not been made known whether they are

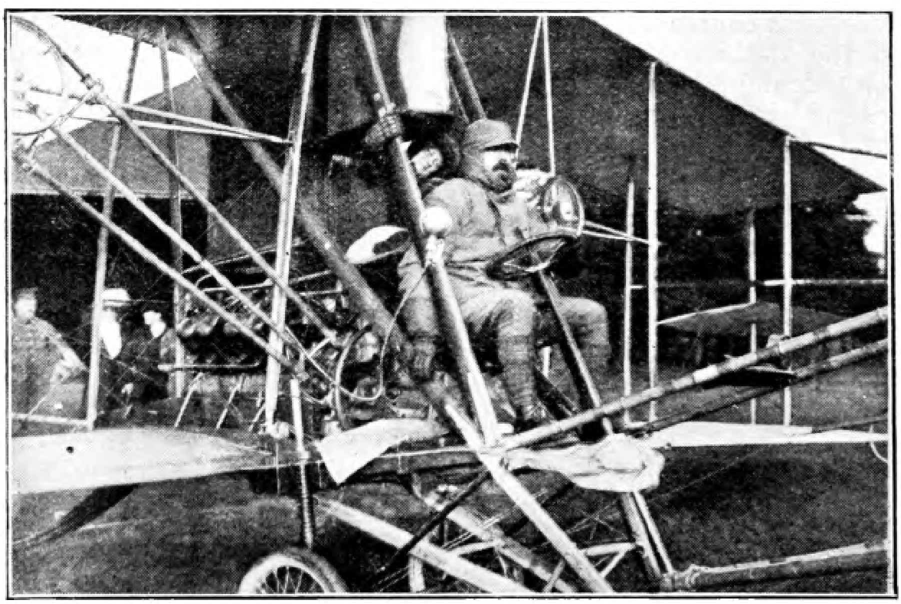


Fig. 146.—Mr. S. F. Cody starting to make a flight with Mrs. Capper as passenger.

controlled by hand or automatically by means of a pendulum device. Vertical rudders are placed in front between the two halves of the divided elevator and also at the rear, carried on an outrigger. The machine is mounted on a very strong three-wheeled chassis, the forward wheel, however, only being employed to protect the machine in case it pitches forward. When travelling along the ground the machine runs on the two wheels below the pilot, and a kangaroo-tail skid prevents any backward tilting. The Cody aeroplane is driven by an eight-cylindered E.N.V. engine developing 80 h.p., driving two propellers, the drive being by chains running through tubes, one being crossed so that the propellers run in opposite directions. Many of Mr. Cody's early troubles arose through defective water cooling, but he has now adopted the spiral-tube radiator, which, whilst being strong and efficient, is particularly light, the total weight with water being from 16 oz. to 20 oz. per indicated horse-power. The radiator consists of thin copper tubes placed in rows, each tube spirally wound with thin copper tape, acting as gills. It is placed end on to the wind, and so offers a minimum of resistance. The radiator and the whole of the power equipment showed up well when Mr. Cody made a cross-country flight of about 40 miles, occupying 63 min., this distance being a world's record. The total weight of the Cody is about one ton, and to facilitate transport the wings divide into three sections, the tail folds over against the main portion of the wings and the elevator and its framework can be removed bodily.

Messrs. Short Bros'. Productions.

Messrs. Short Brothers have constructed a large number of aeroplanes at their workshops at Shellbeach in the Isle of Sheppey. They are making aeroplanes to the order of the Brothers Wright, who, for the present at least, are working their English patents themselves. The machines can, if necessary, be built and delivered at the rate of three per week. Wright engines (made by Leon Bollee, of Le Mans) and the Green engines made by the Green's Motor Patents Syndicate, Ltd., are chiefly employed. The Wright designs are being faithfully reproduced down to the minutest detail, because the inventors have a reason for everything they do, even though some of the reasons may be obscure. The machines already delivered to the Hon. C. S. Rolls, Mr. Percy Grace, Mr. Maurice Egerton and Mr. Alec Ogilvie have been flown with success.

Three types have been designed and made by Messrs. Horace and Eustace Short, and two have flown. "Short No. 1" was shown in an early stage of construction at the Aero Show in March, 1909, and has been equipped with a 30 h.p. Bariquand and Marre car engine, the total weight of the power plant being nearly 750 lb. The engine that is being made for it will permit of the reduction of this weight by about 300 lb. The machine is a biplane of 40 ft. span, the planes being deeply cambered and 6 ft. 7 in. in width, 6 ft. at each end of the upper and lower planes being extended rearwards to a total depth of 10 ft. 2in. to form flexible balancing

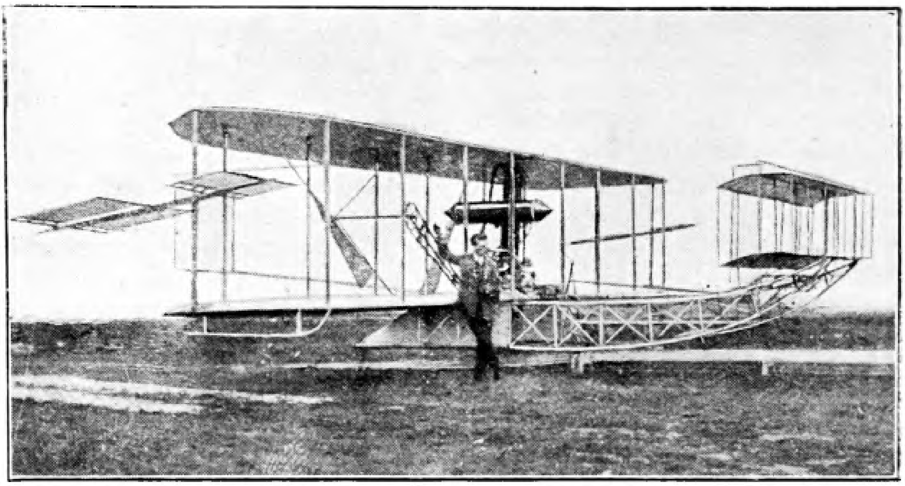


Fig. 147.—" Short No. 2 " aeroplane at Shellbeach.
Mr. J. T. C. Moore-Brabazon, pilot.

planes. In front, carried on outriggers, is the double biplane elevator, 14 ft. long by 3 ft. wide, with a central vertical fin. There are four rudders, two at each end of, and between, the main planes—mounted, in fact, between the balancing planes. The engine drives two propellers through chain gearing, the propellers being rotated in the same direction, thus saving the crossing of one of the chains. The propellers are of wood. The machine is mounted on two wooden skids and is started on a rail as a Wright is started.

" Short No. 2 " embodies several modifications on " No. 1," and both machines may be said to show a resemblance in line of thought to the Wright aeroplanes. It is 48 ft. 8 in. wide, the chord being 6 ft. 6 in., the total area being 495 ft. The front

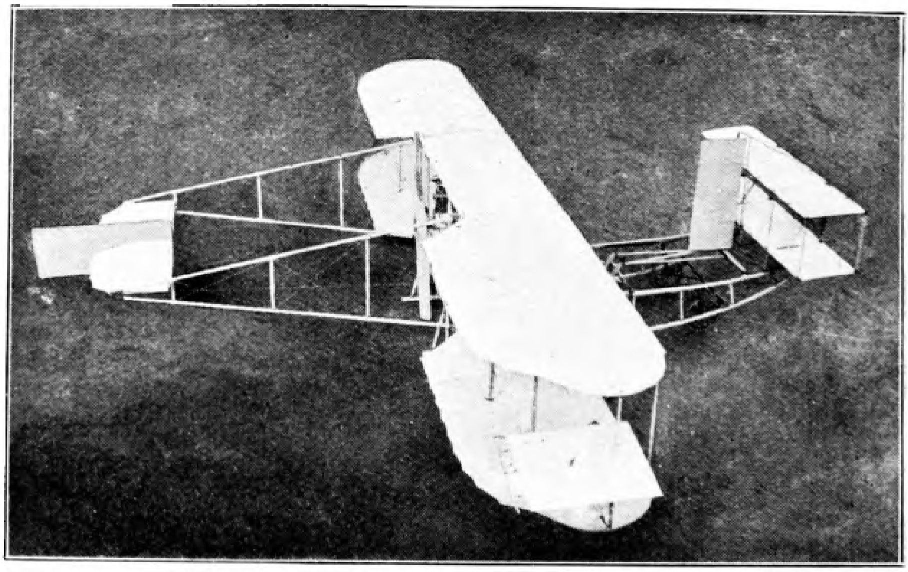
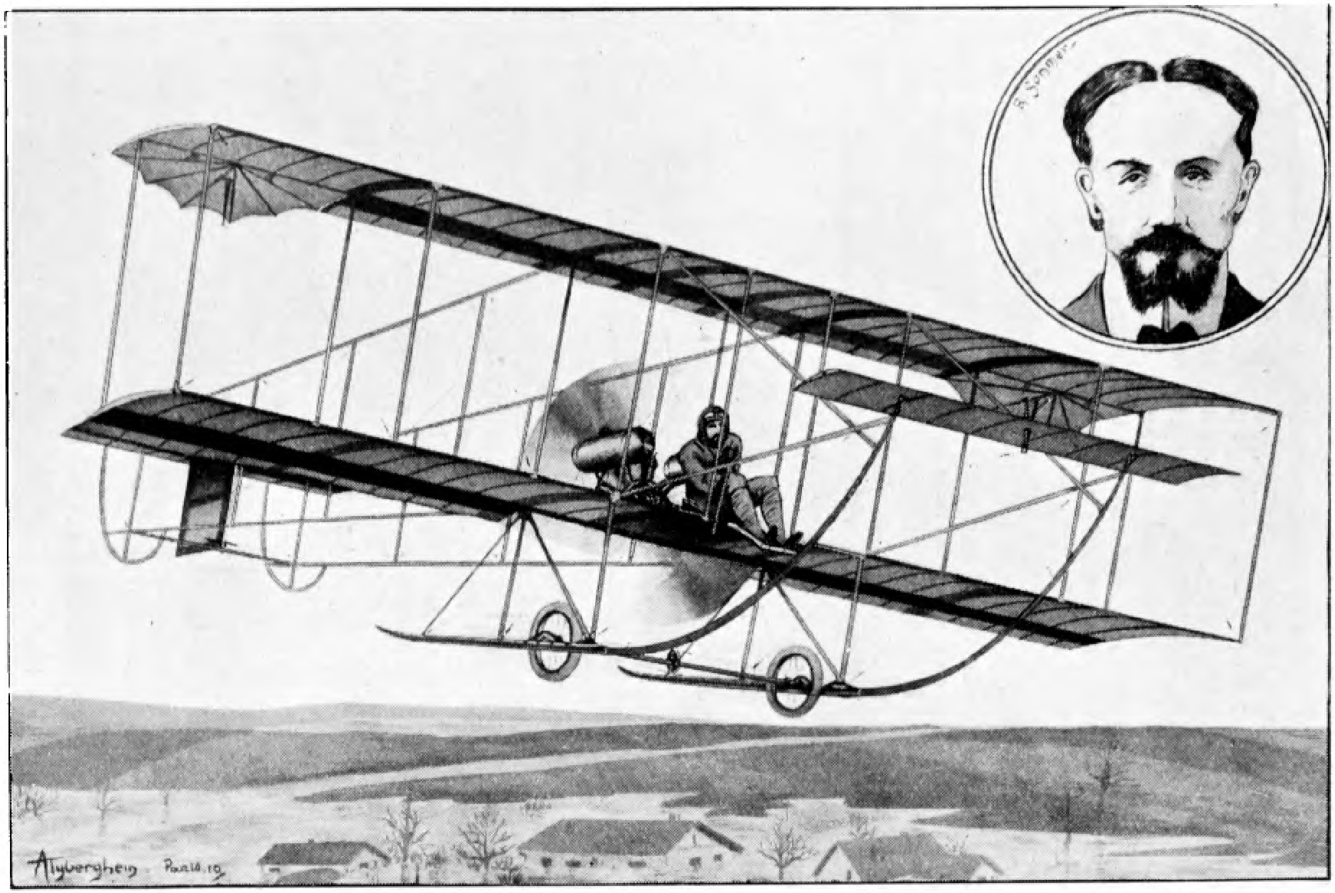


Fig. 148.—" Short No. 3."



AVIATORS AND THEIR MACHINES.
M. Roger Sommer and the Sommer biplane.

elevator consists of two planes controlled by a lever. At the rear of the elevator is a vertical fin, and behind the planes is a vertical rudder, on either side of which is a small sustaining plane. At each extremity of the gap between the main planes is a balancing plane, the two being operated oppositely by a single control system. The engine is a 35 h.p. Green driving two 9 ft. propellers by means of chains.

"Short No. 3" shows many advances in detail design. It is 31 ft. 8 in. wide, the chord measuring 5 ft. 4 in., and the total area of the main planes 282 sq. ft., an extra 55 ft. of sustaining surface being offered by the biplane elevator in front and 21½ sq. ft. by the tail planes. The balancing planes at the ertremities of the gap each have an area of 12 sq. ft., and the surface fabric is secured to the rear of the frame by spiral springs so that the camber is automatically adjusted to the air pressure. The tail has a vertical fin and the horizontal fin is capable of being set at any desired angle within certain limits. The rudder is at the rear of the elevator and is foot-operated. The skis are of the lattice girder type, and four pneumatic-tyred wheels are suspended on helical springs wound up by a pawl and ratchet arrangement. After the aeroplane has left the ground, the pilot releases a catch and the wheels are pulled by the springs above the level of the skids, which take the landing shocks. A 35 h.p. Green engine drives a 7 ft. 6 in. propeller, the engine shaft being central in the gap.

The Hanriot Monoplane.

The Hanriot machine, now being built in series at Rheims, is a monoplane having a spread of 30 ft., wing surface 8 ft. from front to rear, with a total bearing surface of about 230 sq. ft. The wings, covered with rubbered cloth above and below, and having a pronounced dipping front edge, are attached to a long square section fuselage, at the extremity of which are horizontal and vertical rudders. The motor, usually a six-cylinder vertical Buchet, is mounted in the forward portion of the fuselage, the propeller being carried directly on the main shaft. The pilot's seat is in the rear. The running gear is of a very simple nature, consisting of four struts attached to the upper portion of the fuselage, united at their base by cross bars and skids and carrying a couple of castor bicycle wheels with rubber shock absorbers. A third wheel prevents the tail from dragging when running over the ground. The extremities of the wing tips are capable of being flexed by cables in the usual manner. The elevation rudder consists of a long horizontal tail, the extremity of which is capable of being flexed up or down by means of cables. The lateral rudder consists of two planes movable around a vertical axis.

The Sommer Biplane.

Roger Sommer's biplane has naturally much in common with the Henry Farman machine, on which Sommer first succeeded in making flights. It is a biplane without vertical planes, with the Farman type of elevation rudder in front, a combined system of skids and wheels, and a rather distinctive tail. The machine is one of the lightest biplanes yet built, the total weight only being 700 lb. Wing spread is 32 ft. 6 in., with a total bearing surface of 333 sq. ft. At a distance of 8 ft. 3 in. in front of the main planes is an elevation rudder measuring 3 ft. 4 in. in width, mounted on three supports attached at their opposite extremities to the upper and lower planes and the running gear. Lateral stability is secured by the use of a pair of ailerons attached to the rear extremities of the upper plane and operated by the swaying of the pilot's body.

The tail is one of the most original features of the machine, for it consists of a light single plane having an area of 53 sq. ft., mounted in such a way that its angle of incidence can be varied.

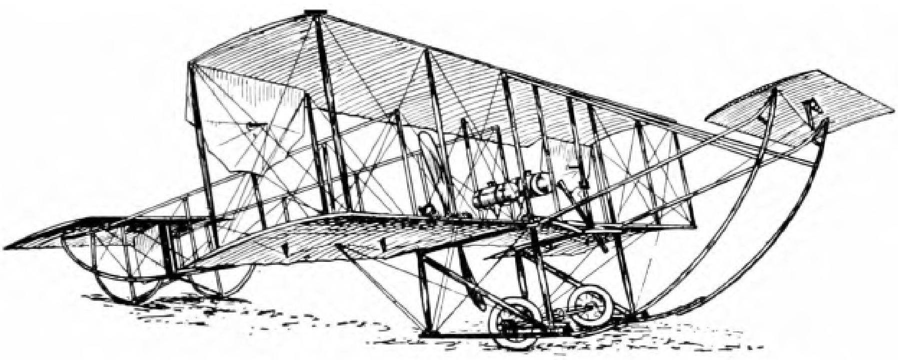


Fig. 149.—The Sommer biplane

Just ahead of this horizontal plane, and within the four frame members uniting the main body to the tail, is vertical rudder giving lateral direction, and operated by means of a pedal. The motor employed on this aeroplane is a 50 h.p. Gnome driving a two-bladed Chauviere propeller.

The initial run is made on pneumatic-tyred wheels under the wings, and two smaller wheels under the tail. The system is a combination of skids and wheels, with these latter mounted on a steel axle. The shock on landing is taken up by the tyre, by the flexibility of the axle, by rubber bands uniting the axle to the skids, by the elastic skid, and by a patented shock absorber.

With a view to easy transport, the structure carrying the front elevation rudder and the framework for the rear plane are mounted on hinges to allow them to be folded up against the main wings, thus reducing the width of the machine to that of the width of the main planes. The front elevation rudder is dismounted and secured between the main planes, the curved members from the skids to the front rudder are also dismounted, leaving the forward triangular framework free to fold to the left alongside the main wings. The same applies to the rear structure, the tail being dismounted and fixed between the wings, and the framework, with the vertical rudder untouched, folding alongside the main wings.

The Collier Monoplane.

Of the Blériot type, the Collier monoplane promises to be a success, especially as its pilot, H. A. Collier, combines caution

L 2

and sound judgment with a large measure of dash and daring. As a racing motorcyclist he has been wonderfully successful, mainly because he is thorough in all that he undertakes and " gets there " in front of more dashing drivers, for he knows the limits and keeps up to them. The machine was made by Messrs. H. Collier and Sons, of Plumstead, and it is now at Plumstead Marshes, where a few trials have already been made. The overall length is 27 ft. The span of the main

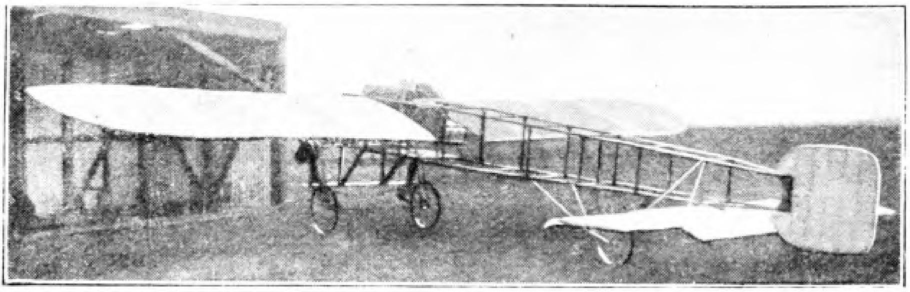


Fig. 150.—The Collier monoplane.

plane is 30 ft. and the chord is 6 ft., giving a total area of 180 sq. ft. The framework and the planes are constructed of wood all through, the latter being surfaced with waterproof silk. The engine is a four-cylindered V-type, air-cooled Jap, 85 mm. in the bore and 85 mm. in the stroke, and its normal speed is 1,200 revolutions per minute, and it drives a laminated wooden propeller 6 ft. 8 in. in diameter and with a pitch of 3 ft. 6 in. The elevation plane at the rear has movable tips, and beyond and above it is the vertical rudder. The movements of the tips of the elevator planes and the warping of the main planes can be controlled by one hand, the system being new. The running gear consists of three pneumatic-tyred wheels, strong rubber being used for absorbing the shocks. The unladen weight is 500 lb.

AEROPLANE SPARS, RIGGING, AND FITTINGS.

The structure of an aeroplane consists of three principal portions, in addition to the propelling machinery, and these three may be termed (1) the struts or members of the framework which are under compression, torsion, or cross strain; (2) the tension rods or wires; and (3) the material of which plane surfaces are made. In the case of the first two portions of the structure, aeroplane constructors might do worse than turn to the builders and designers of light racing sailing boats and canoes, as, in these little craft, piano-wire stays and hollow spars have been brought to a high state of perfection for some years. Probably, every possible variety of spar has been tried in these vessels at some time or other, from the original solid stick to the modern hollow spar, which has superseded everything else, next in value being the bamboo. Of all these kinds, the one now in use consists of a piece of perfectly clean-grained Californian or Nova Scotian spruce, cut in half lengthways, and, after the centre has been scooped out, glued together again. These spars are only about 30 per cent. of the weight of a solid spar of the same size and material, yet they have about 75 per cent. of the strength of the solid wood, thus showing a great advantage, which more than counterbalances their high price. After the two halves are glued together they are screwed up between two planks by means of a series of cramps, as, unless the glue be under great pressure, a good joint cannot be obtained. The two principal makers of hollow spars in this country are Messrs. G. Hollwey and Sons, of Dublin (who were the first firm in Great Britain to take up the manufacture of hollow spars), and Messrs. A. Burgoine, of Kingston-on-Thames, who have made several hollow frames for the Clarke aeroplane. Many people think that a bamboo is as light and strong as a hollow spar of the same size, but this is by no means the case, as a series of tests carried out by us some years ago proved the hollow spar to be 15 per cent. lighter and nearly 20 per cent. stiffer than a bamboo of the same length and diameter. In the larger spars the difference in favour of the hollow spar is even more marked, as the shell can be kept thinner in proportion to the outer diameter. Steel tubes have often been tried in place cf wooden spars, but they are not so good, being heavier for a given strength, and, moreover, they are prone to buckle and dent.

Wire Stays.

Quite as important as the wood frame is the wire used for the stays and the method of attaching it to the frame, as lightness and neatness are essential on the aeroplane. It is of no use to fasten off the ends of the wire in such a manner that they will slip, or in any other way be weaker than the rest of the wire. Before going further into the details of the end fastenings it will be well to consider the nature of the wire employed. This should be the best silver-plated piano wire, which may be bought in 50 ft. coils of various gauges; No. 26 is about .06 diameter or, say, .002 sq. in. in sectional area, and as the breaking strain is over 800 lb., the tensile strength is about 125 tons per sq. in.! The next size smaller has a breaking strain of about 520 lb., and is quite strong enough for many of the lighter parts of the machine. The weight of the No. 26 wire is approximately 2¼ lb. per hundred yards and the smaller size about 1¾ lb. for the same length. This piano wire is not easy to obtain of the best quality, and unless it be absolutely reliable it is of no use to the maker of aeroplanes. Although the wire is very stiff, it is not tempered, but is merely drawn hard and not annealed; this makes the wire very strong without being brittle, and so soft is it that it can be cut with any ordinary wire cutters without damage to the cutting edges. It can also be filed to a point with a fine saw file, but there is one thing to be carefully avoided, and that is heating it in any way. For this reason it must never be soldered, as that will greatly reduce its strength at the point where it has been heated. In addition to being easy to cut, this wire can be bent flat upon itself and then straightened out again without breaking, and it can be twisted up as tightly as possibly round itself without difficulty or damage; but so flexible is it that, when under great strain, the twisted portion will pull out straight; therefore, it is not a safe way to fasten the ends unless several turns are first taken round some fixed object.

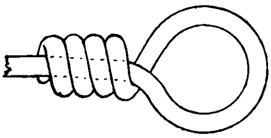


Fig. 151.—An ordinary twisted eye of wire.

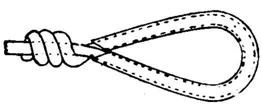


Fig. 151a.—Wire taken through a thimble.

Fig. 151 shows an ordinary twisted eye in the end of a piece of piano wire, which, although it is the simplest and lightest way of making an eye, is, as we have just said, not to be trusted. Fig. 151a shows a somewhat similar eye, but in this case the wire is taken round a light heart-shaped thimble, and, when twisted at the end, solder is run into the twisted portion and round the thimble with a blow pipe. This will prevent any possibility of the wire slipping, but it will also reduce the strength at that point, so neither of these two methods is to be considered satisfactory. Figs. 152-156 show a simple form of shoe which Mr. Linton Hope has devised, and which has been found quite satisfactory after two years hard testing. The drawings show a front and back view, a section through the centre of its length and plans of the top and bottom. It will be seen that the shoe consists of a small stamping of steel or gunmetal with a flattened conical end through which the wire passes. This end has two holes of the same size as the wire, drilled at a small angle, so that, while they start side by side underneath (Fig. 156), they both come out of one hole at the top (Fig. 155). Another method in the smallest shoes when they are made of gunmetal is to drill a central hole and drift it out at the bottom to twice its width or a little more. The lower part of the shoe may have an eye as shown in the accompanying figures or it may be one of the ends of a rigging screw as in Fig. 157. In all cases the method of attaching it to the wire is the same, and can easily be understood from the illustrations. In these figures A is the wire, B the shoe with an eye (E) at the lower end, D is the tapered hole in the upper part of the

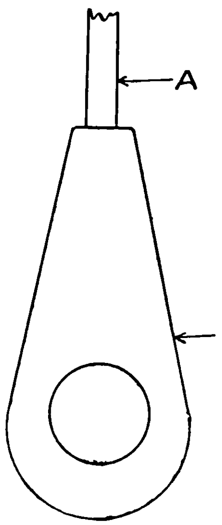


Fig. 152.
Rear view.

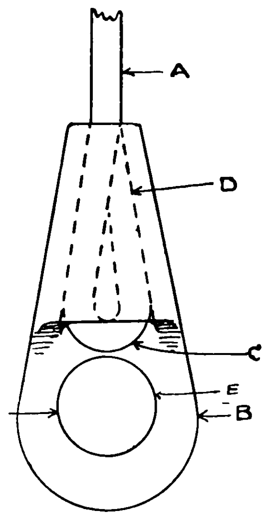


Fig. 153.
Front view.

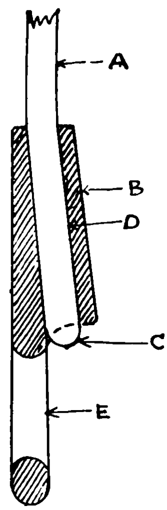


Fig. 154.
Sectional view.

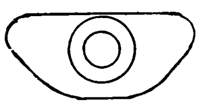


Fig. 155.
View from top.

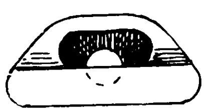


Fig. 156.
View from bottom.

The Hope Rigging Eye.

shoe, and C is the end of the wire (A) bent round upon itself and driven up into the tapered hole in the shoe. The method of fitting the shoe on the end of the wire is as follows:—The wire is passed down through the shoe from the small end or top. It is then bent slowly over until the end is turned back upon the main piece at a sharp angle, but, before it is bent far enough to touch it, the point is filed off on the inside to a long bevel, so that, when the two parts are closed together with the pliers, they form a reverse taper, which fits closely into the tapered hole in the shoe as in D (Fig. 153). If the wire is carefully filed and bent, it should jam tightly in the shoe, and the strain on the wire will then close it up tighter and cause it to grip the inside of the shoe and itself. It should be noted, however, that, although the wire is very " kind " in bending, yet it is fairly hard steel, and if bent too suddenly may break in the nip. One great advantage of this form of shoe is that it can be removed with the loss of only ½ in. of wire, as if it is cut at the point where it is doubled over only the short piece is wasted.

The best method of tightening the wires is by the use of the rigging screw (Fig. 157) or "turnbuckle," as it is called in America. It consists of a right and left-handed bow nut, the centre of which is cut away and a pair of screws, one with a right-handed thread and the other with a left-handed thread, fitting the two ends of the

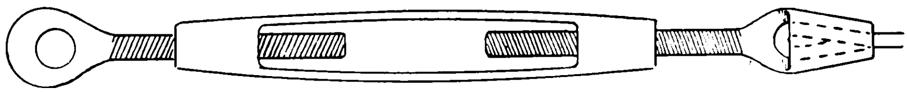


Fig. 157.—A turnbuckle or rigging screw.

nut as shown in the figure. One of these screws has on its outer end a shoe exactly the same in design as that already described and illustrated in Figs. 152-156, while the other end is fitted either with an eye as shown or with a pair of shackle lugs as may be most convenient. With a screw of this description any degree of strain can be put on the wire, but great care must be taken in selecting the screws, as unless they are of the very best quality, they are very apt to break at the end of the thread. For this reason it is always safest to have the screws

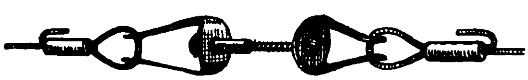


Fig. 158.—A simple rigging screw made out of a short cycle spoke and nipple, and two strips of metal.

nearly twice the diameter of the piano wire, and the threads should be carefully examined, while the nuts should be as long as possible. Screws of a size suitable for the fine wire required can now be bought ready made, and, no doubt, as the demand for aeroplanes increases, both shoes and rigging screws will soon be obtainable as a stock article.

Covering Materials for Aeroplanes.

Rubber-proofed cloths have come almost into universal use as covering materials for aeroplanes, and although the initial expense is greater there is a great saving in trouble, for replacing of parts affected by the weather is greatly reduced. A rubber-proofed cloth requires to be good, for it must be impervious to moisture and must protect the spars and ribs of the planes and such other details as are, with advantage, covered in, and with a good quality cloth the expansion is small and the durability is satisfactory. A good quality solution should be used with these cloths, and joining strips can be bought of any required width for the seams. We give the prices of the two leading manufacturers (the Dunlop Rubber Co., Ltd., Aston Cross, Birmingham, and the Continental Tyre and Rubber Co., Ltd., of 102, Clerkenwell Road, London, E.C.), ruling on 1st March, 1910, but in view of the fluctuations in the price of rubber these prices may only be regarded as approximate. The other particulars of the cloths will be found useful to designers. Samples can be obtained if required.

M. Santos-Dumont has used oiled Japanese silk, but though light it is costly. Fine canvas coated with pegamoid is good, being about the same weight as rubber-proofed cloth but much cheaper, the price ranging from 1s. 6d. to 3s. per sq. yd.

Dunlop Aeroplane Cloths.

No.	Facing.	Width.	Weight per square yard.	Strength of Warp.	Price per yard.
1.	Single	39 in.	4.47 oz.	2,200 lb.	3s. 0d.
1.	Double	39 in.	4.72 oz.	2,200 lb.	3s. 6d.
5.	Single	36 in.	2.25 oz.	1,750 lb.	6s. 4d.
5.	Double	36 in.	2.5 oz.	1,750 lb.	7s. 0d.
7.	Single	42 in.	3.5 oz.	2,350 lb.	4s. 9d.
7.	Double	42 in.	4.0 oz.	2,350 lb.	5s. 4d.

No. 1 is suitable for model aeroplanes only.

Continental Aeroplane Cloths.

No.	Facing.	Width.	Weight per square yard.	Strength of Warp.	Price per yard.
22.	Single	39 in.	4.25 oz.	2,200 lb.	4s. 2d.
23.	Double	39 in.	4.5 oz.	2,200 lb.	4s. 8d.
24.	Single	36 in.	4.25 oz.	1,940 lb.	5s. 6d.
25.	Double	36 in.	4.5 oz.	1,940 lb.	6s. 0d.
26.	Single	36 in.	2.0 oz.	1,750 lb.	10s. 4d.
27.	Double	36 in.	2.5 oz.	1,750 lb.	10s. 10d.
28.	Single	44 in.	3.75 oz.	2,350 lb.	7s. 0d.
29.	Double	44 in.	4.0 oz.	2,350 lb.	7s. 6d.
30.	Single	44 in.	3.25 oz.	1,250 lb.	7s. 0d.
31.	Double	44 in.	4.0 oz.	1,250 lb.	7s. 6d.
32.	Single	42 in.	2.75 oz.	1,000 lb.	5s. 4d.
33.	Double	42 in.	3.0 oz.	1,000 lb.	5s. 10d.
34.	Single	42 in.	3.75 oz.	2,100 lb.	6s. 2d.
35.	Double	42 in.	4.0 oz.	2,100 lb.	6s. 8d.

Nos. 26, 27, 32, and 33 are suitable for model aeroplanes only.

Untreated canvas alters considerably with the weather, slackening under damp conditions. Boiled oil is a cheap damp-proofing and is easily applied. M. Blériot has used strong paper parchment for some of his machines, but his standard types have rubber-proofed cloth. Mr. A. V. Roe used a cotton-oil paper backed with muslin, weighing only 2 oz. per sq. yd. It is easily prepared and glued on whilst damp, drying with a smooth surface. But it is easily damaged, although easily repaired.

Hollow Wood Spars and Their Relative Strength.

HOW TO MAKE THEM.

One of the principal factors of success in the construction of an aeroplane is lightness, but lightness alone is not enough, as combined with it must be rigidity and strength, and at the same time the windage or area exposed to the direct resistance of the air must be as small as possible consistent with the necessary strength, lightness and rigidity.

In a number of aeroplanes steel tube appears to be the favourite structural material, but it is an open question whether a hollow wood frame would not be so much lighter and stiffer that it would more than compensate for any increase in windage.

The spars of a racing yacht are subjected to very similar stresses and strains to those of an aeroplane, and as the result of very many years' experience all over the world, it has been found that, for the smaller spars, up to, say, 8 in. or 9 in. diameter and 40 ft. to 50 ft. in length, a hollow silver spruce spar is far stronger and more rigid for its weight than a steel tube. A bamboo is also stronger than a steel tube of equal weight, but the hollow spar is stronger than the bamboo. In a test between a bamboo and a hollow spar of equal length, the bamboo being heavier by $13\frac{1}{3}$ per cent., the deflection of the hollow spar under a given load was $33\frac{1}{3}$ per cent. less than that of the bamboo. This may have been an unusually good hollow spar, but it will be quite safe to assume that, as a rule, the hollow spar is 10 per cent. lighter and 25 per cent. stiffer than bamboo.

It will be agreed that the strains on an aeroplane are more severe than on a boat's sails and spars, and, no doubt, area for area, this is so, but it must be remembered that the boat, when sailing in a rough sea, is subject to a constant succession of severe shocks, which are absent in the aeroplane, except when the latter lands badly.

Whenever steel or aluminium tube has been tried, in place of bamboo even, it has always given out by doubling up under sudden stresses, to which the spar or bamboo will accommodate itself, and this will appear only natural if we calculate the bending moment of a steel tube and a hollow spar of equal weight, supposing them to be of equal length and of a parallel section, that is, true cylinders.

To ascertain this, we have only to take the generally-accepted formulæ for calculating the strength of beams of various shapes and sections as given in "Molesworth's Pocket Book," and as they may be of interest, it will be as well to repeat them in full.

To ascertain the strength of parallel beams of various sections when fixed at one end, with the load distributed throughout the length. (This would apply to that portion of the main transverse frame outside the centre fore and aft frame, supposing it to be unsupported by stays, etc.)

$$W = \frac{2K\,V}{L}$$

With both ends supported and load distributed

$$W = \frac{8K\,V}{L}$$

The latter would apply to any portion of the frame between two supports or stays.

In each of these formulæ

W = the total load in cwts.
L = the length of the beam in *inches*.
K = the coefficient of strength of the material (13 to 14 for silver spruce, 130 to 140 for steel).
V = the coefficient of strength of section.

The method of finding the coefficient V varies with the form of section, and the formula is stated below each section.

From these figures it will be seen that the I section is the strongest for a given diameter and area. It is only equalled by a hollow rectangle of the same dimensions and area. A hollow square, with sides equal to the depth of the I, and of

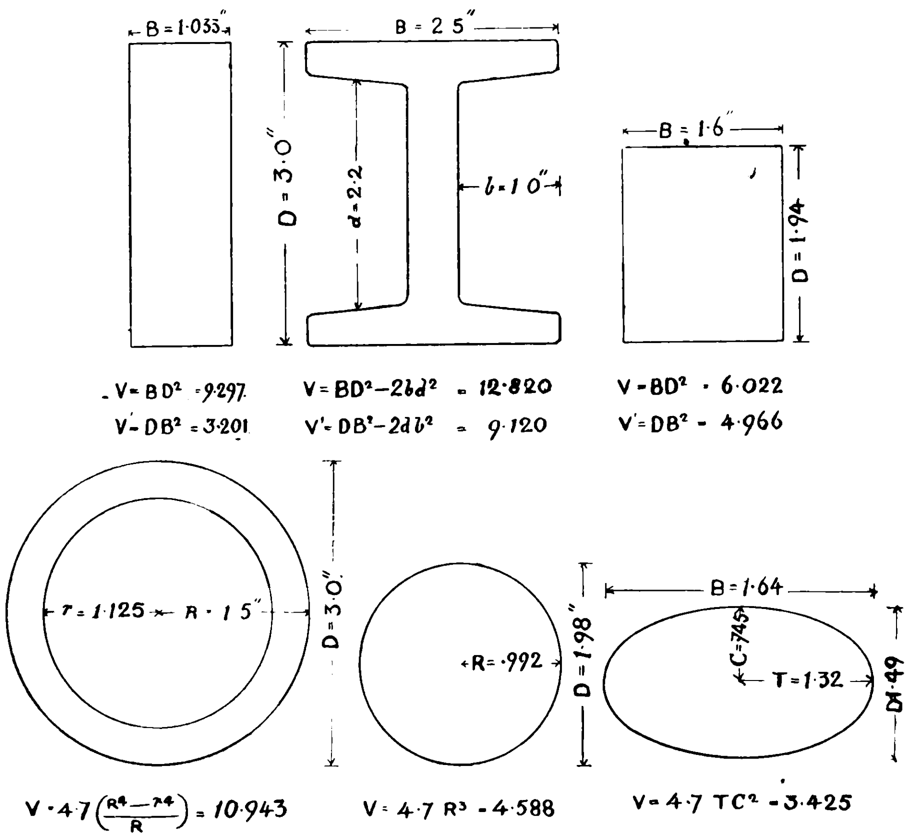


Fig. 159.—The co-efficients of strength of various sections,

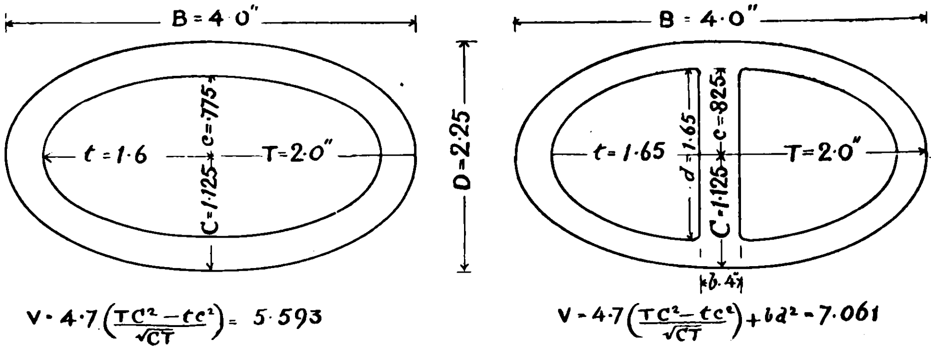


Fig. 159 (contd.).—The co-efficients of strength of various sections.

the same sectional area, is only a trifle weaker than the I, or the equivalent rectangle, V being in this case 12.7 instead of 12.82. The hollow square has a greater mean strength than the rectangle, as V is the same either for horizontal or vertical strains. In the I and in the hollow rectangle it will be seen that V1 (for the horizontal strains) is considerably less than V, the mean of the two being 10.97 or only very slightly greater than that of the hollow circle, which is 10.943. Therefore, the hollow square is the strongest form for a given sectional area, provided the strains are only horizontal or vertical, but if the load is vertical only, then the hollow rectangle is the strongest, while, with varying strains which may come in any direction, the hollow circle is the best.

Where wind resistance is all important, the hollow ellipse with a vertical stay is very good, and in flattened ellipses two stays may be used with advantage, but it is a question whether, for the main transverse frames, the round, hollow wood spar is not the best of all.

So far, in the figures the form of the section only has been considered, but an equally important point is the material. This has already been touched on in a general way, but it will be more convincing to study the following examples of wood and steel:—

Comparison of Four Hollow Spars.

	Silver Spruce.	Steel.		
Weight per cubic foot	32 lbs.	500 lbs	500 lbs.	500 lbs.
Weight per cubic inch	·2963 ozs.	4·629 oz.	4·629 oz.	4·629 oz.
Diameter	= 3·000 in.	1·500 in.	1·0000 in.	3·000 in.
Thickness of shell ...	= ·375 in.	·045 in.	·0666 in.	·025 in.
Sectional area of shell	= 3·100 sq. in	·1984 sq. in.	·1984 sq. in	2·337 sq. in.
Weight per inch ...	= 0·918 oz.	0·918 oz.	0·918 oz.	1·08 oz.
$V = 4·7\left(\frac{R^4 - r^4}{R}\right)$ ..	= 10·943	·4385	·2463	·914
K	= 13·000	130·000	130·000	130·000
VK	= 142·259	57·005	32·016	142·259

The first example is a hollow spar of the same section as the hollow circle already referred to among the various forms of section. Silver spruce is probably the stiffest wood for its weight obtainable, and as it can be procured up to about 50 ft. in length, practically clear of knots and blemishes, it is the most suitable wood for the purpose. Its weight is about 32 lb. per cubic foot, and its coefficient of strength (or K in the formula for strength of beams) is 13 to 14, whilst that of steel is 130 to 140 with a weight of 500 lb. per cubic foot. That is to say, steel is ten times as strong and more than 16½ times as heavy as silver spruce.

This is merely with reference to the bending moment of the two materials, as, of course, steel has a far higher tensile strength than any wood, and is also capable of bending where wood would break; but, so far as the strength of spars and beams is concerned, stiffness is of greater importance than tensile strength, so long as there is a reasonable amount of toughness and resilience, which spruce possesses to a considerable extent.

Returning to these examples, we find the weight of the hollow spruce spar is .918 oz. per inch of length for a diameter of 3 in., and its coefficient of strength (V K) is 142.259. The next example is a steel tube 1.5 in. diameter and .045 in. thick, its weight being exactly the same as that of the wood spar, but V K is, in this case, reduced to 57.005; that is to say, for the same weight, the strength of the wood is about 2½ times that of the steel for twice the diameter.

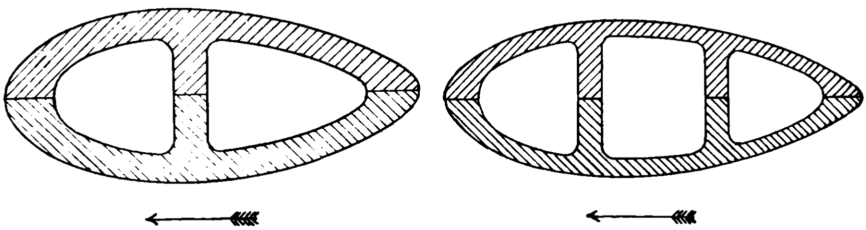


Fig. 160.—Flattened ellipses with one or two stays.

The next example is a smaller and thicker steel tube of more normal proportions. It is 1 in. in diameter, .0666 in. thick, and of the same weight as the last. With the reduction of the diameter to one-third that of the wood spar, V K is reduced to 32.016, which gives the wood an advantage of nearly 4½ times the strength for three times the diameter on a given weight. As a last example, we have a larger steel tube of the same diameter and strength as the wood, but, to get this strength, the weight has to be increased 15 per cent., whilst the steel shell is reduced to one-fortieth of an inch, which would be too light for such a large diameter.

From the foregoing figures we may assume that, on the whole, a circular or modified circular section hollow spruce spar is the stiffest frame we can get, and, although 3 in. by ⅜ in. in thickness has been taken as giving fairly simple figures to work on in actual practice, that section would suffice for an unsupported spar of 25 ft. in length.

In an aeroplane, however, the whole frame is tied with struts and tension wires until it becomes one complete girder, so the load on any part of the frame is well supported, and probably a smaller diameter would be sufficient for this length, unless very high power is to be used. That, however, is a matter for calculation, and, with the data given, that should prove simple enough to those who have practical experience of the strains to be encountered.

Another point in favour of hollow wood spars in place of steel tubes is that they can be made of any desired taper, so

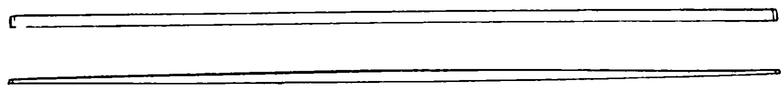


Fig. 161.—Two spars of equal strength showing how weight may be saved.

effecting a great saving in weight and windage when compared with a tube or true cylinder.

In the case of a spar supported in the centre, with the load evenly distributed throughout its length, a saving of nearly 40 per cent. may be made in the weight and 25 per cent. in the windage by tapering the ends in accordance with the law that the section should be in proportion to the distance from the point of support.

How to Make Hollow Spars.

Before leaving the subject of hollow spars, it may be as well to consider the method of manufacture.

The first essential is to procure a perfect piece of silver spruce of the required dimensions, free from knots and shakes and well seasoned, with a straight grain throughout its length. It is next cut down the centre with a circular saw, and both halves most carefully planed up until their surfaces are absolutely true and touch one another all over when laid together.

The outline of the spar is then set out on each half, but in such a manner that they are changed end for end, the butt of one end being at the point of the other to get the greatest strength out of the wood. Each half is roughly sawn to shape and the centre is carefully hollowed out to the exact shape required, being frequently tested by means of small templates made to the drawings. The spar is seldom hollowed entirely from end to end, as there are several small solid portions left, to which any external fittings can be screwed or bolted as may be required. These diaphragms also greatly increase the strength of the spar and add very slightly to the weight, as they are quite small.

When the two halves of the spar are hollowed out, they are tied together again to see that the joint is still perfectly true, and, if necessary, the edges are re-shot with the plane, but it is best to avoid this if possible. They are now ready for glueing together, and this is an operation requiring great skill and experience and a special kind of glue, of which the composition of the best kind is a trade secret, known only to a few makers.

Good results, however, may be obtained with the best quality of ordinary glue if it is mixed with litharge or formalin or some other waterproofing substance, but there is really nothing to compare with the special glue used by the best makers. Any other glue can only be preserved by constant and careful varnishing.

The great difficulty with ordinary glue is that it must be laid on thin and the joint rubbed together quickly before it cools. The spar is then cramped tightly together at frequent intervals throughout its length, and allowed to set for 12 hours or more. When the glue is thoroughly hard, the spar is rounded up to the required shape and thickness, and it is here that the greatest care is needed. If there is any doubt about the thickness of the shell, a fine hole can be bored and an ordinary pin inserted head first; the head will then form a gauge, and the thickness can easily be ascertained, the hole being plugged up afterwards. The art of making these spars is almost beyond the powers of most amateurs, and there are only a few firms in the country capable of turning out really reliable hollow spars, but no doubt others will soon learn the secret of the glue.

PROPELLERS.

Of propellers and propelling devices there is a great variety, each the object of the supreme belief of its inventor. Some have reached the experimental stage, others have not got thus far, but up to the present time it has generally been found that some type of screw propeller is most suitable for practical work.

The aerial screw propeller differs little in its action from its marine prototype, each depending for its action on the imparting of a sternward velocity to a column, in the one case of air, and, in the other, of water. When the propeller screws itself forward the air slips past the blades, so that the propeller does not move forward so quickly as if there were no "slip." The distance moved forward at every revolution of the propeller, if

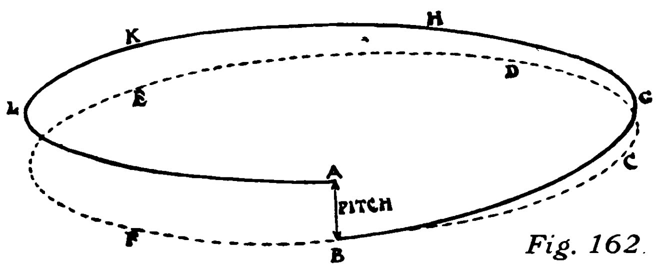


Fig. 162.

there were to be no slip, is called the "pitch." Thus in Fig. 162, neglecting slip, a point on the propeller blade tip, instead of merely revolving in the circle B C D E F also advances the "pitch" distance A B. The resultant path which the tip actually takes is therefore B G H K L. The pitch multiplied by the number of revolutions per minute is the distance moved forward per minute. This will be the speed of the machine if there were to be no "slip." If "slip" be taken into account,

Speed of machine (in ft. per min.) = Pitch (ft.) × revs. per min.—slip (ft. per min.).

The slip velocity is that which is imparted to the column of air upon which the propeller acts. The thrust that is obtained from the action of this column of air is equal to

Weight of mass of air acted upon per second × slip velocity (ft. per sec.).

In the case of a stationary propeller there is no forward movement, so that there is only the slip velocity to consider, which is then much greater. At first it would appear that the thrust at starting would be much greater than when the propeller is travelling through the air, owing to the slip velocity being so much greater. It is found experimentally that this is not the case. In Sir Hiram Maxim's experiments, the thrust, with the propeller travelling at 40 miles per hour, was the same as that when the propeller was stationary, the revolutions per minute of the propeller remaining constant throughout. The reason for this is that, although the slip velocity is decreased, the propeller acts upon undisturbed "virgin" air, the equivalent of acting upon a greater quantity of air.

Great claims are often advanced, as to the thrust per h.p. that can be obtained with a given propeller. This quantity—the thrust per h.p.—cannot exceed a certain figure for a given pitch and number of revs. per min., as the following will show:

The thrust multiplied by the number of revs. per min. and by the pitch gives the work done per minute. This figure divided by 33,000 gives the h.p. required to do the work, or

$$\text{H.P.} = \frac{\text{Thrust} \times \text{R.P.M.} \times \text{Pitch}}{33{,}000.}$$

The maximum value of the thrust per h.p. for any given number of revs. per minute and pitch (in feet) is therefore equal to

$$\frac{\text{Thrust}}{\text{H.P.}} = \frac{33{,}000}{\text{Pitch} \times \text{R.P.M.}}$$

If the propeller is a good one, the thrust per h.p. will almost coincide with the amount calculated from the right-hand side of the equation above.

This holds good for a stationary propeller, but if the propeller travels through the air the thrust that will be obtained is

$$\frac{\text{H.P.} \times 33{,}000 \times \text{efficiency of propeller}}{\text{Speed of machine (ft. per min.).}}$$

The whole blade of the propeller has to move forward the same amount. The parts near the boss will thus have to be set at a steeper angle, since the distance they move through circumferentially is less. Fig. 163 shows this more clearly. The outside tip (A) of the propeller moves round a circumference equal to $2 \pi \times R$ every revolution. At any point B on the blade where the radius is r the distance moved through per revolution is 2π **r.**

In both cases the point (A or B) must advance a distance equal to the pitch. Thus in Fig. 164 A O and B O are the distances 2π R and 2π r respectively through which the parts revolve, and both move forward the same distance O C. The outside point A moves along A C, but the point B moves along a steeper path B C. By setting off points E, F, G (Fig. 164), corresponding to the circumferences through which the points at E, F, and G (Fig. 163) move, the angles at which the parts of the blade at E, F, and G must be set are obtained.

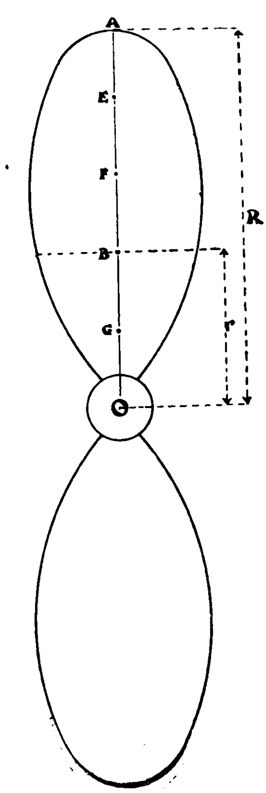


Fig. 163.

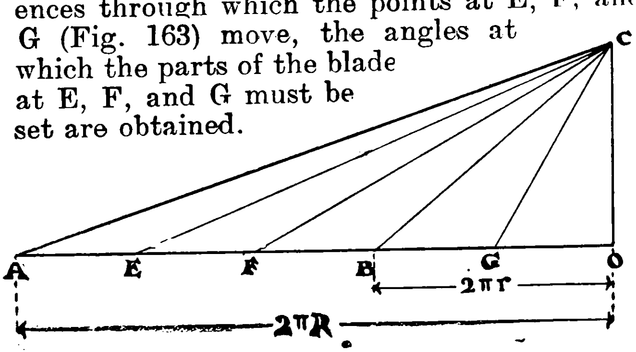


Fig. 164.

M

To determine with accuracy the thrust that a propeller will give and the h.p. that it will absorb requires a great amount of experimental work. Maxim tested his screws when stationary by mounting them on a shaft driven by belt from a steam engine. The shaft was free to move in its bearings and to one end of the shaft was fixed a spring balance, measuring the

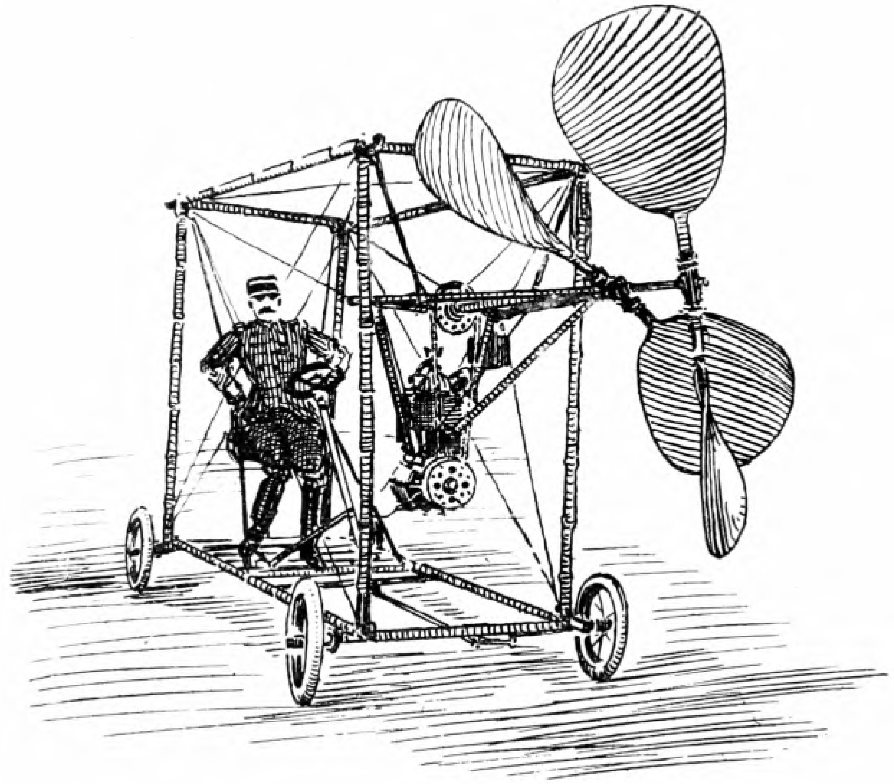


Fig. 165.—The late Capt. Ferber's road carriage for testing the values of propellers.

thrust due to the propeller when revolved. To test them when moving through the air, the screws were mounted at the end of a long arm, and the latter was rotated. By various ingenious means he measured the thrust when moving at a given speed through the air and at a given number of revolutions.

Captain Ferber carried out a series of tests on propellers by making them drive a small chassis. This arrangement ran along the road under its own power, and various measurements of thrust and power were made.

For heliocopteres, where vertical screws are used, the pitch is made small and the diameter large. There is then a large column of air acted upon and a low velocity imparted to it. From a consideration of the equations given above it will be seen that this ensures a large thrust per h.p.

AERIAL MOTORS.

From the earliest stages of the flying movement it has been recognized that a power-producing plant of lower weight per horse-power than anything employed for land or marine travel must be procured for successful navigation of the air. Long before the petrol engine was sufficiently developed to be of service, special light-weight steam engines were constructed for early flying machines, two important examples of their use being on the Langley model aeroplane, probably the first power-driven, heavier-than-air machine to leave the ground, and on the Adler and the Maxim, the first man-carrying aeroplanes to accomplish flight.

But the petrol engine offered distinct advantages over the steam engine for use on aeroplanes, and, during the active period from 1904 to the present day, has been used almost exclusively. French engineers, in particular, recognized that, for flying to be successfully developed, the petrol engine, as used on motorcars, must be made lighter and, generally, more reliable. Thus, in France, experimental work in light-weight petrol engines has been carried on concurrently with researches in the best form of sustaining surfaces and methods of securing equilibrium, until, at present, there are at least a dozen successful aeroplane engines, all of the internal-combustion four-cycle type, but differing considerably from their predecessors built for use on motorcars. Now, certain aeronauts maintain that the search for feather-weight engines is labour lost, and that flights can be made with any well-controlled car engine. Facts, however, are against this theory, for all flights, up to the present, have been accomplished by special engines, even the Wright motor, the one which most closely approximates to the car type of engine, being specially lightened and distinctive in design.

Low weight per horse-power is undoubtedly not only desirable, but essential for driving an aeroplane. Smoothness of running, reliability and regularity are equally important, and it remains to be seen whether the newer light-weight engines with six, seven, eight or fourteen cylinders, can be made as satisfactory in this respect as the standard but heavier type of engine with only four cylinders.

The Wolseley Engine.

The Wolseley Co. has taken up the construction of light engines for aerial work. The firm has reduced the weight of its new type to 8 lb. per horse-power, this figure being inclusive of flywheel, ignition, water-pipes, gas-pipes, etc., everything necessary to the running of the motor being weighed. Although there are many lighter engines, the Wolseley Co. has

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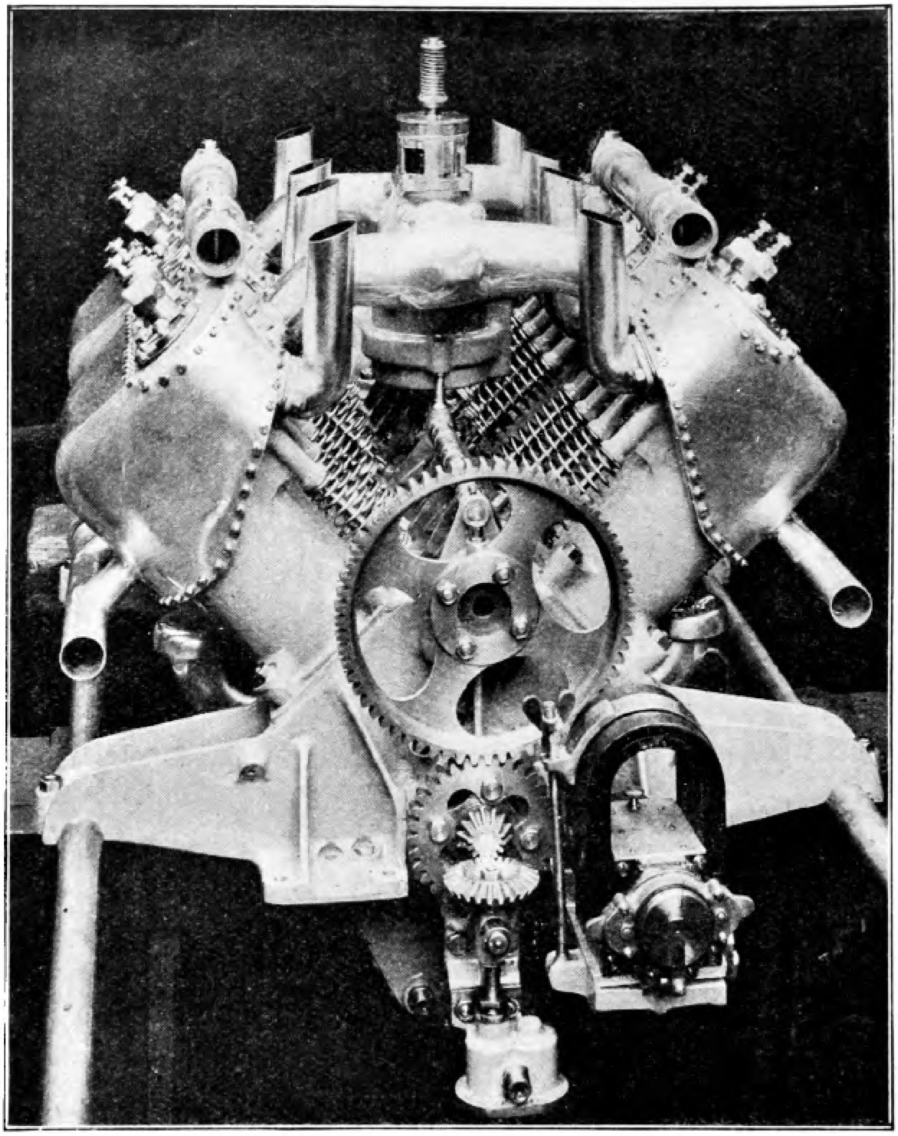

Fig. 166.—The Wolseley aerial engine.

not been led to reduce wholly the several working limits, its principal consideration being to produce a motor that can be relied upon to work for long periods at full load, without breaking down. The cylinders are set " V " fashion, four on either side of the crankcase, at 90 degrees to each other. The cylinders are cast in pairs, with jackets and liners in one piece, the metal being close-grained cast-iron, ground to gauge, the bore being $3\frac{3}{4}$ in. and the stroke 5 in. Sheet aluminium is employed for the water jackets, which are screwed to the cylinder castings. This method of construction allows the thickness of the metal to be uniform throughout, and offers advantages in the matter of cooling. The pairs of cylinders are staggered in relation to each other, the two connecting rods throwing on the same crankpin, and the big ends being of

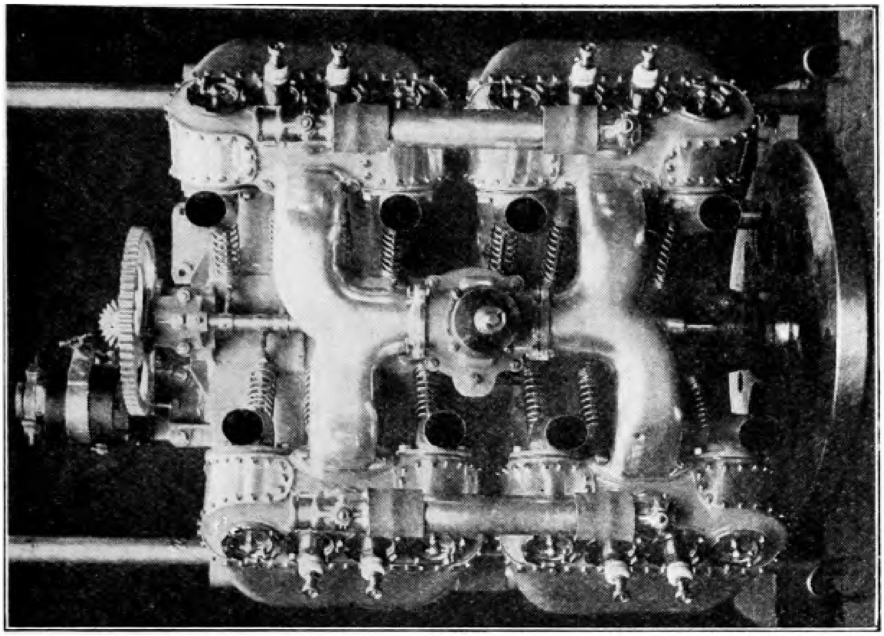

Fig. 167.—The Wolseley aerial engine seen from above.

phosphor-bronze, white metal lined. Three large bearings are provided for the crankshaft, and the lubrication is effected under pressure to all the main bearings and connecting rods. All the valves are side by side facing the centre, and are operated by a central camshaft, lifting shoes being interposed between the cams and tappets. The exhaust and induction piping is therefore situated between the cylinders over the top of the crankcase, the carburetter being mounted in the centre. Thermo-syphon cooling has been adopted. For the ignition, there is one eight-cylinder high-tension magneto running at crankshaft speed, a separate distributor being fitted and driven off the camshaft. One of the many good features of this engine is that the position of the carburetter enables a symmetrical induction system to be obtained, the distribution of gas to the cylinders being uniform.

The Gobron Engine.

Within each cylinder of the Gobron engine are two pistons, the upper one having its head turned downwards and connected up to an overhead beam, which in turn is connected to the mainshaft of the engine. Instead of the explosion taking place between the piston and the cylinder head, it occurs between the heads of the two pistons, which come together on the compression and exhaust strokes and leave one another, one ascending and the other descending, on the intake and power strokes. The principle will be understood by a reference to Fig. 168.

On the aeronautical engine there are eight cylinders, and consequently 16 pistons. Instead of being mounted vertically on the crankcase, as in the car engine, the cylinders form an X.

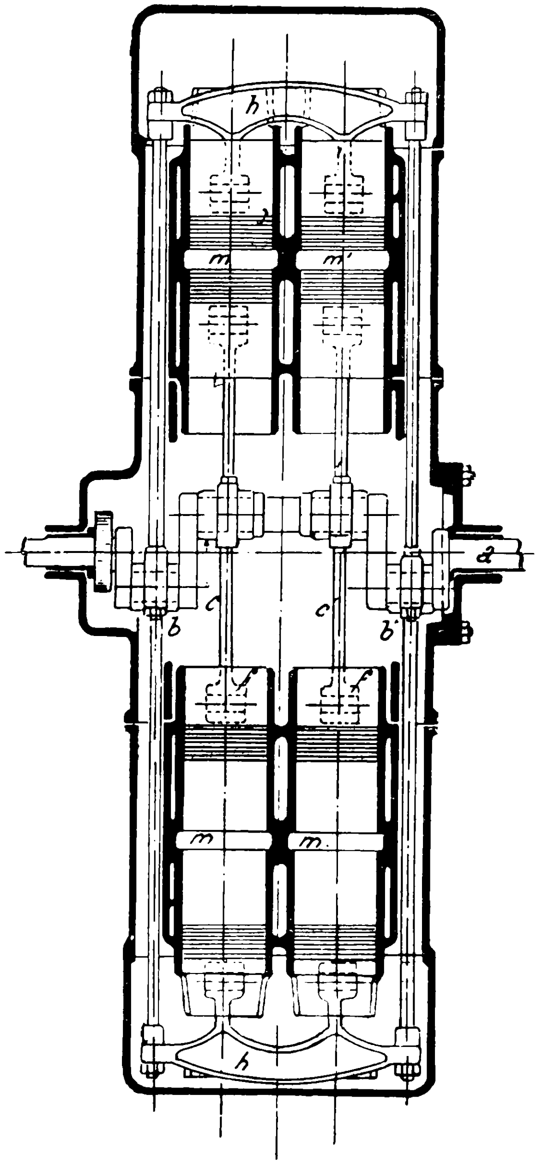

Fig. 168.—The Gobron aerial engine.

a, crankshaft; *b*, connecting rods for outer pistons; *c*, connecting rods for inner pistons; *f*, inner pistons; *h*, overhead beam attached to outer pistons; *m*, combustion space.

The engine may be regarded as a twin double-opposed motor, the pair of cylinders on the upper left-hand side being opposed to the pair on the lower right-hand side, while the pair on the upper right-hand side are opposed to the pair on the lower left-hand side. There is obviously a great saving of weight with this design, for the even torque of the eight cylinders allows the fly-wheel to be dispensed with, the crankcase is a remarkably light organ, and the crankshaft for the eight cylinders is of practically the same design as for the Gobron two-cylinder engine. As all the reciprocating parts are opposed, there is an absence of shock and an evenness of running specially desirable for flying-machine work.

The cylinders are cast separately, are turned inside and out, and are fitted with copper jackets for the circulation of cooling water. The bore is $3\frac{1}{2}$ in. and the total stroke $6\frac{1}{2}$ in.; this comparatively long stroke in relation to bore is only made possible by reason of the double-piston principle.

The valve mechanism is remarkably free from complications: the inlet valves are all automatic, while the exhaust valves are operated without the use of any gearing. The only gearing employed on the engine is that for driving the two high-tension magnetos carried to left and right of the rear extension of the crank. The same gearing is also employed for driving the lubricating pump. Naturally, the tendency of the oil is to descend to the lowest point of the four cylinders with their heads downwards. The pump, therefore, is employed to carry the oil from this point to the heads of the cylinders that are upwards, and to the bearings of the main shaft, thus establishing a complete circulation.

Complete weight of the Gobron engine is about 440 lb. At 1,200 revolutions a minute the engine develops 80 h.p., but on being accelerated to 1,800 revolutions will furnish 90 h.p.

The need for lightness of details led to the development of multiple-cylinder engines, the cylinders of which radiated from a central circular crankcase, and the pistons of which were all connected up to one point. This type of engine has almost invariably seven cylinders, for it is only with an odd number of cylinders that the explosions can be obtained at equal distances. This can be best explained by means of a diagram of

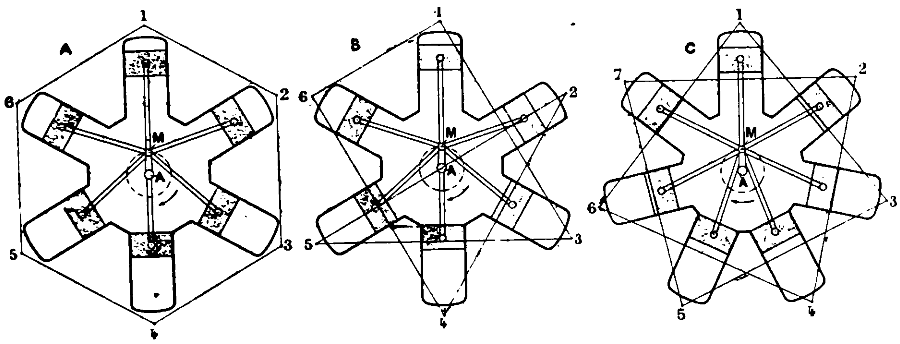

Fig. 169.—Why seven cylinders make a smooth-running engine.

a six and seven-cylinder " star " engine. In Fig. 169 (A) the explosions take place in their natural sequence from cylinder 1 to 6. This, of course, would give six explosions per revolution of the engine shaft, and, further, all at equal distances, but for a whole revolution no power would be developed.

The next method appears to be to fire alternate cylinders; but this would be no better, for, as followed out in Fig. 169 (B), the distance between 1, 3, and 5 would be shorter than the interval between cylinder 5 and 2, while there would be a very short interval between cylinder 6 and 1. With a seven-cylinder engine these difficulties disappear, for it is only necessary to fire on alternate cylinders, 1, 3, 5, 7, 2, 4, 6, to have the explosions at equal distances. This is shown clearly in Fig. 169 (C), an engine of this type having $3\frac{1}{2}$ power strokes per revolution, or seven for every two revolutions of the mainshaft.

The R.E.P. Engine.

The first successful engine produced on this principle was the R.E.P., named after its inventor, Robert Esnault-Pelterie. Although, for special reasons, the inventor of the R.E.P. has preferred to mount the cylinders on the upper portion of the crankcase only, the method of operation does not differ from those engines having the cylinders placed at equal intervals around the periphery of the crankcase. It being impossible to get such a large number of cylinders on the upper half of a circular base of moderate dimensions, the designer has slightly staggered them, four being in one plane and the three others slightly in the rear and in another plane. For such an engine, the crankshaft must have two arms, or throws, to one of which the connecting rods of four pistons will be attached, and to the other will be linked up the three remaining pistons. As is shown in Fig. 170, there is one main connecting rod receiving three separate rods, two being on one side and one on another.

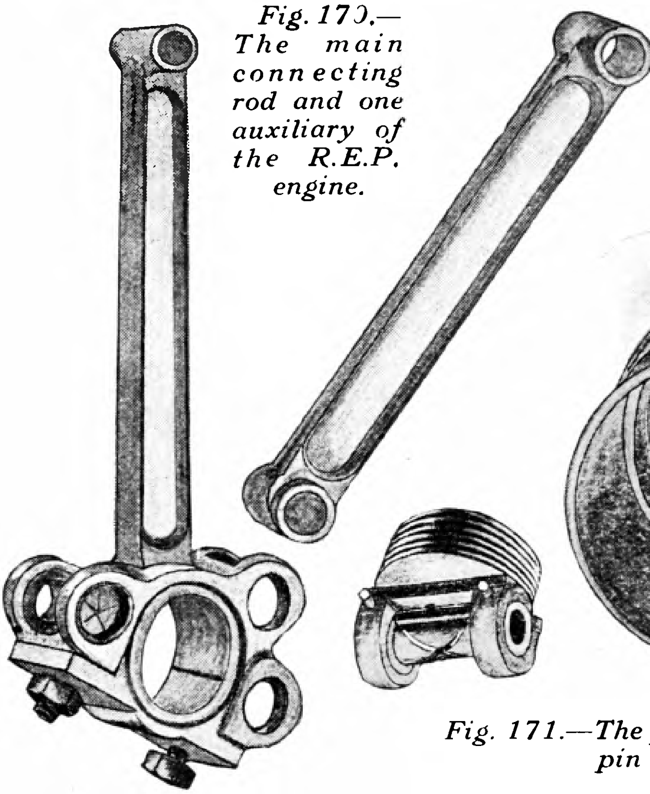

Fig. 170.—The main connecting rod and one auxiliary of the R.E.P. engine.

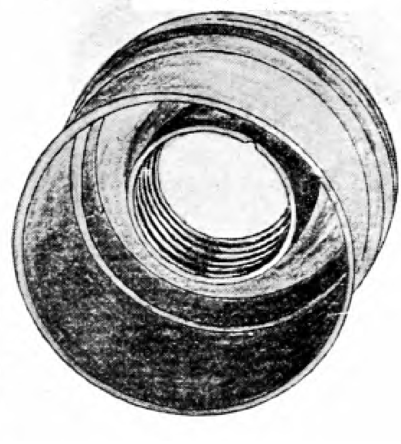

Fig. 171.—The piston and gudgeon-pin bearing.

The circular crankcase is an aluminium casting to which the cast-iron cylinders are each secured by three bolts, nuts, and lock-nuts. Very light steel pistons are employed, the walls being so thin that it would be impossible to attach the gudgeon-pin in the usual manner by bearings in the wall of the piston. The central portion of the head of the piston is, therefore, threaded to receive a special bearing. This piece, shown in Fig. 171, is screwed into the head of the piston, being prevented from turning by means of a countersunk screw, and carries, integral with it, the two bearings for the gudgeon-pin.

On the R.E.P. engine there is but one valve for both the intake of the fresh charge and for the exhaust of the gases. It is carried in the head, and is operated in a special manner by an overhead rocker arm. The manner in which the two functions are fulfilled by one organ is both simple and effective. The rocker arm, operated by the camshaft, can maintain the valve in three distinct positions. On the full opening, the valve is lifted off its seat in the usual manner, allowing the aspiration of explosive mixture. In another position, a steel collar surrounding the valve stem uncovers a number of holes within a cylindrical cage, thus giving communication between the exhaust pipes and the combustion chamber and allowing the spent gases to be driven out. In its third position, these holes are closed and the valve face is resting on its seating, thus shutting all connection with both inlet and exhaust pipes.

The valves are operated by a single cam, or, more correctly, by a single disc, the face of which has three pairs of bosses, the three larger ones corresponding to the lift of the valve for intake and the three smaller ones to the lift for the exhaust.

The seven-cylinder R.E.P. engine has a bore of 3.3 in. and a stroke of 3.5 in. It is rated at 30 h.p. at 1,500 revolutions a minute, and weighs complete, ready for running, 115 lb.

The Gnome Engine.

The seven cylinders of the Gnome aeronautical engine radiate from a circular crankcase. Unlike the standard type of engine, on which the cylinders are stationary and the crankshaft is driven round by reason of the power strokes on the piston, the Gnome engine has a fixed crankshaft, with cylinders and crankcase revolving round it. With such a type of engine, air-cooling

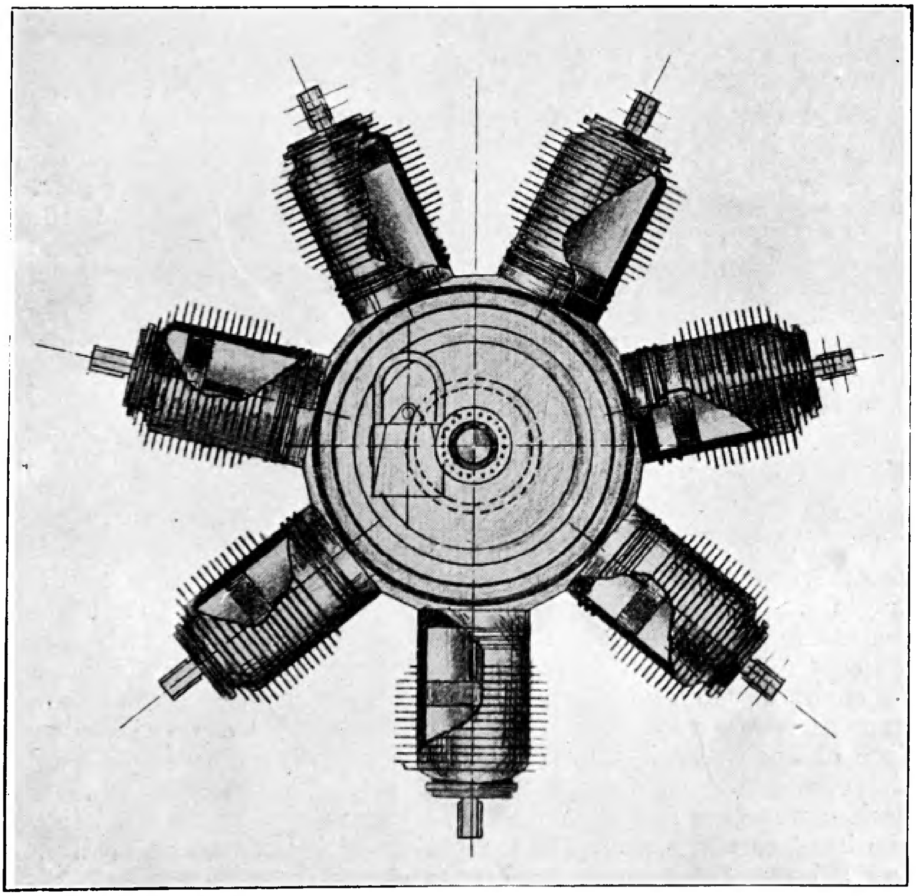

Fig. 172.– The seven-cylindered Gnome engine.

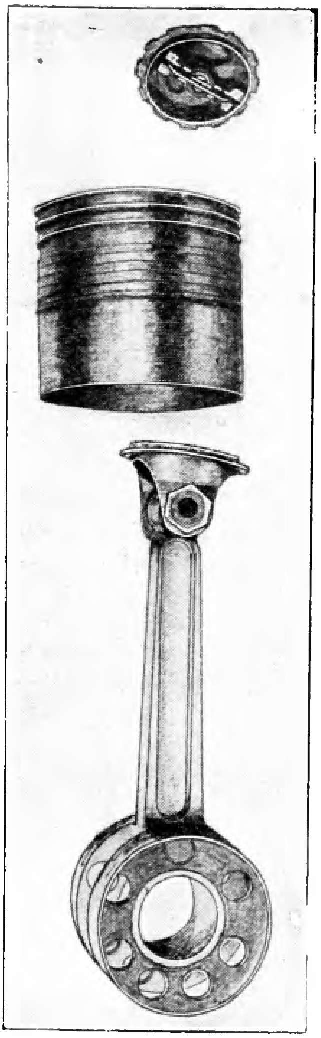

Fig. 173.—The piston main connecting rod, and inlet valve of the Gnome engine.

is naturally employed, for the speed of the cylinders through the air is ample for dissipating the excess of heat.

Practically every portion of the Gnome engine is machined out of nickel steel. The cylinders, for instance, are produced from a solid bar of steel, machined to the required shape, with their radiating fins, then bored out until the walls are very much thinner than would be possible with a cast-iron cylinder, and yet possess even greater strength. They are mounted around the circumference of the circular crank-case.

The axis of the wheel thus formed is the crankshaft, having a single crank, or throw, secured in bearings in the centre of the two end plates, or hub caps, bolted to the face of the hub. It each of the pistons is connected up to the single crank pin of the crankshaft it is obvious that, on the wheel being revolved, the pistons will ascend and descend in their cylinders in just the same manner as on the standard type of engine where the crankshaft revolves and the cylinders remain stationary.

In the head of each cylinder is an exhaust valve, operated by a rocker arm. Instead of being in the head of the cylinder, the intake valve is in the head of the piston, the charge passing from the crankcase to the combustion chamber above the piston. The carburetter, which may be of any ordinary type, is carried on the outside of the engine, the mixture obtained from it passing through the hollow crankshaft into the crankcase, and from there, as explained, into the cylinders. Lubrication is suitably provided for.

One of the most interesting features of the Gnome engine is the method of attachment of the seven connecting rods to the single crank pin. There is one main connecting rod, its lower end terminating in two steel discs, through the centre of which the crank pin is passed, and around it being six holes in each of the two discs to receive the ends of what are known as the secondary connecting rods. Within the hollow face of each disc is mounted a large ball bearing carrying all the connecting rods on the crankshaft. The gudgeon-pin for each connecting rod is carried in a separate piece screwed into the head of the piston. The engine, which is rated at 50 h.p., has a bore of 4.3 in. and a stroke of 4.7 in., the total weight being 165 lb.

Vivinus.

In the Vivinus engine a great feature has been made of accessibility. In the main, the design follows that which has been used for many years in the firm's productions, but a lot of metal has been saved, and the weight has been reduced to about 3½ lb. per horse-power. All the exhaust and induction piping, which is on one side of the engine only, is held by four boxes. The camshaft is in a small box outside the crank chamber, and can be removed bodily by removing six screws. In an equally easy manner the camshaft can be drawn through one end without touching any part of the engine. The base chamber is one barrel, the front cover being in one piece with the box covering the gears. Thermo-syphon cooling is employed and high-tension magneto ignition. The tappet guides are held down by four dogs, and can be very quickly removed.

The Wright Bros.

There is very little departure from standard practice in the Wright aeronautical motor. It has four separately-cast cylinders of 4.4 in. bore and 3.9 in. stroke, fitted with separate water

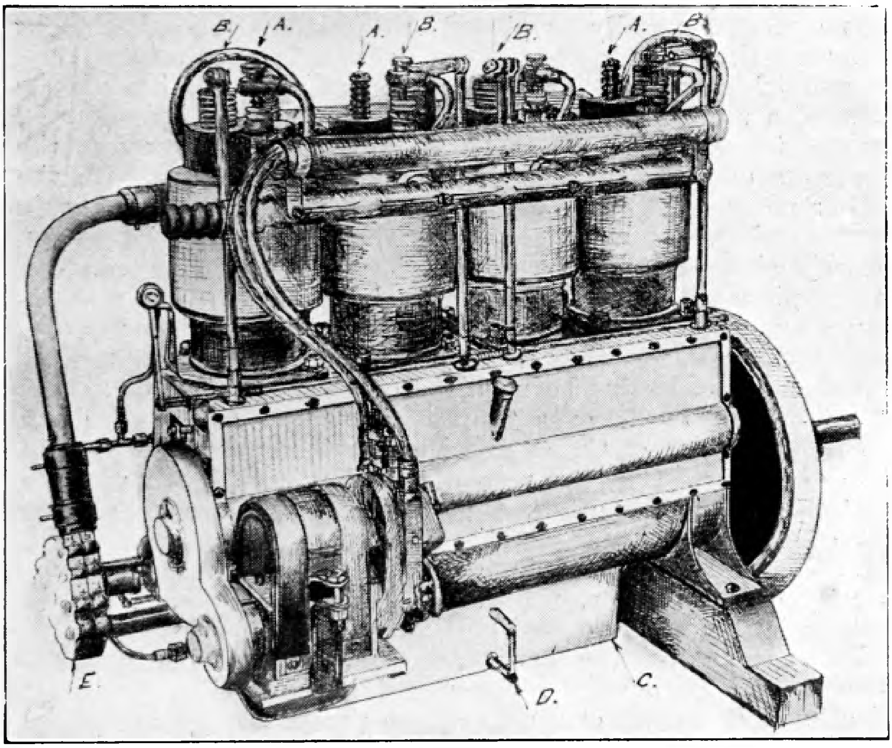

Fig. 174.—The Wright Bros. engine.

jackets and mounted on an aluminium crankcase. All valves are in the head, the exhausts (B) (Fig. 174) being mechanically operated by a simple vertical spindle and rocker arm, and the inlets (A) being automatic. The only really distinctive feature about the engine is that there is no carburetter, the petrol being supplied by direct injection by means of a pump on the right-hand side of the engine, worked through worm gear off the camshaft and by a short shaft across the interior of the crankcase. On the same side of the engine is the lubricating oil pump, also worked off the camshaft through worm gear and by a short shaft across the crankcase. The base (C) of the crankcase forms an oil reservoir, from which the lubricant is pumped up to the main bearings, then drips down again to the reservoir through pipe (D), being filtered on the way.

Ignition of the engine is by means of a high-tension Eisemann magneto, carried on a platform near the base of the crankcase, and worked off the forward end of the camshaft. The water for cooling the engine is circulated by a rotary pump (E), mounted on the forward end of the mainshaft. The radiator consists of a series of plain, flat copper tubes attached to one of the stanchions of the aeroplane. The petrol tank is a cylindrical vessel carried in a vertical position and also secured to the stanchions. The engine has free exhaust, and has also auxiliary exhaust ports at the end of the stroke.

The Antoinette Engine.

The most generally employed Antoinette engine has eight cylinders, though larger models are also made with, respectively, 16 and 32 cylinders. The aluminium crankcase, having the form of a rectangular prism, receives two rows of cylinders on each of its faces inclined at 45 degrees, the angle between the two rows of cylinders thus being one of 90 degrees. On the earlier models the cylinders were cast separately, had separate heads, and were copper jacketed. The 1909 models have been entirely changed in this respect, the cylinders being of steel, in one piece with their heads and valve pockets. The machining of such a piece is really a work of fine metallic sculpture, the justification for which is found in the decreased weight, no less than 1½ lb. having been gained on each cylinder, or a total of more than 12 lb. over the entire engine.

The main shaft of the engine has four throws, and is carried in five bearings. The two rows of cylinders are slightly offset in relation one to the other, thus allowing the two connecting rods of opposed cylinders to be connected up to the same crankpin. The camshaft is carried above the main shaft, and driven directly off this latter, the valves being side by side, and in pockets, in the angle formed by the two rows of cylinders.

One of the distinctive features of the Antoinette engine is the absence of a carburetter, the petrol being suplied by direct injection. By means of a gear-driven pump, a supply of petrol is fed to each of the distributors at the head of the eight cylinders, where it is stored until the intake stroke. The intake valve is automatic, and, on its opening, the petrol is drawn out of its lodging place, finely sprayed and mixed with air as it is carried into the cylinder. The petrol pump has a variable stroke, thus allowing more or less fuel being fed to the distributors according to the speed required. There is little if any saving in weight by direct injection, for in place of a carburetter. a pump, special piping, and distributors have to be employed; but the advantage claimed for the system is more reliable carburation under all conditions. Lubrication of the motor is assured by a gear-driven pump. The propeller, which is built up with forged steel blades, is generally mounted on the forward extension of the main shaft.

The Green Aviation Motors.

The Green Motor Patents Syndicate, Ltd., of 55, Berners Street, W., produce two special engines for aeroplane work, the one a 30-35 h.p. and the other a 50-60 h.p., though neither is exactly new, as an engine of this pattern was constructed some seven years ago, but they embody the latest design, whilst the

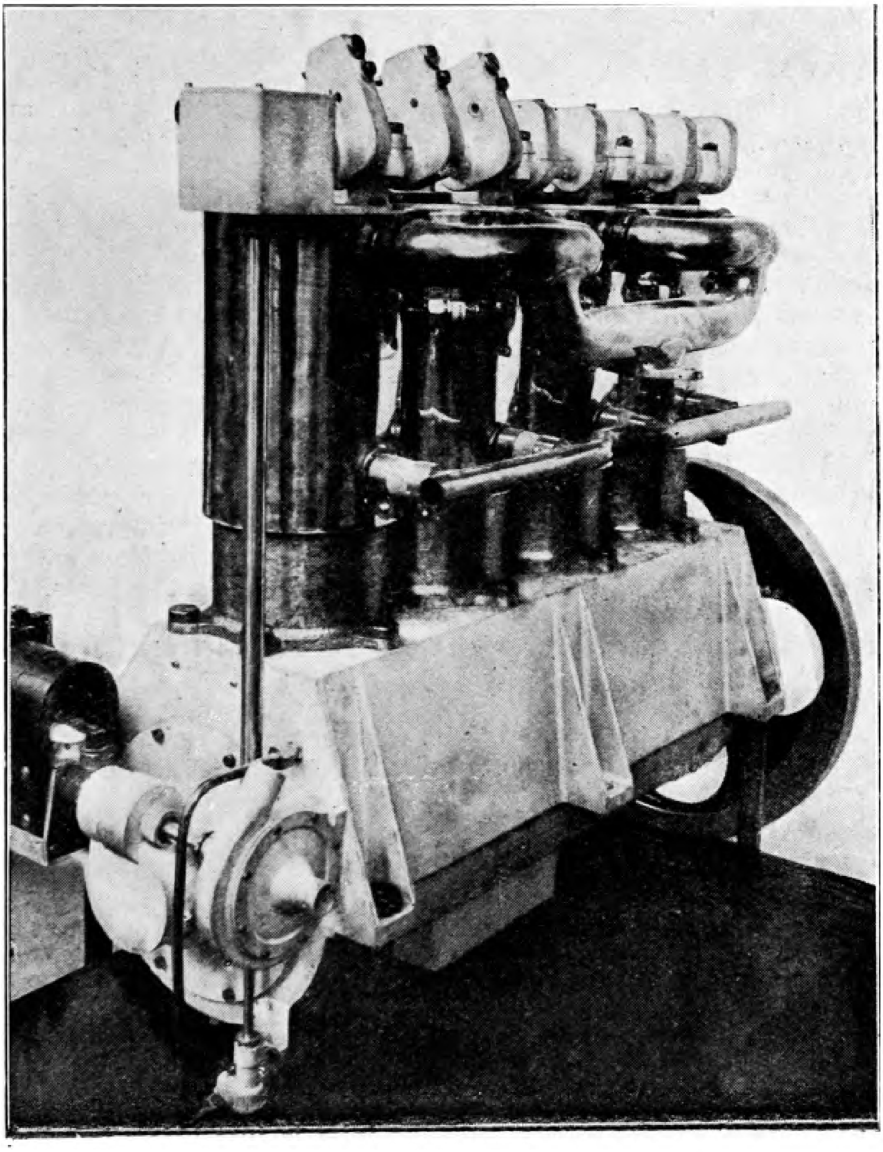

Fig. 175.—The 60 h.p. Green aviation motor.

fact that they are manufactured by the Aster Engineering Co. warrants the quality of material and workmanship embodied in their construction:

The reduction in weight is effected by the employment of pressed copper water jackets, overhead valve gear, and a sheet-metal bottom for the crankcase. One of the advantages of employing this system of detachable water jackets is the facility thus afforded for machining the outside of the cylinders, thus ensuring an equal thickness to the walls. The joint is made with a rubber ring, which, owing to the heat of the water, becomes partly vulcanized during the engine "testing," remaining soft only at the point of contact with the copper. The inlet and exhaust valves are set in pockets in the head of the combustion chamber, and provision is made to prevent the valve entering the cylinder in the possible, though very improbable, event of it breaking. The overhead camshaft is constructed in one piece, but the camboxes are arranged to swing back, in sets of four, so as to give access to the valves. The actuating rockers have rollers at the cam-operating ends, and each is contained in its own oil-tight case. Forced feed lubrication is employed, and ignition is by high-tension magneto, whilst the double-acting ball bearing is self-contained. A special feature in the mounting of this engine is that the holding-down bolts pass through pillars in the upper crankcase casting, and some of these bolts are utilized for the main bearings, which are five in number and of phosphor-bronze with white metal linings. This system of construction enables the successful adoption of the metal tray for enclosing the crankcase. Particulars of the two engines are as follow:—The 30-35 h.p. four-cylinder has a bore and stroke respectively of 105 mm. by 120 mm., the weight complete with all pipes, connections, and carburetter being 150 lb., a flywheel, if fitted, adding another 23½ lb. The power ranges from 30 h.p. at 1,100 r.p.m. to 40 h.p. at 1,220 r.p.m., and petrol consumption is three gallons per hour at 30 h.p. In the 50-60 h.p., also four-cylinder, the bore and stroke are 140 mm. by 146 mm., the weight (as above) 250 lb., flywheel 37 lb., and the power ranges from 50 h.p. at 1,050 r.p.m. to 70 h.p. at 1,200 r.p.m.; petrol consumption, 4¾ gallons per hour at 50 h.p. The illustration is of a 60 h.p. engine, and a bigger one of the same general design, but with V-set cylinders, is used on "Baby," the War Office dirigible of 1909.

New Engine (Motor) Co.

The engine made by the New Engine Co., Ltd., is a two-stroke motor that differs from others of its kind in that special scavenging arrangements are provided. At each stroke an enormous volume of air is swept through the cylinders, driving out all products of combustion. Water cooling has now been adopted, as it was found to be more effective than air cooling alone. The exhaust port is very high up, in fact, it opens half-way down the stroke, and the inlet is just below it. Both ports are exceptionally large, and a fan, driven off the engine,

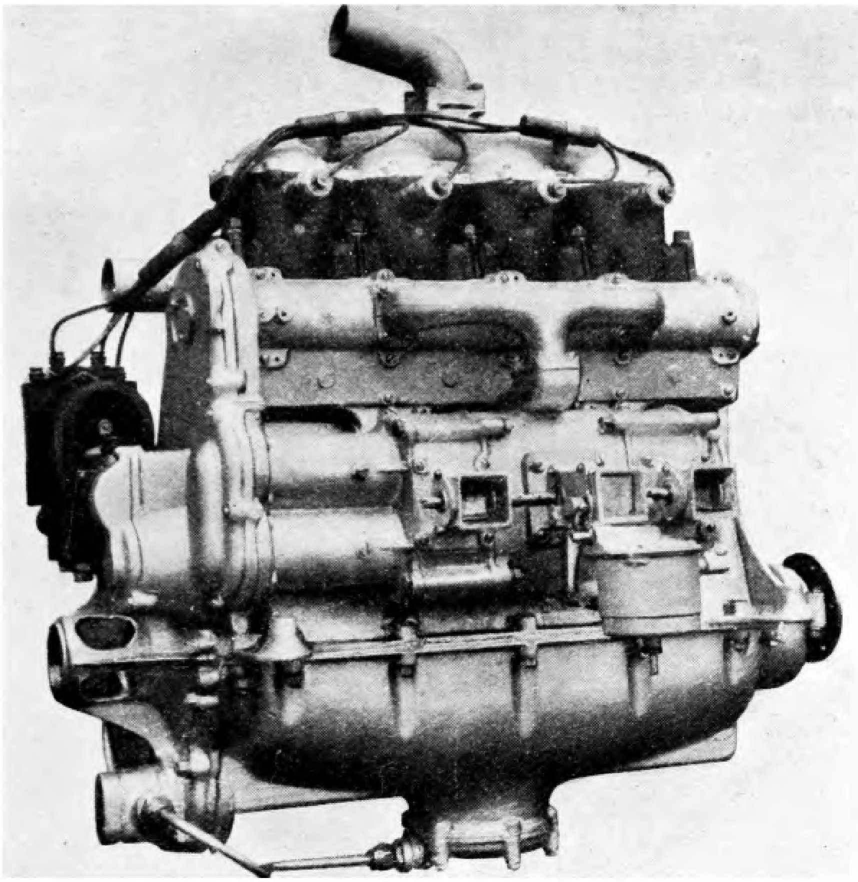

Fig. 176.—The 25-30 h.p. New Engine.

forces a large volume of air through from inlet to exhaust, thoroughly scavenging and at the same time cooling. This action continues during the rest of the down stroke and for part of the up stroke, but before the inlet valve is closed a very rich mixture is introduced, which, mixing with the air already in the cylinder, forms a gas of the right strength, which is compressed and fired in the ordinary way. The compression used equals 80 lb. per square inch. To introduce the rich mixture, a pump is required, working at slightly higher pressure than the scavenging fan, and there is a distributing arrangement in the induction piping. The bore of the engine is 4½ in., stroke 4 in., and 40 h.p. is developed at 1,500 r.p.m. A feature of this very interesting motor is the high speed at which it can run. These features combined naturally make it possible to obtain a high power for a given cylinder capacity, and it is stated that, for a given size, one-third more power can be developed than is obtained from any ordinary four-stroke engine. The sizes made are the 12-18 h.p. (two-cylinder), 25-30 h.p. (four-cylinder), and 35-50 h.p. (six-cylinder). On the bench 40 h.p. has been obtained from the four-cylinder engine, and the b.h.p. develops in the same ratio as the number of revs. per min.

The E.N.V. Engine.

The E.N.V. engines are French productions, from English designs, having eight cylinders, in two rows, which are set at an angle of 90 degrees to one another. There are two sizes—the 40 h.p. and the 60 h.p.—of which the respective bore and stroke

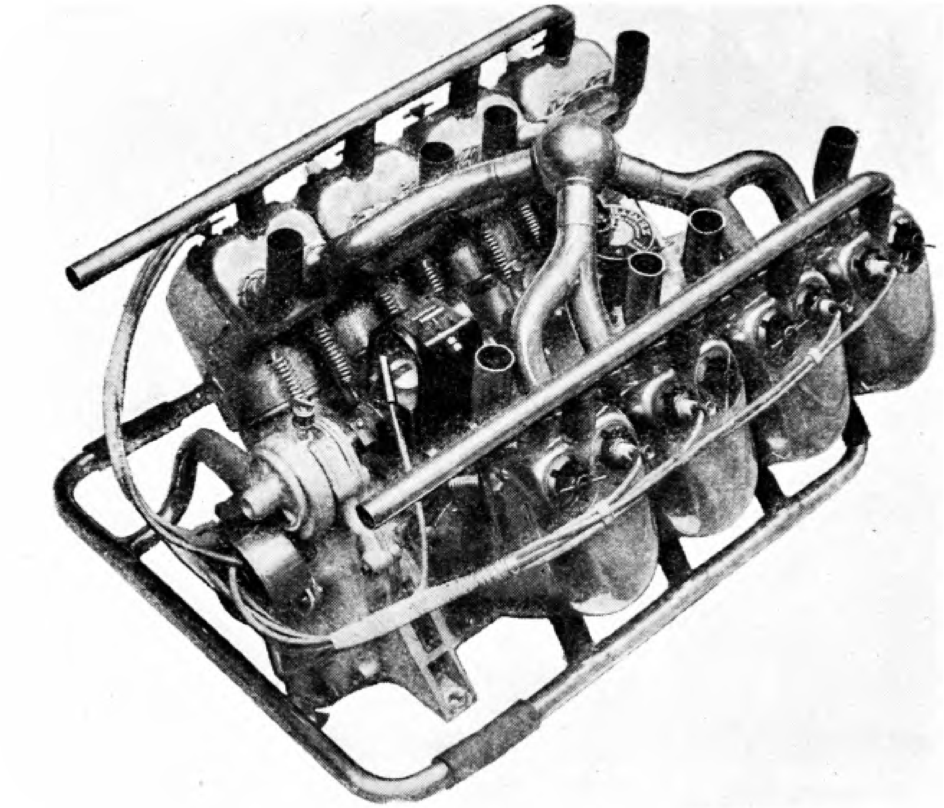

Fig. 177.—The E.N.V. engine.

are as follow:—85 mm. by 90 mm. for the smaller and 105 mm. by 110 mm. for the larger. Lubrication is by force pump at 22 lb. to the square inch, and the ignition is by Bosch high-tension magneto, supplemented by coil and accumulator in the case of the larger engines. The overall length of the 40 h.p. is 2 ft. 3 in., whilst the weight, including carburetter, magneto, and all necessary pipe work, is 155 lb., this engine being listed at £350. It consumes about three gallons of petrol and about three pints of oil per hour at 40 h.p., this power being obtained at 1,500 r.p.m., whilst, when accelerated to 1,700 r.p.m., 52 h.p. is obtained.

The 60 h.p. has an overall length of 3 ft., weighs 287 lb., and sells for £450, and consumes about 4.8 gallons of petrol and about three pints of oil per hour at 60 h.p., which power is obtained at 1,100 r.p.m., whilst an acceleration to 1,550 r.p.m. produces 80 h.p.

In both these engines the cylinders have jackets which are the result of electro-deposition. This method of construction

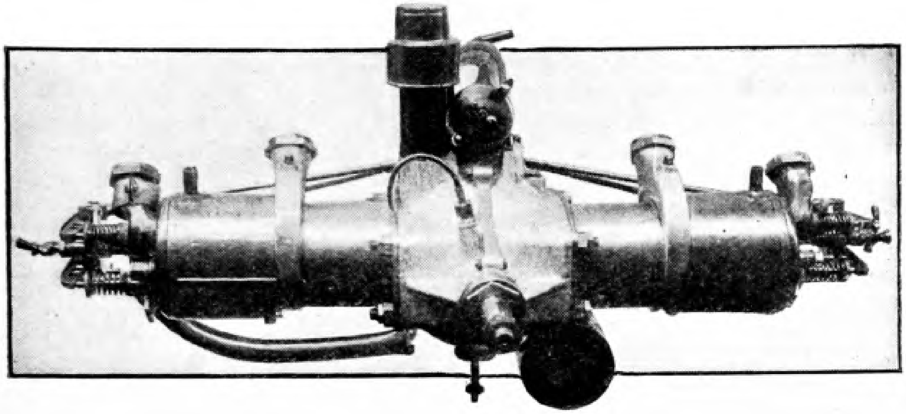

Fig. 178.—The two-cylindered horizontal Darracq motor.

allows of cylinders of accurately the same weight and thickness of wall, while the system of deposit allows the copper to be so closely joined to the cast iron of the cylinder that it is impossible to say where the copper leaves off and the iron begins.

All valves are carried in the angle formed by the two lines of cylinders, and are operated by a single camshaft, machined out of the solid and hollowed for lubrication purposes. A distinctive feature of the camshaft is that it is slidable in a longitudinal direction at the will of the operator, thus varying the lift of the valves. The crankshaft is a fine piece of workmanship, with four throws and circular webs, which have the effect of aiding the flywheel action. The shaft is mounted in plain bearings of exceptional length, while the crank pins are of the same diameter as the bearings, each one receiving two connecting rods side by side.

The Darracq Motor.

A two-cylinder opposed motor of very low weight and embodying a number of interesting features has been produced at the Darracq factory. The cylinders, having a bore and stroke of 120 mm. by 130 mm., are machined out of a solid bar of forged steel, fitted with a copper water jacket, and mounted on a light aluminium crankcase. The pistons are also of steel; they are connected up to a two-throw crankshaft, thus causing both pistons to throw inwards or outwards at the same time. The feature of the engine is the manner in which the four valves are operated by two cams only, one operating the exhaust valve for each cylinder and the other the two inlets. There are only two gear wheels in the motor, one being mounted on the crankshaft and the other, meshing with it, being on the camshaft. The magneto and the water circulating pumps are driven directly from each end of the camshaft, while the lubricating oil pump is operated by an eccentric, machined with the pinion on the mainshaft. The pump, running at the engine speed, delivers the oil to the two main bearings of the crankshaft; the oil then falls into the crankcase for the lubrication of the connecting rod ends and the cylinder walls by splash.

N

As the tendency is for the pistons to drive the oil out of the crankcase on their inward stroke, a special copper cylinder is mounted on the upper part of the crankcase and provided with two valves, through the first of which the oil and air pass, while through the second the air escapes, allowing the oil to return by a by-pass to the lubricating oil tank. Auxiliary exhaust ports are provided at the end of the stroke and are surrounded by an aluminium collector at the same angle as the exhaust ports, so that if it is desired to fit a muffler this can be done without any difficulty. The carburetter is mounted on the single length of intake pipe feeding the two cylinders, and is warmed at the base of the jet by a lead from the exhaust. In complete running order, with enough oil for three hours, the motor weighs 120 lb. A four-cylinder model, similar in general design to the twin-cylinder, is also built. Its weight is 230 lb. complete.

The Bayard-Clement Motor.

The motor produced by the Bayard-Clément Co., and fitted to all the biplanes of their construction, belongs to what may be designated the normal class, for it conforms to car engine design, with a saving in weight on all parts not subjected to

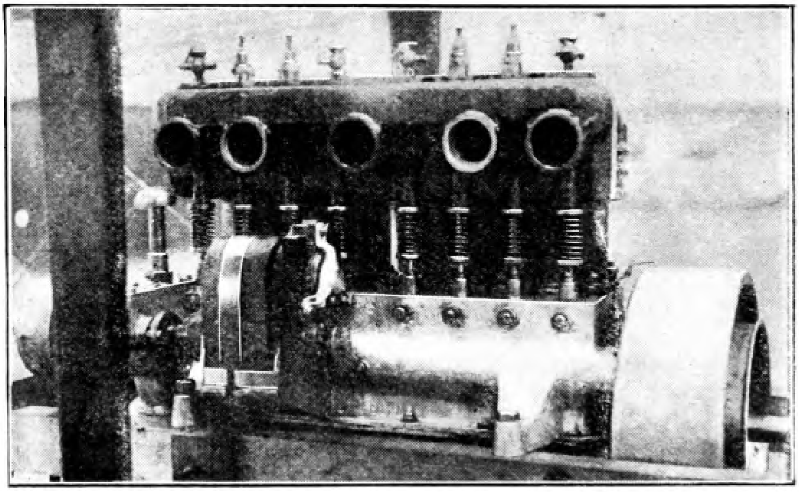

Fig. 179.—The four-cylinder (100 mm. by 120 mm.) Bayard-Clement engine.

strain. The four cylinders of 100 mm. by 120 mm. bore and stroke are cast in one block without a water jacket, the valves all being on one side and operated from below, according to standard practice. A sheet copper water jacket, suitably ribbed to allow of dilation of the metal, is afterwards riveted and welded into position. With such a construction, it is naturally unable to compare favourably in the matter of low weight with some of the special engines, but, the design being normal, perfect reliability and regularity of running are assured. Experience has shown that a 40 h.p. motor, weighing $6\frac{1}{2}$ lb. per horsepower, is not at all too heavy for a properly-designed aeroplane.

On the Bayard-Clément motor the two inlet valves are side by side, flanked in each case by an exhaust, thus giving only two leads from the carburetter to the cylinders, and three exhaust ports discharging into a common collector. A light steel piston is employed, the connecting rods are as light as possible consistent with safety, compression is high, and the crankshaft is of very stout construction, carried in three bearings.

A carburetter has been specially designed for this motor, its feature being the placing of the spray nozzle in the centre of the float chamber. There is nothing unusual in the ignition, a high-tension Bosch magneto being employed, driven from enclosed gearing at the forward end of the motor, the single shaft also operating the water circulating pump. A by-pass from the water circulating outlet delivers a supply of water to the carburetter. Force feed lubrication is employed, with the big ends fed by splash. When used on the Bayard-Clément biplanes the motor is fitted with a starting handle and a band clutch, allowing the propeller to be declutched by a foot pedal in the same way as on a motorcar. The total weight of the motor, with magneto, carburetter, intake and exhaust piping, but without the clutch, is 242 lb.

The Buchet Motor.

Six vertical cylinder motors are not common for aviation work, one of the very few that has been successfully employed being manufactured by the Buchet Co. The cylinders are cast in pairs with only a framework water jacket, the space left open being covered in afterwards by sheet-metal plates screwed in position. The combustion chamber is hemispheric, with all

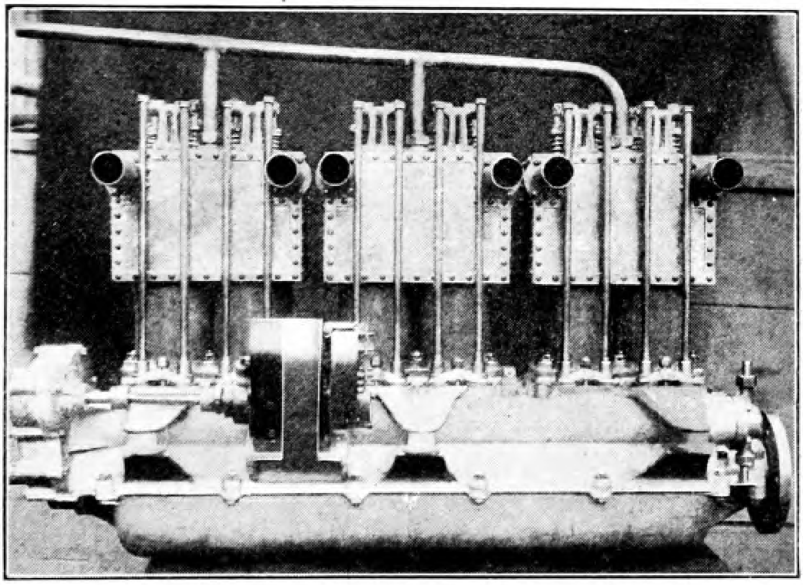

Fig. 180.—The 50 h.p. six-cylinder Buchet engine.

N 2

valves in the head, operated by overhead rocker arms from a single camshaft and vertical push rods.

In all other features standard lines of construction are followed. The lower portion of the piston is drilled to decrease weight, and the connecting rods have been made light, according to modern methods of construction. Ignition is by high-tension magneto, mounted in an inclined position in order to save a certain amount of weight on the bracket; the carburetter is of the usual car type, and lubrication is under pressure to the main bearings and by splash to the wrist pins and cylinder walls. Only a very small flywheel is employed, although it is possible to run the motor with the propeller only as flywheel. Cylinder dimensions are 100 mm. bore by 150 mm. stroke; the horse-power is 50 at 1,100 revolutions for a total weight of 285 lb , complete with everything except radiator and cooling water.

The Renault.

Air cooling is employed on the Renault eight-cylinder aeronautical engine. The cylinders, which have a bore of 90 and a stroke of 120 mm., are mounted in the form of a "V"

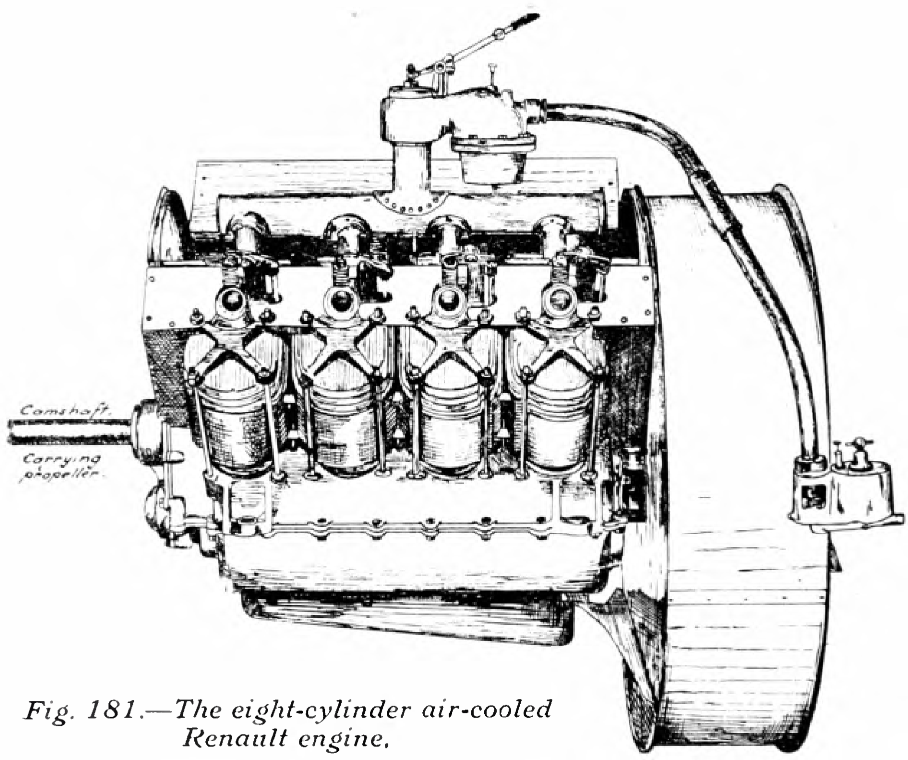

Fig. 181.—The eight-cylinder air-cooled Renault engine.

on an aluminium crankcase. The two lines of cylinders are slightly offset, thus allowing two connecting rods to be attached side by side on a single throw of the crankshaft. The main shaft is mounted on five bearings.

All the valves are worked off a single camshaft, the inlets being in outstanding pockets within the angle formed by the two lines of cylinders, and exhausts immediately above them are operated by rocker arms. The arrangement of the carburetter and inlet piping is somewhat original. The float chamber and nozzle are carried quite on the outside of the engine and very low down, the top of the carburetter being on a level with the base of the cylinders. This has been done in order to make it possible to place the tank in a convenient position to feed by gravity, instead of by pressure, as is done on most aeroplanes.

Probably the most distinctive feature of the engine is that the

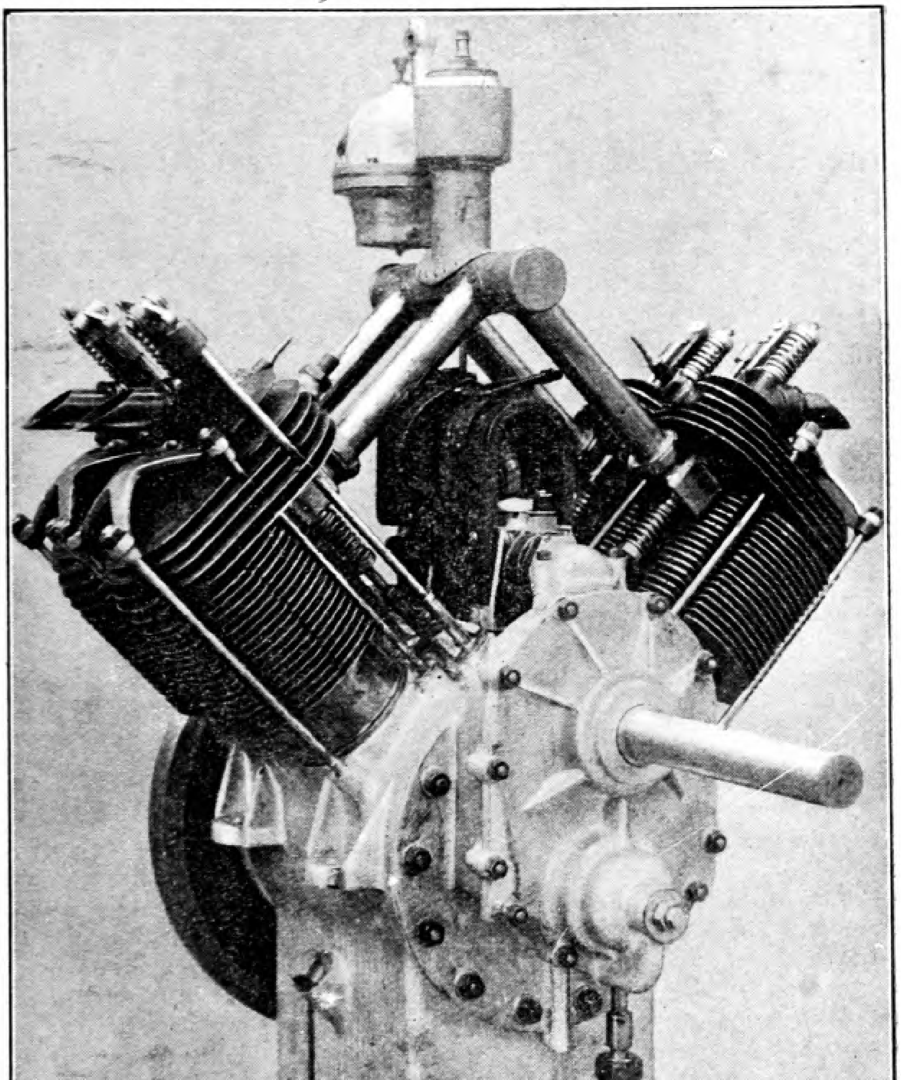

Fig. 182.—The four-cylinder 25 h.p. Renault air-cooled engine.

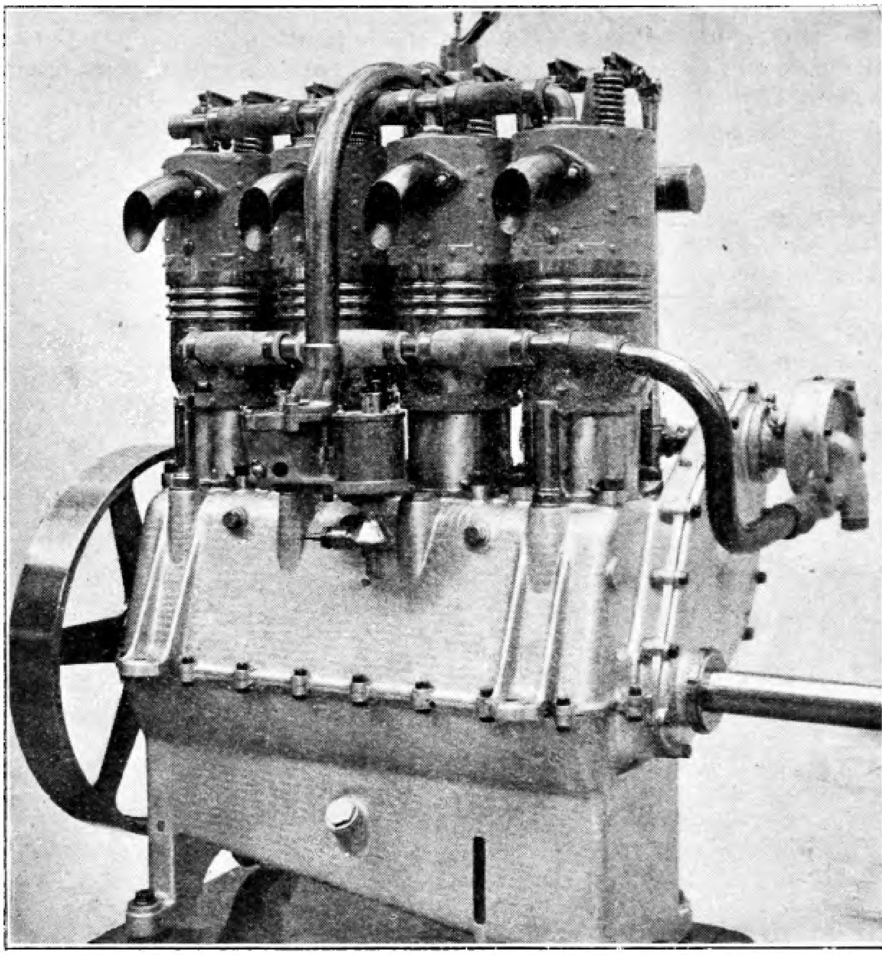

Fig. 183.—The 45 h.p. four-cylinder Renault engine.

propeller is mounted on the extremity of the camshaft, and not on the main shaft. It is now generally recognised that greater efficiency is obtained from a propeller turning at 600 to 900 revolutions a minute than from one running at 1,200 to 1,800 revolutions a minute. A suitable reducing gear has been difficult to find, and it needed the daring of a Wright to adopt the somewhat clumsy transmission by chain. On the Renault engine no reducing gear is required, the crankshaft turning at half the speed of the main shaft, giving 900 revolutions per minute of the propeller with the engine running at full speed. The camshaft is specially constructed for the work it has to perform, and is mounted on ball bearings.

The engine is enclosed by a light aluminium housing at both ends and on the top, and even the small amount of space between the cylinders has been closed up by aluminium plates. At the rear of the engine, and mounted on the end of the main shaft, is a powerful centrifugal ventilator, also partially housed, which draws a strong current of air into the V-shaped space formed by the cylinders. Everything being closed up, the only possible escape for the air is between the fins of the cylinders with the result that these latter are kept at a normal temperature. Ignition is by high-tension magneto, which is carried within the angle formed by the cylinders. Lubrication is assured by pump circulation, the supply of oil being carried in a reservoir forming the extreme base of the crank chamber and delivered under pressure to the main bearings of the engine. Under brake test the engine gives 55 h.p. at 1,800 revolutions, and in full running order, but with tanks empty weighs 375 lb.

Fig. 182 shows the new 25 h.p. four-cylinder air-cooled Renault motor, shown for the first time at the Aero Exhibition in Paris in October, 1909. The smaller engine closely follows the lines of the eight-cylinder engine. Fig. 183 shows the 45 h.p. four-cylinder Renault vertical engine with water cooling. This has overhead valves and, unlike the other two types, is designed to carry the propeller upon the extension of the crankshaft. It will be observed that brackets are cast upon both the upper part of the crankcase and upon the sump, forming, in the latter case, feet. These provide a quadruple method for securing the engine in the framework.

Aero Motors, Ltd.

The Aero Motors, Ltd., which is under the guiding power of Mr. F. R. Simms, who brought the original Daimler engine to this country, has produced a six-cylinder engine which develops 50 h.p. at 1,000 r.p.m., weighing only 220 lb., this weight being exclusive of the flywheel and exhaust piping, but including water and induction piping, magneto, etc. The cylinders are set at 120 degrees to each other, on opposite sides of the crankcase, and slightly staggered, in order to bring two big ends on each crank throw. They are 110 mm. bore by 110 mm. stroke, and are cast separately, with super-imposed valves in a pocket facing the centre. All the valves are operated from a single central camshaft on the top of the crankcase, the exhaust valves being operated by a direct push, lifting shoes being fitted between the cams and tappets. The inlet valves open automatically, but are closed mechanically by a spring-rotated rocker arm on top of the engine. To permit the valve to open, this rocker arm is drawn down by a tension rod operated by a bell-crank pivoted on a spindle above the camshaft. One end of the rocking lever carries a shoe which runs over the face of the cam. Gas is supplied from a carburetter situated centrally above the engine, and delivering the mixture through two branches to a pipe along the top of each set of cylinders. Forced feed lubrication is employed for the main bearings and big ends. For the gearwheels, grey fibre is used, with magnolia cheeks. The magneto is mounted on a bracket above the cranks at the forward end. A rather neat fitting is used to secure the two side plates of the mixture chamber on which the air and mixture throttles are mounted. The fastening is a simple blade spring attached to the main pipe pressing on the centre of the plates, which can, of course, then be quickly detached.

All the originality of the Panhard aviation motor lies in the valve design. The engine has four steel cylinders with separate cast-iron heads and copper water jackets, being similar, indeed, in this respect to most of the large touring car and all the racing motors of the firm. Dimensions are 110 mm. bore by 140 mm. stroke. Although the cylinders are naturally separate, water piping has been avoided by placing them so close together that a rubber-bound collar between each gives a water-tight connection. This construction is light, while at the same time it has the advantage of having had several years' testing on ordinary models.

The cylinders are mounted on an aluminium crankcase, with the main shaft carried in five bearings, according to usual Panhard practice. Pistons and connecting rods are made specially light, whilst the crankshaft has been designed to secure the lowest weight with the greatest amount of strength. Lubrication is by forced feed to the main bearings, with splash for

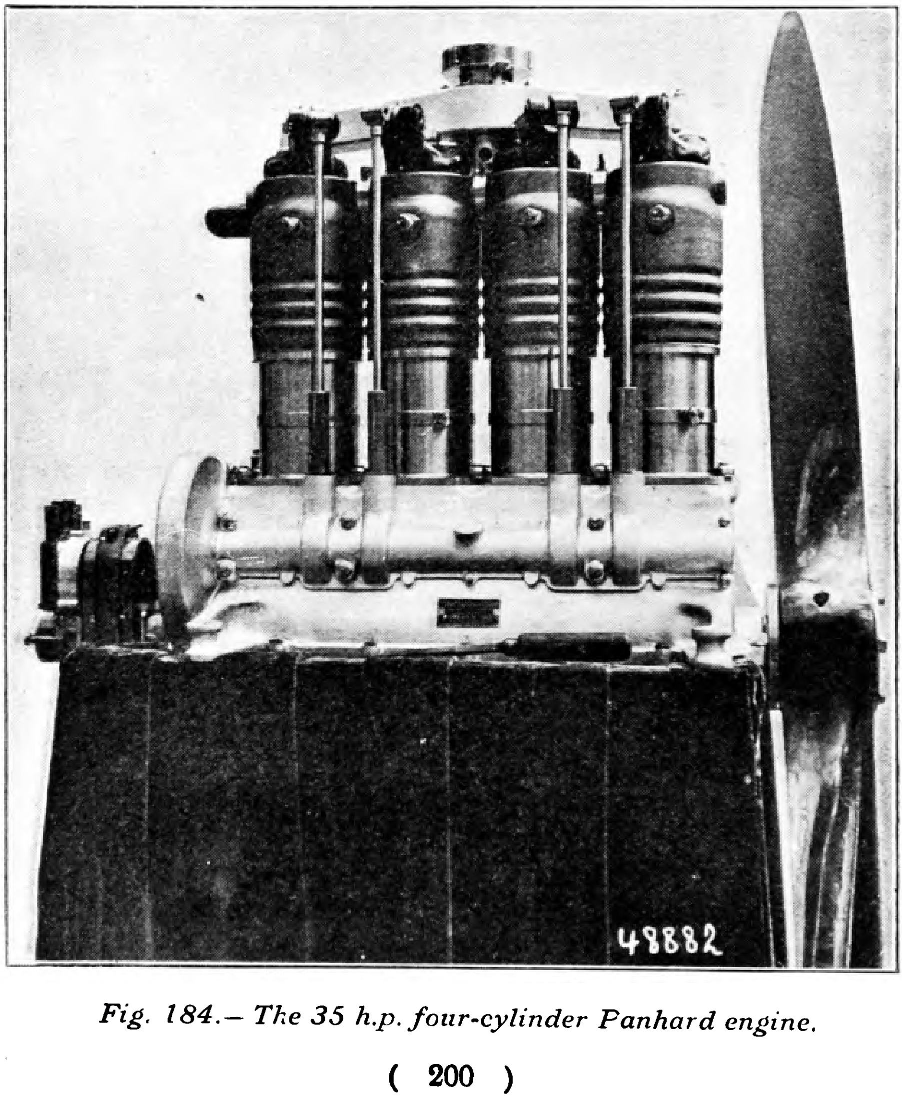

Fig. 184.— The 35 h.p. four-cylinder Panhard engine.

the connecting rod ends. Ignition is secured by high-tension magneto driven off an extension of the crankshaft.

A single camshaft and four vertical push rods operate all the valves. It is here that the originality of the motor is seen, for the valves are of the concentric type mounted in the head of the cylinder. A single intake pipe runs along the heads of the four cylinders, and is secured by a bolt projecting from the valve housing. The fresh gases pass down the hollow stem of the exhaust valve, thus assisting in cooling this latter. On a 48 hours bench test, the motor has continued to furnish 43 h.p. at 1,100 revolutions. Its weight, with everything necessary for running except a radiator and cooling water, is only 209 lb.

The Clement Motor.

A two-cylinder motor has been specially designed by the Clément-Bayard Co., for use on their "demoiselle" type of monoplanes. The cylinders, which are horizontal, have a bore of 130 mm. and a stroke of 120 mm., developing from 30 h.p. to 32 h.p. They are mounted on an aluminium crankcase and cooled by a circulation of water within a copper jacket. The feature of the motor is the valve-operating mechanism, the two valves being side by side in the head, operated by rocker arms obtaining their movement from a single cam. A peculiarity is that the exhaust valve spring is not around the valve stem, but is a helical spring secured to the extremity of the rocker arm and a point on the crankcase. The intake valve spring is of the ordinary type. Ignition is obtained by means of a high-tension magneto, lubrication is by pressure to the main bearings, and the circulation of water is by pump. The Clément type of carburetter, unchanged in design, but lightened for aviation work, is employed on this engine. When mounted on the aeroplane the tank is above the motor, allowing the flow of fuel to be by gravity. In addition to the supply of water in the cylinder jackets, the tubular radiator and the two collectors, a quantity is also carried in a small tank mounted above the motor and immediately in front of the petrol tank.

SOME LEADING AERODROMES AND THEIR FEATURES.

It is easy to forecast that the aerodrome, as a place where exhibition flights are held, will cease to exist within a very short time. The most skilled aviators no longer fly a few feet from the ground, but at such a height that their evolutions are visible to outsiders just as much as to the privileged within the barriers. Aerodromes, however, will always exist for experimental work and for the use of learners, and must be chosen with these special objects in view.

The learner is exacting. Not only must the ground be large, smooth, and free from obstructions, but it must be in such a position that it is almost untroubled by variable winds. It is not necessary that it should be sheltered from all winds, but it should be free from fluky winds, cross currents, and gusts. An open plain, over which the wind blows free and uninterruptedly, is generally better for the aviator's purpose than a piece of land, sheltered by hills and trees, but liable to be crossed by strong local gusts.

Naturally, the larger the ground the better. But it is not necessary to have a 10-mile course; a circuit of two to three miles, without any obstruction, will generally be found ample for three or four machines to be out at the same time. One of the conditions demanded by a leading aeroplane constructor, in selecting a training ground, is that a motorcar should be able to run over every portion of it without danger at a speed of 25 to 30 miles an hour. In order to do this, it is not necessary that the ground should be absolutely level, but it should be free from ridges and gulleys or thick undergrowth. If the motorcar test had been made, many of the so-called aerodromes that sprang up with the sport would never have been put forth. The nature of the soil should be taken into close consideration. For preference it should be of a light, sandy nature. A heavy clayey ground that is only hard and dry under frost, or in midsummer, should be avoided for aviation purposes.

The first aerodrome to be used in France was the military plain at Issy-les-Moulineaux. Although not ideal, by reason of the surrounding hills and tall factory chimneys, it has the advantage of being perfectly level and of a sandy surface, allowing aeroplanes to run at full speed over any portion. Being close to the Paris aeroplane factories, it is very convenient for testing new machines, and is indeed now chiefly used for this purpose. Two large dirigible balloon sheds, one of them for M. Clément, and the other for M. Deutsch (de la Meurthe), have recently been erected on this ground.

Juvisy, about 12 miles due south of Paris, is a ground belonging to the Société d'Encouragement de l'Aviation. Its chief advantage is its proximity to the capital, for, being in a hollow, it is disturbed at certain points by strong currents, and, although large amounts of money have been spent in preparing it, there is such a thick undergrowth that landing and starting are not possible everywhere. It is the only prepared aerodrome, constructed with a view to exhibition flights, with grand stands, sheds, repair shops, and a measured track, in the neighbourhood of Paris.

A small but very satisfactory aerodrome exists on the plateau of Buc, a few miles to the south-west of Versailles, where Robert Esnault-Pelterie and Maurice Farman have been established for some time. It is rather inaccessible to any but motorists, this, however, being an advantage rather than otherwise. M. Maurice Farman considers it ideal as the starting point of the western aerial route, for only a slight detour has to be made to get over country continuing in an unbroken level stretch as far as Chartres. Buc seems likely to become the starting point of the Paris-Bordeaux aerial line. Near by, at Saint-Cyr, is an excellent stretch of ground on which M. Santos-Dumont makes most of his experiments.

Mourmelon, or Chalons, as it is variously called, has now become the most important aerodrome within easy distance of Paris. It is an open plain forming part of the Chalons camp, and loaned by the military authorities. Chalons, however, is 15 miles away, the nearest village being Mourmelon-le-Grand, two miles away, and the nearest railway station Mourmelon-le-Petit, four miles away. Except in summer, the only means of conveyance from the station to the aerodrome is by an old-world horse omnibus.

Henry Farman, the Antoinette Co., and Voisin Freres have all important establishments on the Chalons plain, the Farman machines being constructed here, the Antoinette assembled, and the Voisins finally tested. All three firms have well-attended aviation schools here. The ground is an ideal one, for it makes possible a circuit of nearly three miles, on any portion of which a landing can be made without danger. Beyond the limits of the aviation plain is other open country, with so few obstacles that it is most suitable for cross-country flights.

The Betheny plain, on the outskirts of Rheims, is the largest established aeodrome, its official circuit being over six miles round, with plenty of margin for making the turns. For the learner it has the defect of being cut up and of having two or three hollows in which adverse air currents are met with. The ground is now used by the Hanriot syndicate for training pupils and testing the Hanriot monoplanes. The Rheims Aviation Committee has still an option on the land and will use it for the annual meetings inaugurated so successfully in 1909.

At Croix d'Hins, near Bordeaux, the Ligue Meridionale Aerienne has created an aerodrome of 1,800 acres on the vest planes, or "landes," having a total area of about 8,000 acres. The position is unique in being a desert within close proximity to a large town. The ground is absolutely level, the greatest difference between the highest and the lowest points not being more than 10 ft., and a straightaway flight of 10 miles can be made without crossing a road, stream, railway, or dwelling.

There is an undergrowth that can easily be cleared away by fire.

It is on this aerodrome that M. Louis Blériot has established one of his schools, and will probably erect a large factory for the construction of aeroplanes. The city of Bordeaux is interested in the aerodrome and will hold an important annual aviation meeting here, the first one to take place in September, 1910.

Three distinct aerodromes have been established in the vicinity of the town of Pau, a district of such exceptional climatic conditions that flights can be guaranteed 28 days per month. The first of these to be established was the Wright aerodrome, where Wilbur Wright made flights during the early portion of 1909, giving lessons to Comte de Lambert and M. Paul Tissandier. This is now used as a training ground by the French Wright Co., with M. Paul Tissandier as professor.

Less than three miles across country is a second aerodrome, forming the headquarters of the Blériot school, under the charge of M. Alfred Leblanc. The Voisin and the Antoinette companies have also some sheds here. A little further to the east is the third aerodrome, with a dirigible dock to receive the "Espana" and the airship "Ville de Pau." The district is also an important ballooning centre.

TABLE OF WIND PRESSURES.

Miles per hr.	Ft. per min.	Ft. per sec.	Lbs. per square foot. Max.	Min.	Mean.
1	88	1·47	·006	·0025	·004
5	440	7·33	·147	·062	·0997
10	880	14·7	·591	·249	·401
15	1320	22·0	1·32	·559	·898
20	1760	29·3	2·35	·991	1·59
25	2200	36·6	3·67	1·55	2·49
30	2640	44·0	5·3	2·4	3·59
35	3080	51·3	7·2	3·04	4·88
40	3520	58·6	9·43	3·98	6·39
45	3960	66·0	11·92	5·03	8·08
50	4400	73·3	14·7	6·2	9·97
55	4840	80·6	17·8	7·5	12·05
60	5280	88	21·2	8·9	14·4
70	6160	102·7	29	12·2	19·7
80	7040	117·3	37·5	15·8	25·4
90	7920	132	47·7	20·1	32·3
100	8800	146·6	59·1	24·9	40·1

For the calculation of this Table from the formula

$$p = kv^2$$

(where p = pounds per square feet
v = speed in ft. per sec.
and k = coëfficient)

the values adopted for k have been :—

Minimum value, k = ·001154 (Carus Wilson)
Maximum value, k = ·002737 (Clark)
Mean value, k = ·001855.

The mean value has been taken from :—

k= ·001154 — C. Carus Wilson.
·001378 — J. Aspinall.
·002330 — Smeaton & Rouse.
·002502 — Hawksley.
·002737 — D. Kinnear Clark.
·001700 — du Buat.
·001670 — Langley.
·001370 — National Physical Laboratory.

To convert feet per second into miles per hour, a very good approximation is obtained by multiplying the number of feet per second by ⅔.

Ex. :—30ft. per sec. = 20 miles per hour (approx.).

CONVERSION TABLE.

Metres per sec. to Miles per hour.

Metre per second.	Feet per second.	Miles per hour.	Metre per second.	Feet per second.	Miles per hour.
1	3·28	2·24	11	36·09	24·61
2	6·56	4·47	12	39·37	26·84
3	9·84	6·71	13	42·65	29·08
4	13·12	8·95	14	45·93	31·32
5	16·40	11 80	15	49 21	33·55
6	19·68	13·42	16	52·49	35·97
7	22·97	15·66	17	55·77	38·03
8	26·25	17·90	18	59·06	40·27
9	29·53	20·14	19	62·34	42·51
10	32·81	22·37	20	65·62	44·74

FLIGHTS OF ONE HOUR AND OVER.

An interesting list given below of flights extending over an hour or more has been compiled by a French contemporary, and although these are not in all cases official records, only in a few cases is there any doubt of the duration of the flights.

The name of the Hon. C. S. Rolls is included, but it will be remembered that the longest flight on 31st December was of 55 minutes duration. Maurice Farman's flight on 22nd October was also five minutes under the hour.

	H.	M.	S.
Orville Wright (9th Sept., 1908, Fort Meyer) ...	1	2	30
Orville Wright 10th Sept., 1908, Fort Meyer) ...	1	5	52
Orville Wright (11th Sept., 1908, Fort Meyer) ...	1	10	0
Orville Wright (12th Sept., 1908, Fort Meyer) ...	1	15	20
Wilbur Wright (21st Sept., 1908, Auvours)... ...	1	31	$25\frac{4}{5}$
Wilbur Wright (28th Sept., 1908, Auvours)... ...	1	7	$24\frac{4}{5}$
Wilbur Wright (6th Oct., 1908, Auvours)	1	4	26
*Wilbur Wright (10th Oct., 1908, Auvours)	1	9	$45\frac{2}{5}$
Wilbur Wright (18th Dec., 1908, Auvours)... ...	1	54	$53\frac{2}{5}$
Wilbur Wright (31st Dec., 1908, Auvours)	2	20	$23\frac{1}{5}$
Paul Tissandier (Wright, 20th May, 1909, Pau) ...	1	2	0
Hubert Latham (Antoinette, 5th June, 1909, Chalons)	1	7	37
Henry Farman (20th July, 1909, Chalons)	1	23	$3\frac{1}{5}$
Roger Sommer (Farman, 22nd July, 1909, Chalons)	1	5	30
Roger Sommer (Farman, 27th July, 1909, Chalons)...	1	23	30
*Orville Wright (27th July, 1909, Fort Meyer) ...	1	12	40
Roger Sommer (Farman, 1st Aug., 1909, Chalons)...	1	50	30
Roger Sommer (Farman, 4th Aug., 1909, Chalons)...	2	10	0
Roger Sommer (Farman, 7th Aug., 1909, Chalons)...	2	27	15
Louis Paulhan (Voisin, 7th Aug., 1909, Malo-les-Bains)	1	37	0
Louis Paulhan (Voisin, 25th Aug., 1909, Rheims)...	2	43	$4\frac{4}{5}$
Hubert Latham (Antoinette, 26th Aug., 1909, Rheims)	2	18	$9\frac{3}{5}$
Hubert Latham (Antoinette, 26th Aug., 1909, Rheims)	1	1	$51\frac{1}{5}$
Comte de Lambert (Wright, 26th Aug., 1909, Rheims)	1	52	0
Henry Farman (27th Aug., 1909, Rheims)	3	4	$56\frac{2}{5}$
Hubert Latham (Antoinette, 27th Aug., 1909, Rheims)	1	45	0
Paul Tissandier (Wright, 27th Aug., 1909, Rheims)	1	46	52
Roger Sommer (Farman, 27th Aug., 1909, Rheims)	60 kiloms.		
E. Buneau-Varilla (Voisin, 29th Aug., 1909, Rheims)	1	56	0
Cody (8th Sept., 1909, London)	1	3	0
Orville Wright (10th Sept., 1909, Berlin)	1	2	38
Henri Rougier (Voisin, 12th Sept., 1909, Brescia)	1	9	0
Lieut. Calderara (Wright, 12th Sept., 1909, Brescia)	1	3	0
Louis Paulhan (Voisin, 13th Sept., 1909, Tournai)	1	25	0
*Orville Wright (18th Sept., 1909, Berlin)	1	35	47
Hubert Latham (Antoinette, 24th Sept., 1909, Berlin)	1	2	56

* With passenger.

	H.	M.	S.
Henri Rougier (Voisin, 28th Sept., 1909, Johannisthal) ...	1	20	0
Henry Farman (28th Sept., 1909, Johannisthal) ...	80 kiloms.		
Rougier (Voisin, 29th Sept., 1909, Johannisthal) ...	1	37	21 1/5
Hubert Latham (Antoinette, 29th Sept., 1909, Johannisthal) ...	1	10	18 2/5
Hubert Latham (Antoinette, 30th Sept., 1909) ...	1	21	0
Henry Farman (1st Oct., 1909, Johannisthal) ...	1	31	24
Rougier (Voisin, 1st Oct., 1909, Johannisthal) ...	2	38	18
Louis Blériot (1st Oct., 1909, Cologne) ...	1	4	56
Henry Farman (3rd Oct., 1909, Johannisthal) ...	2	40	0
Louis Blériot (10th Oct., 1909, Frankfort) ...	1	12	0
Baron de Caters (Voisin, 10th Oct., 1909, Frankfort)	1	27	0
Henry Farman (20th Oct., 1909, Blackpool) ...	1	32	16 4/5
Maurice Farman (22nd Oct., 1909, Buc) ...	1	—	
Rougier (Voisin, 28th Oct., 1909, Antwerp)...	1	3	8
Capt. Engelhardt (29th Oct., 1909, Bornstadt) ...	1	6	30
Louis Paulhan (Farman, 30th Oct., 1909, Brooklands)	2	49	20
*Henry Farman (1st Nov., 1909, Chalons) ...	1	17	0
Henry Farman (3rd Nov., 1909, Chalons) ...	4	17	53
Capt. Engelhardt (Wright, 5th Nov., 1909) ...	1	50	0
Chateau (Voisin, 12th Dec., 1909, Chalons) ...	1	1	53
J. de Lesseps (Blériot, 16th Dec., 1909, Issy) ...	1	30	28
Mortimer Singer (Farman, 20th Dec., 1909, Chalons)	1	1	23
Jacques Balsan (Blériot, 27th Dec., 1909, Pau) ...	1	11	0
Hubert Latham (Antoinette, 30th Dec., 1909, Chalons) ...	1	20	0
Leon Delagrange (Blériot, 30th Dec., 1909, Juvisy)	2	32	0
Hubert Latham (Antoinette, 31st Dec., 1909, Chalons) ...	1	22	0
C. S. Rolls (Wright, 31st Dec., 1909, London) ...	1	4	0
Henry Farman (31st Dec., 1909, Chalons) ...	1	10	0
Van den Born (Henry Farman, 5th Jan., 1910, Bourg)	1	16	0
Curtiss (11th Jan., 1910, Los Angeles) ...	1	—	
Olieslaegers (Blériot, 16th Jan., 1910, Oran) ...	1	5	12 3/5
Louis Paulhan (Henry Farman, 18th Jan., 1910, Los Angeles) ...	1	57	27
Louis Paulhan (Henry Farman, 21st Jan., 1910, Los Angeles) ...	1	49	40
*Van den Born (Henry Farman, 31st Jan., 1910, Chalons) ...	1	48	50
*Effimoff (Henry Farman, 31st Jan., 1910, Chalons)	1	48	3
Rougier (Voisin, 6th Feb., 1910, Heliopolis) ...	65 kiloms.		
Metrot (Voisin, 9th Feb., 1910, Heliopolis) ...	85 kiloms.		
Rougier (Voisin, 11th Feb., 1910, Heliopolis)...	48 kiloms.		
Geo. Chavez (Henry Farman, 28th Feb., 1910, Chalons) ...	1	47	0
Capt. Burgeat (Antoinette, Pau) ...	1	(?)	
Lieut. Camermann (Henry Farman, 2nd Mar., 1910, Chalons) ...	1	5	0
Maurice Farman (2nd Mar., 1910, Buc) ...	1	0	0
Crochon (Henry Farman, 6th Mar., 1910, Chalons)...	1	1	0

* With passenger.

	H.	M.	S.
†Henry Farman (5th Mar., 1910, Chalons)	1	2	25
Gaudart (Voisin, 6th Mar., 1910, Juvisy)	1	10	0
Molon (Blériot, 11th Mar., 1910, Le Havre)... ...	1	24	0
Molon (Blériot, 17th Mar., 1910, Le Havre)... ...	1	4	0
Popoff (Wright, 21st Mar., 1910, Cannes)	1	33	0
Gasnier (Wright 24th Mar., 1910, Pau)	1	(?)	
Grahame-White (Farman, 27th Mar., 1910, Mourmelon)	1	5	0
Crochon (Farman, 27th Mar., 1910, Cannes) ...	1	9	29
Frey (Farman, 27th Mar., 1910, Cannes)	1	9	$2\frac{4}{5}$
Blériot (2nd April, 1910, Pau)...	1	15	0
*D. Kinet (Farman, 2nd April, 1910, Mourmelon) ...	1	2	30
Gibbs (Farman, 3rd April, 1910, Mourmelon) ...	1	12	0
Dubonnet (Tellier, 3rd April, 1910, Juvisy-Orleans)	1	50	0
Frey (Farman, 3rd April, 1910, Cannes)	1	2	58
Sommer (4th April, 1910, Mouzon)	1	6	0
Capt. Dickson (Farman, 5th April, 1910, Mourmelon)	1	33	0
Capt. Marconnet (Farman, 6th April, 1910, Mourmelon)	1	10	0
†D. Kinet (Farman, 8th April, 1910, Chalons) ...	2	19	$15\frac{4}{5}$
Jeannin (Farman, 11th April, 1910, Johannisthal)	2	1	55
*H. Farman (Farman, 17th April, 1910, Beauce to Orleans)	50 kiloms.		
L. Paulhan (Farman, 18th April, 1910, Orleans to Arcis-sur-Aube)	185 kiloms.		
L. Paulhan (Farman, 19th April, 1910, Arcis-sur-Aube to Chalons)	80 kiloms.		
C. Grahame-White (Farman, 23rd April, 1910, London-Rugby)	2	5	0
C. Grahame-White (Farman, 27th April, 1910, London-Roade)	1	26	0
L. Paulhan (Farman, 27th April, 1910, London-Lichfield)	2	39	0
L. Paulhan (Farman, 28th April, 1910, Lichfield-Manchester)	1	32	0

* With passenger. † With 2 passengers.

The following is the chronological order of the respective aviators reaching the full hour's flight:—

1, Orville Wright; 2, Wilbur Wright; 3, Paul Tissandier; 4, Hubert Latham; 5, Henry Farman; 6, Roger Sommer; 7, Louis Paulhan; 8, Comte de Lambert; 9, Buneau-Varilla; 10, Cody; 11, Henri Rougier; 12, Lieut. Calderara; 13, Louis Blériot; 14, Baron de Caters; 15, Maurice Farman; 16, Capt. Engelhardt; 17, Chateau; 18, J. de Lesseps; 19, Mortimer Singer; 20, Jacques Balsan; 21, Léon Delagrange; 22, Van den Born; 23, Curtiss; 24, Olieslaegers; 25, Effimoff; 26, Métrot; 27, Geo. Chavez; 28, Capt. Burgeat; 29, Lieut. Camermann; 30, Crochon; 31, Gaudart; 32, Molon; 33, Popoff; 34, Gasnier; 35, Grahame-White; 36, Crochon; 37, Frey; 38, D. Kinet; 39, Gibbs; 40, Dubonnet; 41, Dickson; 42, Jeannin.