MODEL FLYING MACHINES

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Their Design and Construction

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THEIR DESIGN AND CONSTRUCTION.

BY

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LONDON:

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INTRODUCTION.

IN a work of this nature, which must, to be successful and useful, be practical before everything else, it is not necessary to dwell upon the importance of man's accession to the domain of the air. The discovery of the possibility and, later, the practicability of mechanical flight is such a one as it is given to the people of but few ages to witness; and in point of development as a means of communication ranks with that of the fact that man learnt to turn the seas as well as the land to his own uses.

The conquest of the air has followed in natural sequence, although divided from it by an immeasurable interval of years upon the conquest of the sea; and the two media have naturally enough much in common, although this fact is not at first sight altogether apparent. The thousands of years that have elapsed since prehistoric man first committed himself to the deep in a rude vessel have not, as is attested by the active development of naval practice at the present day, sufficed to bring us to finality in any single respect. Our ships annually increase in speed, size, comfort, carrying power, and economy; and there is no reason to suppose that they will not continue to be further improved so long as the sea remains liquid and there is a vessel to travel upon it.

The advent of the automobile and the attendant widespread diffusion of mechanical science has resulted in the fact that at the present day it is no exaggeration to say that at least one man in every ten is possessed of a useful working engineering knowledge. It would be idle to suggest that he has anything but a nodding acquaintance with the exact sciences, although the increasing number of technical schools in all parts of Great Britain is doing much to bring him into greater intimacy with them; but what he lacks in theory he more than frequently makes up for in practice. Hence development of any mechanical system is at the present day incredibly rapid. Type supersedes type at extremely short intervals of time, and we find ourselves well on the road to perfection almost before we have accustomed ourselves to the idea of the latest discovery.

Now it is worthy of note that much of the development of ship construction has been due to the possibility of small-scale experiments. By means of models constructed and tested at a negligible cost of time and labour, new principles have been discovered, old ones improved, and valuable data furnished, which have resulted in many developments of overwhelming importance.

It is more than reasonable to suppose—it is obvious—that similar conditions will obtain in the development of the flying-machine; and, in fact, already much valuable work has been accomplished in this line.

For the tens of thousands of men who have "ideas" with regard to aerial vehicles, the model provides an ideally simple and convenient method of experiment. Its construction is essentially simple—and it is in the reduction of complication that improvement largely lies—the materials are of the cheapest, and the mechanical skill in their assembling of the humblest; whilst power, when required, may be cheaply obtained and readily installed. Anyone possessed of a little patience, a few pence, a modest handful of cheaply acquired tools, and a trifling mechanical skill, can build a model sufficiently well to enable a demonstration of the correctness or incorrectness of the principle upon which it is constructed to be made.

To pursue even further the analogy between water and air it may be laid down that anyone who can build a model boat can build a model flying-machine.

Apart from the utilitarian side of the question, however, there is another and hardly less important aspect. A model flying-machine, especially the home-made article, is capable of providing the greatest delight and pleasure to its constructor and the spectators of its flights. The writer knows of few sensations which can compare with that which he feels upon seeing one of his models sinking away into the distance, and enquiry has shown him that he is not by any means the only one of this opinion—in fact, all the model aeroplanists he has consulted on this question have been unanimous in confirming his views.

In view of the fact that interest and the likelihood of subsequent development are principally invested in the aeroplane type of heavier-than-air machine, as opposed to the helicopter (or direct lift) and the ornithopter (or flapping wing) machine, the first-named is practically the only one described in this book, the other two being separately dealt with on a general basis in special chapters, whilst a third special chapter on model dirigibles has also been included.

The advice given is throughout the direct result of the author's own personal experience, and all the designs comprised in Chapter VII. have been built and tested by him.

W. G. A.

NOMENCLATURE.

This short glossary makes no pretensions to completeness. It is introduced for the sole purpose of obviating any difficulty which might arise from certain words having one meaning for the reader and another for the author.

AEROFOIL.—A supporting surface, either *plane* or curved.

AEROPLANE.—Heavier-than-air machine, which depends for sustentation upon one or more supporting surfaces. (This word is in reality somewhat of a misnomer, applying as it does only to a machine with flat supporting surfaces; but it has come into such general use that there is no reason why it should be superseded.)

ASPECT RATIO.—Proportion between the dimension of a surface *across* the direction of flight and the dimension *along* the line of flight.

BIPLANE.—Heavier-than-air machine with two main supporting surfaces one above the other.

HELICOPTER.—Heavier-than-air machine which depends for its sustentation upon the upward thrust of rotary screws or helices.

MONOPLANE.—Heavier-than-air machine supported by one surface. (A machine with one main supporting surface and an *adjustable* elevator or tail is not, strictly speaking, a monoplane, but is in each case a "tandem biplane," the elevator or tail being a supporting surface according to circumstance.)

MULTIPLANE.—Machine with more than three main supporting surfaces.

ORNITHOPTER.—Heavier-than-air machine sustained and propelled by means of flapping wings in the manner of certain birds.

NACELLE.—Literally "cradle." (Fr.) the under framework of a dirigible balloon.

PITCH.—The distance through which a helix* theoretically travels forward in one revolution.

PROPELLER.—A helix or screw placed *behind* the main supporting surface of a machine.

TANDEM BIPLANE.—Heavier-than-air machine with two main supporting surfaces one behind the other.

TRACTOR.—A helix or screw placed *in front of* the main supporting surface of a machine.

TRIPLANE.—Machine with three main supporting surfaces.

* The word "helix" will be used throughout the present work to comprise both tractor and propeller screws.

CHAPTER I.

GENERAL PRINCIPLES AND THEIR APPLICATION.

Whilst it is neither desirable nor necessary to include in a work avowedly devoted to practical model construction a mathematical disquisition upon the theoretical aspect of the aeroplane, the author makes no excuse for devoting a chapter to the consideration of a few general principles. All that the model aero maker requires is a rough general idea of how and, especially, why, certain causes produce certain effects, sufficient to guide him in both construction and design. To go more deeply and discursively into the theory of the aeroplane would be to waste space on inadequately explaining what has already been thoroughly dealt with in other notable works; and the risk would also be run of unnecessarily hampering the reader with technicalities scarcely germane to the matter in hand.

Why the Aeroplane Flies. The Analogy of the Kite.

The principle of the aeroplane is also that of the kite and of the sailing boat. The kite is sustained in the air by virtue of the force of the wind, this force being directly dependent upon its speed, or, in other words, by virtue of the kite's *motion relatively to the wind*. When the wind drops the kite descends, since there is no force to sustain it, but it will immediately rise again and remain up in the air provided the holder of the kite string begins to run and continues to run at sufficient speed to provide the required relative motion between the kite and the atmosphere.

An aeroplane is for all practical purposes a kite in which a *mechanical arrangement attached to the kite itself* takes the place of a kite-flier running with the string, and provides the required relative motion.

Relative Motion.

It is important to remember that in speaking of motion in the ordinary way we imply *motion relative to the earth.* Motion relative to the earth, however, is not to be considered as having any effect on the behaviour of a kite or aeroplane.

Assuming that a wind speed of ten miles per hour be sufficient to sustain a kite in the air, then :

(1) If the wind be blowing 10 or more m.p.h., the kite-flier can remain stationary.

(2) If the wind be blowing 7 m.p.h., the kite-flier must run 3 m.p.h. in the *opposite* direction.

(3) If the wind be blowing 5 m.p.h., the kite-flier must run 5 m.p.h. in the *opposite* direction.

(4) If the wind be blowing 5 m.p.h., the kite-flier must run 15 m.p.h. in the *same direction* as the wind to sustain the kite in the reversed position.

In each case the relative motion between the kite and the wind is 10 m.p.h., whilst its actual motion relative to the earth—that is, the motion as apparent to a spectator—is equal to the rate at which the kite-flier runs.

In a similar way the speed of an aeroplane—that is to say, the speed upon which it depends for its sustentation—is its speed relative to the atmosphere. A machine whose speed in a dead calm is 20 m.p.h. remains perfectly stationary in relation to the earth when flying *against* a 20 m.p.h. wind ; on the other hand, when flying *with* the same wind, its speed is 40 m.p.h. relative to the earth. If flown against a 40 m.p.h. wind its speed relative to the earth is 20 m.p.h. *backwards*, yet its actual speed *relative to the atmosphere* is always 20 m.p.h. *forwards*.

Throughout this book all speeds given, except when otherwise stated, are to be taken as *speeds relative to the atmosphere,* not speeds relative to the earth.

* * * * * * *

Action and Reaction.

The force which drives a bullet away from a rifle has an equal and opposite tendency to drive the rifle and the man behind it away from the bullet. It is only prevented from doing the latter by reason of the fact that the weight of the man and the rifle are many thousands of times heavier than the weight of the bullet. The man feels the recoil, but his mass enables him to overcome its effect.

In the illustration (fig. 1) A B represents diagrammatically a kite, which is, for the purposes of illustration,

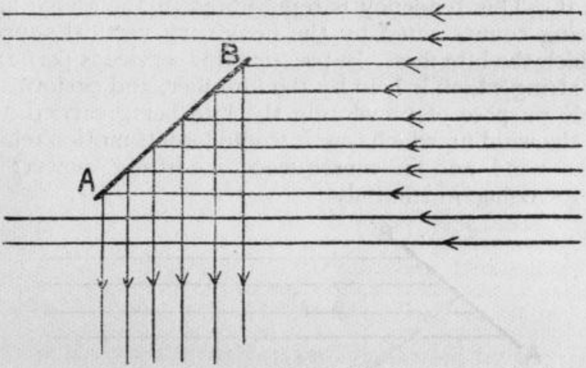


Fig. 1. By the use of an inclined kite the horizontal motion of the wind is caused to have a vertical reaction which supports the kite in the air.

supposed to be fixed in vertical supports in such a manner that, whilst its angle of inclination to the horizontal is kept constant, it is free to move in one direction only, viz., vertically. The wind on meeting this inclined surface is deflected angularly similarly to the manner in which light is reflected in a mirror, the wind being represented by a series of parallel lines, and its direction by the arrows.

The wind after striking the kite has a downward action accompanied by a consequent upward reaction on the part of the kite A B, which accordingly rises. Although the air is gaseous and fluid it nevertheless possesses weight, hence the force imparted to the air which flows unbrokenly under the kite is capable of imparting to the kite a recoil which lifts it.

The greater the speed of the wind the greater the recoil, and hence the greater is the lifting power or pull of the kite. The final recoil is obviously felt on the surface of the earth vertically beneath the kite.

Now the wind has, besides its tendency to lift the kite A B, a strong tendency also to carry the kite bodily along with it. This tendency is represented in the above figure as being counteracted by the imaginary vertical supports in which the kite flies. In practice this service is performed by a string which is held by the kite-flier, and performs the double purpose of preventing the kite being carried away with the wind (in which case it would lose its motion relative to the wind and in consequence its lifting power) and also its rising indefinitely.

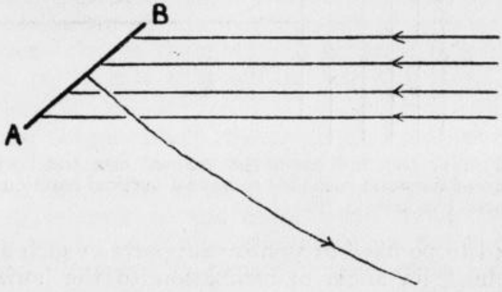


FIG. 2. The tendency of the wind to carry the kite with it is resisted by the kite string, which exercises a pull in the opposite direction.

In fig. 2, which is purely diagrammatic, the kite string is represented as being tied to the centre of the kite, which is supposed to be of some regular shape, *i.e.*, square, oblong, circular, hexagonal, etc. Experiment, however, shows that such a kite, with the string attached to its centre, *will* *not fly*—that is to say, it will not rise in the air, but is simply carried along with the wind as far as its string will allow it to be. The reason of this will be now made clear.

Centres of Pressure and Gravity.

A B in the accompanying diagram represents the section of a thin stiff square sheet of any suitable material secured on pivots about which it is free to rotate in the manner represented in the perspective drawing alongside. The pivots are supposed to be frictionless, and to be so placed that the square sheet is in perfect equilibrium.

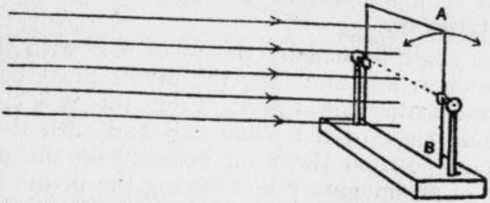


Fig. 3. Apparatus for experimentally determining the locus of the centre of pressure upon a plane held at various angles to the direction of motion of a current of air.

Now if a steady wind current (indicated by the parallel lines) moving in a direction at right angles to A B strike the plane, as shown above, the plane A B will still be in equilibrium, since the pressure is obviously equal on each side of the pivots. and no change of position will result.

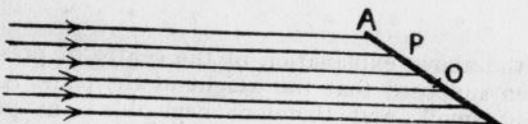


Fig. 4. Locus of the centre of pressure of an inclined plane.

Now if the plane A B be moved from the position it occupies in fig. 3 until it is made to assume that represented in fig. 4, then when the current of wind strikes the plane it will be immediately forced back to its first position, namely, one at right angles to the direction of the wind.

From this fact, which is easily proved experimentally, it is evident that the total pressure on the half of the plane nearer the wind is greater than the total pressure on the half more remote. The areas of the halves are, however, equal, hence it is clear that the wind pressure from A to O is greater than that from O to B.

For the plate A B to remain in equilibrium in the position shown in fig. 4, when the wind current is acting upon it, it is necessary to move the pivots "towards the wind" to such a point as P, when the plate will duly remain stationary.

As the angle formed by the plate A B with the horizontal becomes less and less, the pivots must be moved farther and farther towards A. From this it is clear that for a certain angle of the plane A B and with the pivots in a certain position the total pressure on the plane on each side of an imaginary line joining the pivots is equal.

The centre of the line joining these pivots is called, therefore, the *centre of pressure*, and it should be noted that a straight line drawn in *any* direction through this centre of pressure divides the plane into two equal pressure areas.

In other words, the supporting power of the wind can be represented as an upward force applied to the *centre of pressure*, and acts just as though a string were attached to that point and the plane lifted by its means.

* * * * * * *

In the above explanation of the centre of pressure it has been supposed that the weight of the plane A B was infinitely small, and therefore negligible; in practice, however, the weight of the plane cannot be so neglected.

In the following diagram (fig. 4A) A B is a plane acted upon by a wind which supports it at the point P (centre of pressure) exactly as if a string P Q were tied to that point. The pressure distribution is now in equilibrium, since that on the side A P exactly balances that on the side P B. The *weight* of the side A P is *not*, however, equal to the *weight* of the side P B, hence, although the pressures balance, the weights do not, and it is clear that the side P B will outweigh the side A P, and will consequently fall.

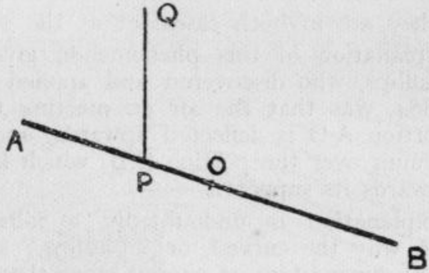


FIG. 4A. The effect of the centre of pressure is similar to the suspension of the plane by a cord attached thereto at a point coincident with its locus.

For the plane A B to be in equilibrium its *centre of pressure must accordingly coincide with the centre of gravity*, when the weight of P B + the total pressure on P B will exactly balance the weight of A P + the total pressure on A P.

In the above explanation a current of air has been imagined as acting on the plane, and the relative motion is therefore between the plane and the atmosphere ; hence whether the plane is flown as a kite or driven through the air as an aeroplane the resulting reaction is the same.

THE CURVED SUPPORTING SURFACE.*

Experiment shows that, other things being equal, a surface having a section—

FIG. 5. The curved aerofoil.

* It is clearly a contradiction in terms to refer to a "curved plane," although this is sometimes done. One might with equal right talk of a "curved straight line" or a "square circle."

is considerably more efficient than one having a section—

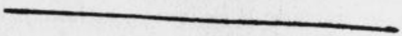


FIG. 6. The p.ane aerofoil.

although they are in both cases set at the same angle.

The explanation of this phenomenon given by Mr. Horatio Phillips, who discovered and applied this principle in 1884, was that the air on meeting the steeply inclined portion A O is deflected upwards, and creates a partial vacuum over the portion O B, which largely contributes towards its support.

This explanation is undoubtedly a fallacious one. The reason why the curved, or "Phillips," surface lifts for an equal expenditure of energy more than the plane surface is that, owing to its closer approximation to "stream-line form," it offers considerably less head resistance.

STREAM-LINE FORM.

It is obvious that a boat with a square-shaped bow (fig. 7A) will not sail so easily, *i.e.*, will offer more resist-

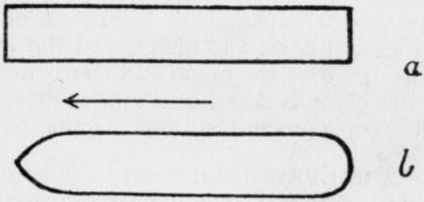


FIG. 7A. Shape of body, which opposes undue resistance to motion in the direction indicated by the arrow. FIG. 7B. More desirable shape, which opposes much less resistance.

ance to motion than a vessel with a sharp bow (fig. 7B), the reason being that the latter will cause considerably less disturbance of the fluid in which it moves than the former.

Now air is a fluid no less than water, and the same considerations apply in each case, subject, of course, to conditions governed by density, viscosity, etc., which it is unnecessary to deal with here.

When a square baulk of wood is held up against the wind, the flow of the wind around it, as can easily be experimentally demonstrated with the aid of a lighted match,

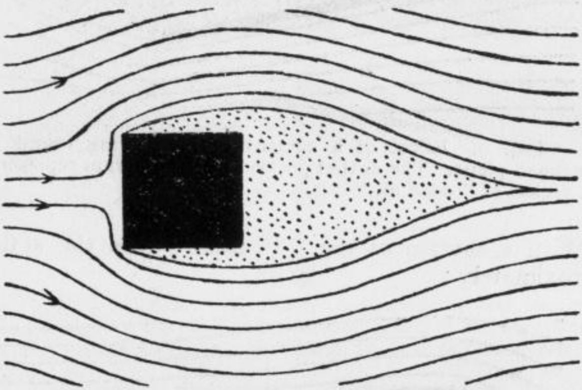


FIG. 8. Effect of a current of air flowing round a fixed column of square section. The dotted portion indicates a region of "dead air," which is, however, disturbed by a system of eddy currents.

is approximately represented in fig. 8, the dotted portion representing a region of "dead air." Exactly the same thing happens in flowing water and a moving boat, which, if not of proper design, draws after it a quantity of such "dead water."

This "dead water," or "dead air," represents so much unnecessary resistance to be overcome, as in the case of a moving air (or water) vessel it requires an expenditure of considerable power to drag it along.

In the case of a plane supporting surface, the flow of air around it is represented approximately as in fig. 9, from which it will be seen that there is a considerable region of dead air.

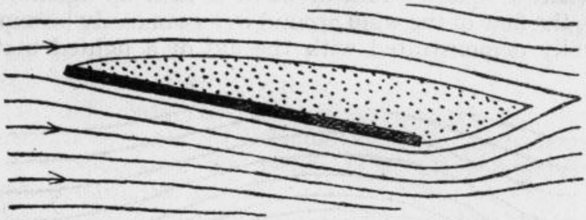


FIG. 9. Effect of a current of air flowing round an inclined plane. The dotted portion of the diagram represents a region of " dead air."

With a surface of the " Phillips " type the action is approximately :

FIG. 10. Effect of flow round a body of a shape approximating to stream-line form.

whence it will be clearly seen that there is an absence of " dead-water " region, whereby the head resistance and the power required to drive it are considerably lessened.

The shapes of the bodies of a fish and a bird are of correct stream-line form. (In the case of certain fishes the interior formation of the gills must, however, be taken into account, since the water flows *through* as well as *round* them.)

ACENTRICITY.

It is a common fallacy, due in all probability to a mistaken analogy with the dirigible balloon, that the stability (*i.e.*, its power to right itself automatically) of an aeroplane is increased by keeping the weight as low down as possible, it having been supposed that if the centre of gravity were vertically under the centre of pressure, the plane would naturally find its own equilibrium. Such, however, is by no means the case, and is probably the cause of numerous failures for which explanation has been otherwise hard to seek.

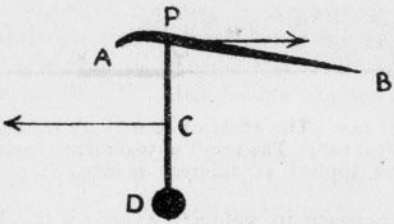


FIG. 11. In an "acentric" arrangement the moment of resistance of the supporting surface and that of the impulse of the propelling force take place at two different points.

A B represents the sustaining surface of an aeroplane, of which P is the centre of pressure ; whilst, owing to the principal mass of the mechanism, for instance, lying low at D, the centre of gravity of the whole machine is at C, which is vertically underneath the centre of pressure.

The momentum of the machine is centred at C, the centre of gravity, whilst the resistance of the aeroplane to forward motion is applied at the point P (centre of pressure). This state of affairs is comparable to having a stick X Y held in the air by two men, one of whom pulls the end X to the right and the other the end Y to the left (fig. 12A). The stick is simply rotated until power and resistance are in the same straight line (fig. 12B).

It may be argued that if the power of propulsion be applied in a horizontal line passing through P (fig. 11) the above rotational effect would be avoided. This, however, is only true when the speed of the machine and the speed of the wind are both constant. If the wind, assumed for the sake of argument to be travelling from left to right

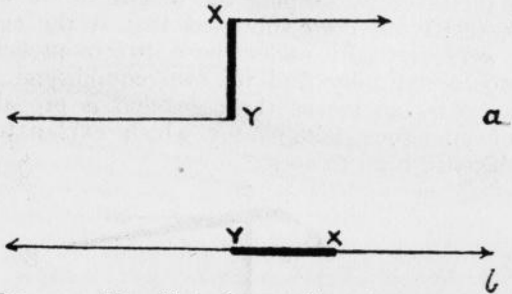


FIG. 12A. The effect of acentricity shown diagrammatically. FIG. 12B. The result of two forces working in opposite directions applied at different points.

(fig. 11), increase in velocity even to the slightest extent the point P will encounter increased resistance, whilst the resistance to motion of the centre of gravity will be practically unaltered, owing to the great difference in exposed surface between the supporting surface A B and the mass D.

The momentum of the whole machine will manifest itself at the centre of gravity C, and will obviously tend to swing the whole machine about the point P.

In a similar way, through whatever point the line of propulsion be drawn, it can easily be proved that the acentric arrangement of an aeroplane must result in a serious tendency for it to upset.

* * * * * * *

ELEVATORS AND TAILS.

The "elevator" or "horizontal rudder," which takes the form of a small surface carried on an outrigger stretched in front of or behind the main supporting surface, performs the function of altering, according to its adjustment, the position of the centre of pressure of the machine, by that means enabling it to take an upward, a horizontal, or a downward course, according to circumstances.

The power of the elevator or tail varies with the distance it is set in front of or behind the main surface and with its size. The nearer the elevator is to the main surface the larger it must be, and *vice versa*.

When the "elevator" or "tail" is set at such an angle that it just supports its own weight and its proportion of the weight of its outrigger, the centre of pressure is at its normal position. When it is desired to bring the centre of pressure forward in order to enable the machine to rise higher up in the air, the elevator is tilted to a greater angle, so that the atmosphere applies a greater pressure to it.

When the aeroplane's course is required to be a downward one, the "elevator" is set at a less angle than the normal, which may even be a negative angle. This has exactly the same effect as a small plane or "tail" *behind* the main surface set at a positive angle, and results in the centre of pressure being brought further back. The centre of gravity is now in front of the centre of support, and the machine accordingly takes a downward glide.

The function of the "tail" is, as can be easily seen, the converse of that of the elevator, although it may be used for a purely directional purpose, in which case it is fixed in a horizontal position, and has no effect on the centre of pressure at all, its weight being supported entirely by the main surface.

Its action is then exactly analogous to the feather of an arrow, and furnishes enhanced longitudinal stability to the machine.

Wing-warping and Ailerons.

When an aeroplane travels round in a curve it is obvious that the outer portion of the supporting surface must travel at a greater speed than the inner portion. "Wing-warping" or "ailerons" are used, therefore, to give more resistance to the inner wing, and less resistance to the outer. By increasing the angle of incidence or inclination of the inner wing, the centre of pressure is caused to recede whilst the reverse of this action takes place in respect to the outer wing; hence the inner wing tends to be depressed whilst the outer rises and also overruns its inner fellow. Thus the machine "banks itself up," exactly like a cyclist taking the curve of a racing track. This arrangement of wing-warping is the invention of Wilbur and Orville Wright, and is patented by them; its use is accordingly restricted to those who work under Messrs. Wright's licence.

The same object, however, is achieved in a different manner by the use of "ailerons," or small adjustable surfaces, attached to the extremities of the main supporting surface. This arrangement has the advantage of being common property, and can therefore be used by all and sundry.

When it is desired to make the aeroplane travel in a curve the inner aileron is afforded a greater angle of incidence, whilst that of the outer aileron is decreased, the consequent unequal resistances resulting in the machine taking a curved path.

Vertical Fins.

Vertical fins, whose action is similar to that of the rudder of a boat, may be used for steering purposes either by themselves or with the aid of ailerons. The vertical fin should extend both above and below the horizontal centre line of the aeroplane, so as to equalise the pressures in the event of a side wind striking the machine. When placed on the upper side only, a fin acts like the sail of a boat, and tends to turn the machine over sideways.

"Swooping" Flight.

Aeroplanes often exhibit a tendency to "swoop." They first rise to a great height, and then dive downwards only to rise again and repeat the performance. This phenomenon, or lack of longitudinal stability, is due to the tail or elevator being adjusted to a slightly incorrect degree, the tendency being to force the machine to rise too quickly. At the top of the "swoop" the kinetic energy of the machine is converted into potential. The machine then falls under gravity until its speed is sufficient to cause it to rise again. The consequent loss of speed, owing to the repetition of this performance, gradually causes the undulations to damp out, and the machine finally adopts a straight flight.

Speed of Flight.

For any particular adjustment of the main surfaces and the elevator or tail, a machine has a certain fixed speed. If at launching this speed be exceeded the machine swoops upwards, the air gets under the supporting surfaces, and the machine endeavours to drive itself vertically up into the air, whence, the power proving insufficient, it comes down backwards.

In testing a machine as a glider, *i.e.*, just thrown from hand and allowed to glide to earth, the elevator or tail should be adjusted to give the machine a greater lift than is required when the machine is driven at a constant high speed.

CHAPTER II.

POWER.

One of the most important considerations in the design and construction of a model flying machine is the question of power. It is somewhat unfortunate that in this respect the model maker is practically obliged to utilise static energy—that is, energy supplied from without, and stored for further use, such as twisted rubber, compressed air, and clockwork, as this form of power is clearly only available for certain specified limits of time. However, this fact is no insuperable drawback, as it is a matter of no difficulty to store sufficient power to carry a model any distance up to half a mile, which in the writer's opinion, in view of the scarcity of clear grounds affording a safe flight of such a length, is a disadvantage less real than apparent.

Steam and internal combustion engines, to the development of the latter of which we owe the possibility of full-sized flying machines, are, unfortunately, accompanied by a weight which is prohibitive for any but models of a considerable size, the minimum supporting surface to carry a practicable petrol engine being some ten square feet. One square foot of surface may be expected, under good conditions, to be capable of supporting rather over a pound (in full-sized machines this weight may easily be exceeded) if the machine be capable of travelling from twenty to thirty miles per hour. A 1 h.p. petrol engine can be produced with as low a weight as 8 lbs., but this is exclusive of magneto or coil and accumulator, either of which ignition systems may easily add another fifty per cent. to its weight. Taking the total weight with fuel and oil at 13 lbs., and apportioning to the rest of the machine the extremely low weight of 7 lbs., this gives a total of 20 lbs., to sustain which a surface at least 10ft.

broad would be required. The author considers that, in view of the trouble and expense entailed in constructing such a machine, the difficulty of flying it, and the likelihood of its meeting with serious accident, time and money would be far better utilised if applied towards the construction of a full-sized machine.

Steam engines, although they can be made marvels of lightness, carry with them much the same disadvantages as petrol engines, as well as some of their own.

Clockwork has, it is to be feared, proved a source of great disappointment to numerous model aeroplane makers. This is entirely due to the fact that few, except those whose experience has taught them wisdom, realise the large amount of power which it takes to drive a screw of reasonable dimensions. Although wide enquiry has been made for a clockwork with some available power in it, no satisfactory arrangements have yet been brought to light. The author has been for some months, and still is, carrying out careful and elaborate experiments with the collaboration of a first-class clockmaker, but up to the present results have been by no means encouraging, although a satisfactory conclusion may yet be reached.

Compressed air holds out some promise of doing useful work, and was satisfactorily employed by Mr. Lawrence Hargraves in his important and pioneer research carried out in Australia in the early eighties. A compressed air engine is, of course, quite a simple affair, but there are at present no suitable ones on the market (as far as the author is aware), and their construction requires a lathe and such tools as are not to be found in any but the best equipped private workshops. For the benefit of those readers who have a pronounced mechanical bent a design for a compressed air engine is given in a separate chapter at the end of this volume.

Far and away the cheapest, easiest procurable, most efficient, cleanest, and handiest form of power for model aero work is twisted indiarubber. This can be obtained in several forms practically anywhere for a trifling expenditure.

The best type of elastic to be obtained is the flat "strip" or "tape" variety, which seems to give at once the greatest torque, the least thrust, and the longest life of any. Failing this, elastic in section from $\frac{1}{16}$in. square to $\frac{3}{16}$in. square may be used. It is worthy of note that old push-bicycle inner tubes (if not perished) make good power plants when cut up into strips from $\frac{1}{4}$in. to $\frac{3}{4}$in. wide.

The simplest form of elastic motor is shown in fig. 13, the elastic being stretched over two hooks—one fixed, and the other free to rotate. The thrust of the elastic, which may be either single, double, treble, or multiple, is

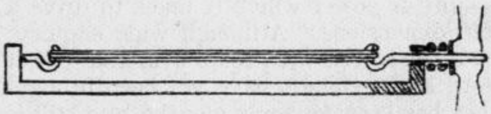
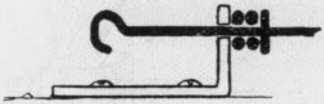


FIG. 13. The simplest form of twisted elastic motor.

taken at the free end by one or more thrust blocks situated outside the main bearing. Glass beads make excellent thrust blocks for small sizes, though difficulty is often found in obtaining them sufficiently true to run glibly. In their place small brass rings of circular section give every satisfaction. They may easily be made by cutting the shank off small screw eyes. With heavy powers ball bearing thrusts may be used, although these are neither cheap nor easy to procure. For the outlay of sixpence or a shilling a ball bearing "top" may be obtained from which a tolerable ball thrust may be fashioned; but the female cone is of rather inferior metal, which does not wear satisfactorily, hence it is advisable to make a fresh one of reliable stuff.

For the screw shaft nothing can compare with a cycle spoke. It is nice mild steel, and can be easily bent with or without heat into a hook, whilst its screwed end and the nipple which fits it make a first-class adapter for the screw. Brass or steel wire of a suitable gauge may, however, be used for this purpose.

A point to be noted is that the hook must be true on the shaft, otherwise the elastic will "jerk" and give an uneven torque.



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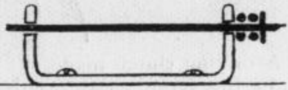

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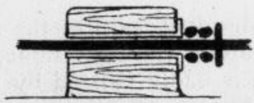


c

FIG. 14A. A simple form of bearing. FIG. 14B. A simple form of double bearing bent out of a piece of strip. FIG. 14C. A long plain bearing which gives very good results.

For a bearing a simple hole in a single strip of metal (fig. 14A) may be used, but the double bearing (fig. 14B) is far more satisfactory, whilst the tubular bearing (fig. 14C) is even better still, though rather more difficult to make. For A and B brass, steel, and aluminium strips give equally good results. The face abutting on the thrust blocks should be filed smooth and flat.

The easiest method of fixing the screw to its shaft, and also one which gives entire satisfaction, is shown in fig. 15. A small brass plate $\frac{1}{4}$in. × $1\frac{1}{4}$in. is drilled in the centre, and soldered firmly to the screw shaft, the ends being turned over to clutch the screw boss, the whole being made fast by the spoke nipple screwed up on the end. This arrangement permits the screw to be readily detachable. The back of the brass plate forms, of course, one bed for the thrust rings.

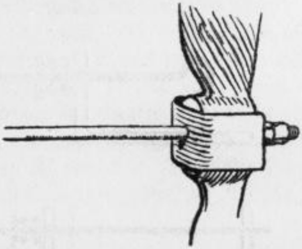


FIG. 15. A driving clutch made out of a piece of bent strip soldered to the screw shaft. This allows the screw to be easily mounted and dismounted.

The principal disadvantages of the elastic motor illustrated in fig. 13 are: (1) The frame, unless extremely heavy and strong, is badly twisted by the reaction of the

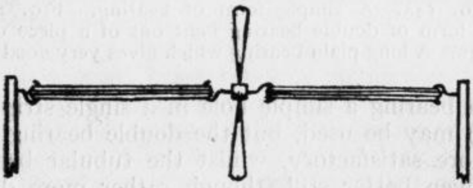


FIG. 16. A balanced form of elastic motor. In this case the rubber skeins are provided at the fixed ends with ratchets for winding.

elastic; (2) there is friction due to end thrust. Of these the first is the worst, but can be overcome in two ways—either by balancing the twist of one elastic by the twist of another of equal length and strength on the opposite side of the screw (fig. 16), or balancing the twist of one by the twist of another in the opposite direction by gearing (fig. 17). Of the two the latter is far and away the more preferable on several counts. Primarily the increase of

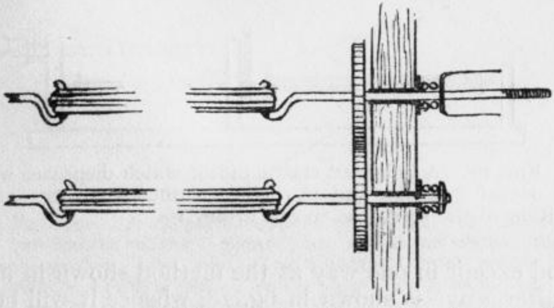


FIG. 17. A double geared elastic motor, which obviates any tendency of the elastic to twist the framework.

weight is trifling, and secondly by using two separate skeins of elastic the screw can be got to run for a considerable length of time. This is due to the following reason:

A single strand of elastic 1ft. long gives, say, 300 revolutions.

If a second strand 1ft. long be added to the same hook, the power will be largely increased, but the number of revolutions obtainable will be only about 150.

If four strands be used on the same hook the power will be proportionate, but the revolutions obtainable will drop to about eighty.

By gearing together and using two strands on each hook the same power will be obtained as with four strands altogether, but the revolutions obtainable will be 150.

In pursuance of this fact the writer generally uses three separate skeins geared together for each screw, and he proposes in the future to carry the number up to eight, as the weight of the gearing is very small, and the advantages accruing very considerable.

In fig. 16 it will be observed that the screw is situated between the elastics. This position is, generally speaking, an inconvenient one; but the arrangement lends itself to an alternative method, which, however, is not

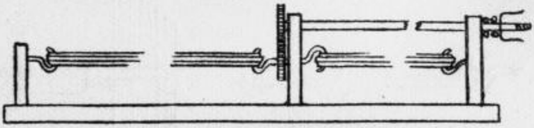


FIG. 18. A balanced elastic motor which dispenses with the use of ratchets, and obviates the inconvenient central position of the screw, as shown in fig. 16.

so good except in one way as the method shown in fig. 17. This alternative is shown in fig. 18, whence it will be seen that the screw is fitted to a long shaft driven by gears from the elastic.

Both in this and in the previous arrangement (fig. 16) it will be observed that there is no end thrust on any of the bearings. In the opinion of the writer, however, this matter is not of such importance as it would seem.

The great disadvantage of the single screw lies in the fact that action and reaction are always equal and opposite, hence the elastic has as much tendency to twist the machine against the resistance of the screw as it has to twist the screw against the inertia of the machine, although, of course, the latter is many times greater than the resistance of the screw. This trouble is present in the full size machine, but not to anything like such a large extent, since in the large aeroplane the screw is made considerably smaller in proportion than in the model. Even so, however, the reaction makes itself felt, and is counteracted in either or both of the following ways: (1) The supporting planes are set at an angle seen in end elevation in fig. 19A—in which case it will be seen that the tendency of the reaction is to make one or other of the wings more horizontal. As, however, a surface has more supporting power when horizontal than when inclined the reaction of the screw is overcome automatically, although the machine flies somewhat one-sided, as in fig. 19B.

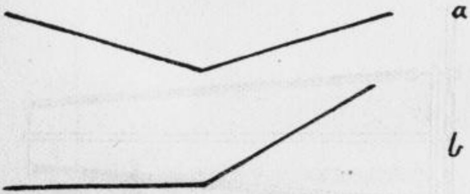


FIG. 19A. A dihedral supporting surface. In this case the two halves of the "plane" are set at an obtuse angle to one another. FIG. 19B. The dihedral aerofoil resists the torque of a single screw by giving more lifting effect on the wing which the torque, due to the reaction of the screw, tends to depress.

(2) The other method is to provide one wing, or one side of the main sustainer, with greater lifting power than the other, in which case variations in speed must be immediately accommodated by extra adjustment of ailerons or wing-warping. Further, if the screw stops, a similar adjustment must be made to prevent the spiral glide which would otherwise ensue.

A method has been suggested to overcome the inherent disadvantage of the single screw. This consists in rigging up along the edge or underneath one of the wings a rail along which a small weight is free to slide. Attached to this weight is a thin string, which is attached to a small pulley mounted on an extension of the screw shaft, or geared thereto. The arrangement is such that when the elastic motor is fully wound up, the weight is at its extreme outward position, and hence exercises the greatest moment. As the propeller revolves, the weight is drawn along its slide, so that, since the power of the elastic varies inversely as the time it has been running for, the resistance of the screw and the moment of the sliding weight are always kept in proportion, and accordingly always balance one another. When the screw is completely wound down, the weight must be at the centre of the machine.

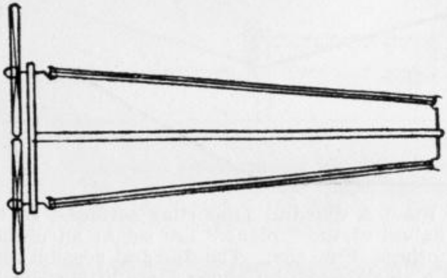


FIG. 20. A double screw motor composed of two simple units.

Infinitely the best plan, at least in the author's opinion, and he has tried every conceivable contrivance, is to use twin screws of right and left-hand pitch running in opposite directions. Fig. 20 shows the simplest arrangement with single skeins, and fig. 21 the arrangement with multiple skeins. The latter the author has every confidence in recommending (although it is his own idea), as it has given every satisfaction.

There is no difficulty in getting the screws to revolve at the same speed. All one has to do is to give each unit an exactly similar amount of elastic, and be careful to wind each one to the same number of revolutions.

A method of driving twin screws with balanced elastic, and with the elimination of end thrust, is shown in fig. 22.

This necessitates the use of belts—one plain, the other crossed—which is a great drawback to an otherwise excellent arrangement. It is a matter of great difficulty to prevent the belts slipping. To this end the grooves in the aluminium pulleys should be made a sharp V, and the belts dressed with resin, or, what acts fairly well, with rubber solution well rubbed in. The elastics in this case are wound up an equal number of times through the medium of a small ratchet at each end. These may be obtained from old clockwork, or made as shown later.

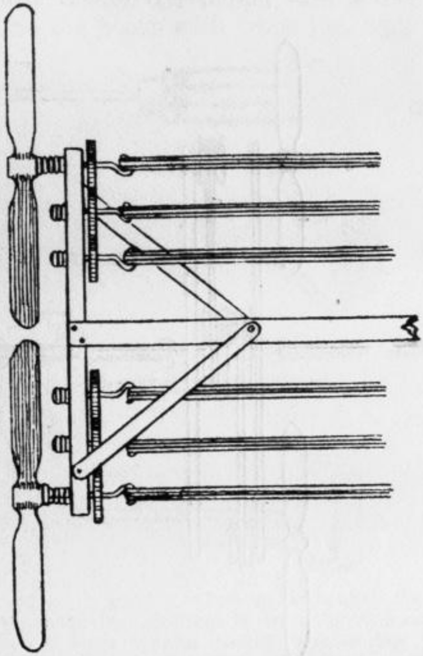


FIG. 21. A double screw motor composed of two triple geared units. This gives a considerably longer duration of working.

As regards gear wheels for the arrangements indicated above, it is well nigh useless to expect good results from ordinary stamped American clock wheels, as these are far too shallow across the face of the teeth, and are only designed for use with small pinions. Well cut gear wheels of a good depth, either in brass or steel, may easily be procured at a moderate cost.

Throughout all the above arrangements of elastic hooks at the driving end of the screw shaft have been shown. A better plan perhaps, however, although it is

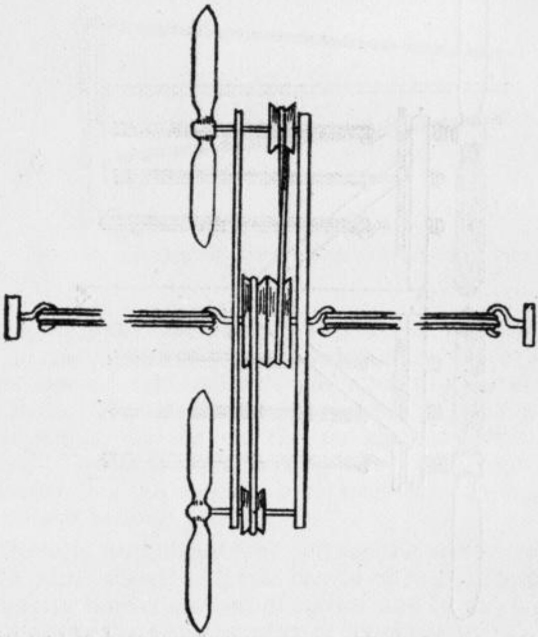


FIG. 22. A double screw arrangement driven by a balanced elastic motor, the power being conveyed through belts.

not so desirable in point of detachability and ease of replacement of elastic, is to fit the inner end of the shaft with a small aluminium or wooden cylinder or drum, as in fig. 23A. Around this the strands of rubber are arranged equidistantly, and secured in place by a binding of thin twine or elastic thread. In this manner the twist of the elastic is ensured central.

A good plan to prevent the hooks at either end of the skein cutting through the rubber, which they are apt to do, is to bind the hooks with twine (fig. 23B), enclose the

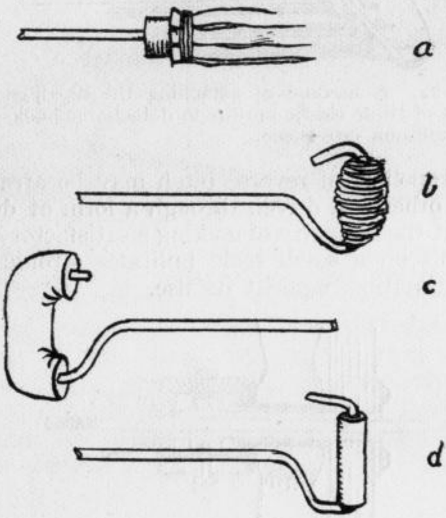


FIG. 23A. A good method of attaching the elastic of the screw shaft by binding it to a boss fixed thereon. FIG. 23B. A hook wound round with string to obviate its cutting the elastic. FIG. 23C. The hook protected with a piece of indiarubber tube. FIG. 23D. The same protected with a section of tubular cane.

squared portion of the hook in thick rubber tube (fig. 23C), or for the rubber tube substitute a piece of tubular cane or brass (fig. 23D).

For a cross piece to hold the fast ends of the multiple skeins in a double screw drive, nothing is better than a piece of aluminium plate about $\frac{1}{16}$in. thick drilled as in fig. 24 to accommodate the required number of hooks.

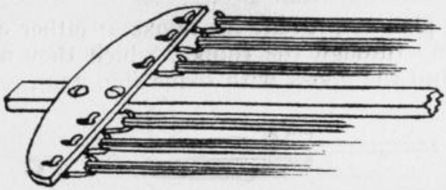


FIG. 24. A method of attaching the fixed ends of a double set of triple elastic motors to detachable hooks carried in an aluminium crosspiece.

Twin propellers of reverse pitch may be arranged one behind the other and driven through a form of differential (fig. 25), but the difficulty of making a satisfactory arrangement of this on a small scale militates strongly, in the author's estimation, against its use.

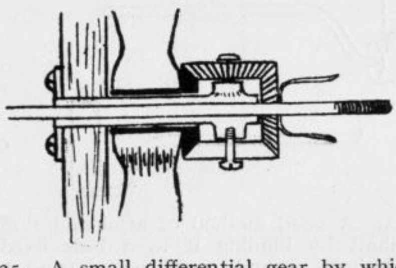


FIG. 25. A small differential gear by which a single elastic motor can be made to drive two propellers in opposite directions.

An ingenious form of elastic motor is shown in fig. 26. As the rubber twists up it draws fresh supplies of untwisted strands from the portion at the further side of the small pulley, this rubber being free to stretch without let or hindrance. The advantage of this plan is that a good number of revolutions can be obtained with quite a moderate overall length.

In setting up rubber motors it is advisable to have the untwisted elastic fairly taut between the hooks, as the elastic soon stretches in use.

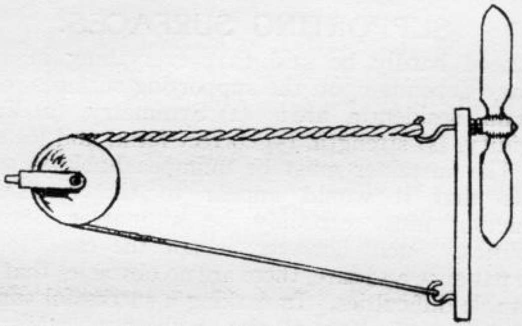


FIG. 26. In this form of motor the rubber as it twists and shortens draws upon an untwisted reserve.

A multiple skein motor similar to that shown in fig. 21, measuring 2ft. 6in. long, each skein being composed of five strands (¼in. strip rubber), gave on test 640 revolutions, and ran for 39s. This is equal to a distance, in a dead calm, of considerably over 600 yards with 1ft. diameter screws.

CHAPTER III.

SUPPORTING SURFACES.

It need hardly be said that everything in a model aeroplane depends upon the supporting surfaces, of which the main desiderata are: (1) Symmetry, (2) lightness, (3) rigidity, (4) strength, (5) correct form, and (6) smoothness. The sustainer must be unimpeachable in so many respects that it would appear to the tyro that its construction must certainly be a matter beyond his capabilities. Such, however, is not the case, for, given a little patience and care, there are no obstacles that present insuperable difficulties. In making a successful supporting surface care must above all else be observed, whilst experience will soon render perhaps the most trying part in the construction of a model a matter of no difficulty whatever.

With regard to the desiderata mentioned above, it is clear that the sustaining surface must be symmetrical, otherwise one side will present a greater resistance to the atmosphere than the other; or if the section be not proportionate all along, one side will lift more than the other, the result being either a curved flight or a complete capsize.

Lightness is, of course, an essential in all the parts of an aeroplane; but it must be borne in mind that it is fatal to sacrifice strength or rigidity for lightness in the case of a supporting surface. Of the three attributes—lightness, strength, and rigidity—the last two are, in the opinion of the author, of paramount importance. The hard knocks which a model aeroplane receives, especially the supporting surface, which spreads out beyond everything else, and consequently in the experimental stage is *always* the first thing to hit the ground, soon play havoc with anything at all flimsy; and it is, accordingly, making a good bargain to let the "plane" weigh an ounce or two more than it *could* be got down to, in order to acquire measure of stoutness for the lack of which it must certainly suffer.

As regards the correct form of the "plane," this is what has the greatest bearing on distance of flight, since, if the shape be incorrect, head resistance will figure largely and entail the installation of extravagant power. This will mean doubling up the elastic at the expense of the revolutions of the screw, and consequently of the distance flown.

The Wooden Aero-curve.

For small supporting surfaces there is nothing like thin wood. It can be made perfectly smooth, and there is no difficulty in getting it down sufficiently light without sacrificing strength. The author has found American white wood (sometimes also known as canary wood) to answer very satisfactorily. It is cheap and easily procurable in planks of the requisite thinness. Mahogany and pitchpine may, however, also be used if preferred, although neither "work thin" quite so well as the white wood.

For supporting surfaces up to 4ft. across, the wood requires to be at its thickest no more than $\frac{3}{32}$in. thick; whilst in parts, *i.e.*, in the rear portion, it must not exceed $\frac{1}{32}$in.

According to the author's experience it is advisable to obtain for this purpose a plank not less than $\frac{5}{32}$in. thick; though to be on the safe side $\frac{3}{16}$in. is even better. The reason of this is that the action of the circular saw, with which such planks are cut, tears the fibres to a certain depth each side, and this brittle portion requires to be afterwards planed away. Thinner planks than $\frac{3}{16}$in. can often be obtained machine-planed, but these are not recommended for the job in hand, as the fierce action of the machine robs them of much of their strength and renders them exceedingly prone to split.

A rough idea of the correct section of a supporting surface, or aero-curve, can be gathered from fig. 5 (Chapter

I.). This illustration is, however, entirely diagrammatic, since it is obvious that a section of uniform thickness cannot be of truly stream-line form. The ideal section of aero-curve for model machines is shown in fig. 27—

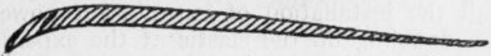


FIG. 27. Section of a curved aerofoil.

its plan form being any of those shown in fig. 28.

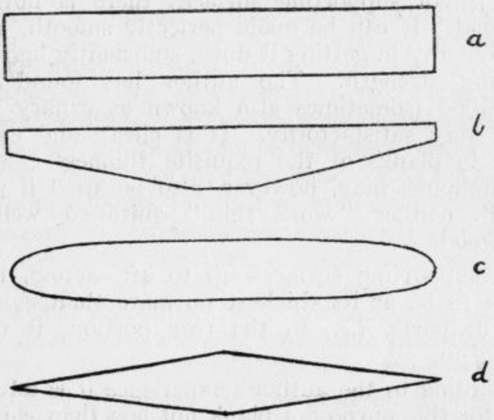


FIG. 28A. A rectangular aerofoil. FIG. 28B. An aerofoil with chamfered rear edge, which reduces the edge disturbance. FIG. 28C. Elliptical aerofoil. FIG. 28D. Diamond-shaped aerofoil.

Of these B is, for reasons that will be discussed later, the most advantageous. The grain of the wood runs, in all cases, longitudinally.

It is clear from fig. 27 that some difficulty attends the making of an aero-curve of the required section out of one piece of wood. This is undoubtedly the case, and although it *can* be done by very careful steaming, the author has no hesitation in recommending the model maker to steer clear of this course. In the first place it is almost impossible, without special moulds by which a constant pressure can be applied to the wood, to obtain a curve of the same section all along. The wood in steaming is distorted in the most uncertain manner, and unless most elaborate precautions be taken to prevent it, cools and dries in a very warped and twisted condition, the result being an altogether unsatisfactory job.

The author has discovered a means of making an aero-curve of the correct (or very nearly correct) section which overcomes all the above difficulties without introducing any inherent disadvantages of its own. This method has afforded the greatest satisfaction, and has never once turned out a failure, the resulting supporting surface being at once stronger, lighter, and more rigid than any that could be produced by the steaming method.

The procedure is as follows: Having cut a piece of the plank to the length required for the supporting surface, but with a breadth some half an inch less, plane it up with

FIG. 29. Wedge-shaped section of main portion of built-up aerofoil.

a light hand plane (the cheap American metal tool is excellent for this purpose) until it is throughout of the section represented in fig. 29, *i.e.*, a wedge tapering from a trifle over $\frac{3}{32}$in. at the forward end to not more than $\frac{1}{32}$in. at the back.

In planing a piece of wood as thin as this, the usual method of butting one end of the plank up against a bench-stop should not be used; instead, the *other* end of the plank should be secured to the bench by a clamp or similar contrivance, by which means the planing can be done with the wood in tension. With a bench-stop the wood is in compression, and it is almost impossible to prevent it rising up into a bow and breaking its own back when being planed.

Having planed the wood down to the required section, *do not sandpaper it,* as sandpaper makes thin wood curl.

The next step is to cut a strip of $\frac{3}{16}$in. wood the same length as the aero-curve, but only $\frac{3}{4}$in. to 1in. wide. This is now planed down to the section (fig. 30)—

FIG. 30. Initial section of front edge of built-up aerofoil.

and is then carefully glued or otherwise securely stuck to the front edge of the flat piece, as in fig. 31, after which it is planed and finished down to the final section (fig. 32).

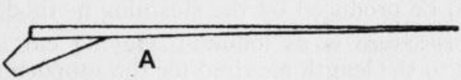


FIG. 31. Section of built-up aerofoil in the rough.

The hollowed-out portion at A (fig. 31) is easily cleared out, being first roughed out with a round-ended scraper (the blade of a penknife acts quite well in this capacity), afterwards being finished up nice and smooth with a piece of medium rough sandpaper wrapped round a pencil or other cylindrical object.

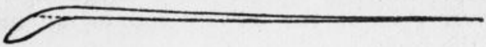


FIG. 32. Section of finished built-up aerofoil.

This curved portion of the supporting surface is the only one that sandpaper should be allowed to touch.

The glued joint should be varnished on both sides so as to render it waterproof, but the whole aero-curve can be so treated if desired.

For the sake of additional strength, cross-pieces of gummed tape may be laid on either side at intervals of 4in. or 5in.; they will prevent any accidental crack spreading. In the event of a crack appearing, it should be filled with glue or seccotine, as much as possible being squeezed out, and afterwards covered top and bottom with a strip of gummed tape or varnished paper.

Supporting surfaces of any of the plan forms illustrated in fig. 28 can be made on the above principle, though in the case D two edging pieces of wood are used, whilst in C a single piece is cut out to approximately the required curve, and finished up with the plane.

Plan-forms of Supporting Surfaces.

The best aspect-ratio of a surface, *i.e.*, ratio between the dimension *across* the line of flight to the dimension *along* the line of flight, has been found experimentally to be anything between 4 to 1 and 9 to 1. A happy medium, and one that will be found to give the most satisfactory results, is an aspect-ratio of 6 or 7 to 1; and the model maker will be well advised to stick to one of these figures unless he has very good reasons for adopting any other in their place.

The lift of an aero-curve depends upon the projected length of its leading edge (*cæteris paribus*). In fig. 28 the actual lengths of the leading edges of the four supporting surfaces there shown are different in every case—that of the elliptical one being the greatest—yet the projected length is in each case the same.

The rectangular surface (fig. 28A) gives the greatest lift, but suffers a disadvantage in that the disturbance of the air at the extremities of the curve is considerable. The air is unable to accommodate itself to the sudden change from interrupted flow to uninterrupted flow, and disturbance is the inevitable result.

In the semi-rectangular surface (fig. 28B) this disadvantage is almost entirely removed, whilst the construction remains the simplest possible.

D

The elliptical and "kite-shaped" plans may be preferred by some model makers, but in the writer's opinion they have little to recommend them. They obviate the disturbance difficulty, but are not so easy of construction as the other two forms.

On the whole the second plan-form (fig. 28B) is the most satisfactory, especially for use in a monoplane, although no great disadvantage will be found to attend the use of the pure rectangular plane, the inherent drawback of which may be to a certain extent counteracted by fitting the ends with vertical planes (fig. 33), which prevent the air flowing sideways over the bluff extremities.

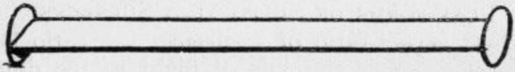


FIG. 33. Rectangular aerofoil with side fins to decrease edge disturbance.

"Bolsters" are used in the centre of wooden supporting surfaces in order to bring them to the correct curvature (fig. 34), cork, leather, or rubber washers being

FIG. 34. Bolster by which the desired curvature is given to a built-up aerofoil.

used to prevent the screws cracking the thin wood. The bolster may be made of white wood or other suitable timber, ½in. or less thick, cut to the shape shown, the reason for which will appear later.

ALUMINIUM SUPPORTING SURFACES

Aero-curves having a section closely approximating to the required "stream-line" form may be made without difficulty of thin sheet aluminium. Surfaces so made, however, are not to be recommended for rough usage, sa aluminium has very little elasticity in it, and readily "crumples" under a shock, when the only resource is a careful hammering out; even so, however, much of its strength will be found to have disappeared.

The construction is obvious from fig. 35. A piece of hard wood planed to the required section is used as a mandrel, and the front edge of the surface bent over it and hammered into position. The joint is all the better for being soldered, but aluminium soldering is not a very easy job, although it *can* be, as the writer has learnt, successfully accomplished.

FIG. 35. Section of aluminium aerofoil with bent-over entering edge.

The only advantage the aluminium aero-curve possesses is that inequalities of curvature can be corrected on trial by "dog-earing" one or other of the rear corners. Aluminium about 1-100th inch should be used.

BUILT-UP SUPPORTING SURFACES.

Built-up supporting "planes" may be preferred by some model makers as being a nearer imitation of the "real thing" than wooden or aluminium aero-curves. Although they are by no means difficult to make, they are, nevertheless, not so easily constructed as the wooden type, over which they do not possess any advantages when used for sizes of less than 4ft. spread. This is due to the fact that the joints between the thin lateral ribs and the longitudinal "spars" are none too easy to make really strongly and satisfactorily, whilst it is also a matter of great skill to make the surface thoroughly smooth and taut, at the same time keeping the whole perfectly rigid. Built-up "planes" will not, furthermore, stand anything like as much rough usage as the wooden aero-curve.

There are two types of built-up aero-curve—the "double surface" and the "single surface." Of these the former is preferable on account of its nearer approach to correct "stream-line form," but the latter is somewhat lighter. There is not much to choose between them in the matter of ease of making.

The method of construction of one form of double surface "plane" is obvious from fig. 36—

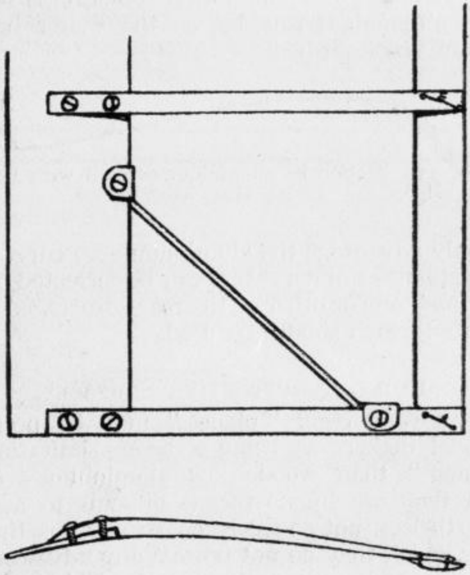


FIG. 36. Method of building up the framework of a fabric-covered aerofoil.

The ribs should be spaced not more than 4in. or 5in. apart. The front and back spars are formed of American white wood or other suitable timber planed to the wedge-shape indicated in the section. The ribs are sewn to the rear spar with brass wire, the ends of which are twisted together, cut off short, and hammered down flat. All joints should be glued. Further security is gained by driving and countersinking a small screw through each rib and the spar at their mutually thickest part.

An aluminium wire or strip angle piece (fig. 36) is attached to the end ribs in order to make all fast. Care must be taken to see that no part of this angle piece extends above the correct section.

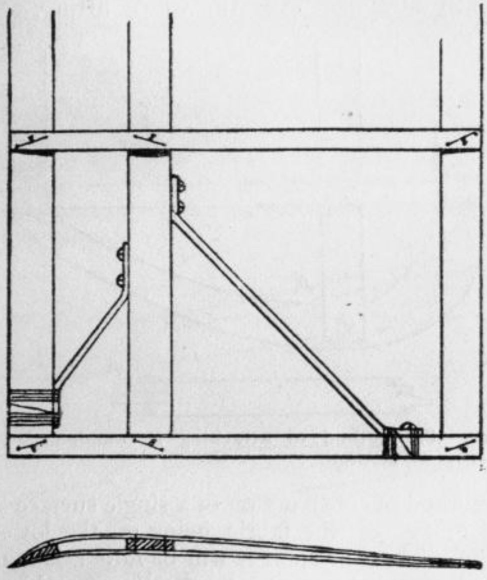


FIG. 37. Alternative method of constructing framework of a fabric-covered aerofoil.

Another form of "double surface" sustainer is illustrated in part plan and section in fig. 37, which is sufficiently clear to render much explanation unnecessary.

The ribs in this case can be made of split bamboo, but any "springy" wood may be used. They are fixed to the front and back spars by "sewing" with brass wire, and to the mid spar by a lashing of thin twine, all joints being well glued up. Angle pieces are used as before.

A nice finish may be given to any of these forms of double-surface plane by cutting a piece of stoutish aluminium sheet to the required shape, and fixing it to the three spars (the middle one being made longer for this purpose) in the manner shown in fig. 38, the fabric being subsequently stretched over the whole fitting.

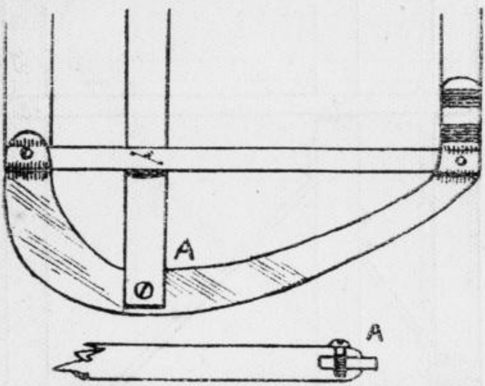


Fig. 38. Method of attaching a rounded end to a fabric-covered aerofoil.

The method of construction of a single surface "plane" is shown in fig. 39, the fabric being on the lower side of the section. The rear spar, it will be noted, is made semicircular so as to accommodate itself smoothly to the "pocket" of fabric which surrounds it.

It is important to observe that the fabric which forms the surface of a built-up aero-curve *must be stretched from end to end of the frame*, and not from front edge to back edge. If the latter were done the fabric would have no curvature between the ribs, but would simply become as nearly a flat surface as it could get.

Bolsters similar to those used with wooden planes are used for mounting the supporting surfaces, the holding-down screws passing through the spars.

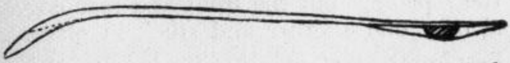


FIG. 39. Section of single-surface fabric aerofoil, showing "pocket" around the rear spar.

Holes for sewing wire and screws should be drilled in all cases, otherwise cracks and consequent failure inevitably result.

FABRICS AND THEIR FIXING.

In the author's opinion there is only one kind of fabric suitable for use with built-up supporting surfaces. This is a light form of "aero-cloth," marketed by the leading pneumatic tyre and other manufacturers. It consists of a fine grade cotton fabric rubberised on one side or otherwise water-proofed.

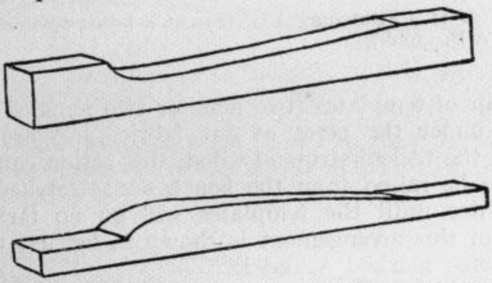


FIG. 40. Moulds for stretching the top and bottom surfaces of a fabric aerofoil.

Tracing linen and paper have been advocated for this purpose, but suffer under the great disadvantage that they are ruined by wet or even slight dampness, the ensuing "cockles" rendering the surface erratic in action and greatly distorted.

"Jap" or other silk may be used, but it is difficult to work on account of its extreme flimsiness.

Joints may be made in rubberised aero-cloth by means of rubber solution.

For greater security the fabric should be sewn at the ends of the "plane," but the front and rear edges should be lapped over one another and stuck in place.

The best method of fixing the fabric to the frame is to cut two male and two female templates to the exact curvature of the "plane," as illustrated in fig. 40. The aero-cloth is then laid down flat and evenly on the bench to which it is tacked securely down (strips of wood are placed over and across the fabric so that it is sandwiched at each end between this wood and the bench), leaving a space between the strips about 1ft. longer than the total length of the frame to be covered.

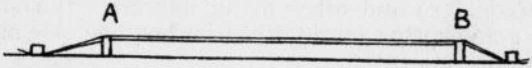


FIG. 41. Stretching a surface of a fabric-covered aerofoil. A B, moulds.

A pair of templates (two male or two female) are then slipped under the piece of flat fabric, and are pushed towards the tacked strips of wood, this action causing the fabric to be raised from the bench and stretched tighter and tighter until the templates will go no farther. A section of this arrangement is shown in fig. 41, the templates being marked A and B.

On top of this well-stretched fabric, which will be either convex or concave in cross section according to whether the male or the female templates have been used, the frame of the "plane" is laid, its ribs and spars having previously been thinly coated with seccotine. The fingers are then thrust underneath, and the seccotine thoroughly "worked" into the fabric everywhere. As soon as this is done, the whole can be left to set, when the other side of the frame is covered in a similar operation.

The procedure for a single surface aero-curve is, of course, precisely similar, except that only a male pair of templates is required.

CURVATURE.

According to some authorities the depth of curvature of the aero-curve should be greatest in the centre of its length, and should gradually decrease as the extremities are reached, where it should be practically flat. The writer has found no advantage to accrue from this practice; but those who desire to try it will have no difficulty in making such a "plane." After the centre ribs have been made, the remainder are made in pairs of decreasing curvature, the whole being fitted up in the manner described above.

The wooden aero-curve when sprung down on to its "bolster" automatically takes a decreasing curvature towards the extremities.

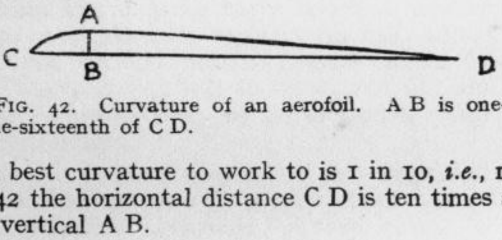


FIG. 42. Curvature of an aerofoil. A B is one-tenth to one-sixteenth of C D.

The best curvature to work to is 1 in 10, *i.e.*, referring to fig. 42 the horizontal distance C D is ten times as great as the vertical A B.

FIG. 43. Angle of incidence of an aerofoil. C E is one-tenth to one-twentieth of E D.

The aero-curve should be mounted on the bolster at an inclination between 1 in 20 and 1 in 10 (this can best be determined by experiment), *i.e.*, referring to fig. 43 the vertical distance C E is 1-20th of the horizontal E F.

* * * * * * *

A wooden supporting surface (fig. 28B) made as described, 2ft. 9in. long, average aspect ratio 9 to 1, weighs 1½ ozs., and lifts 6½ ozs. easily at twenty miles per hour.

A double surface "aero-curve" made of special aero-cloth (lightest gauge rubbered one side only) has a length of 4ft. and a uniform width of 6½in. Made as described above, it weighs 3 ozs.,* and carries 14 ozs. easily at twenty miles per hour. When supported between two uprights, one at each end, it sustains a weight of 2¼ lbs. in the middle with no sign of giving.

* The weight of the aero fabric alone is 1¼ ozs.

CHAPTER IV.

SCREWS.

Although a model aeroplane will be productive of considerable instruction and amusement as a glider pure and simple, *i.e.*, when it is not fitted with any propulsive or tractive mechanism at all, but is simply projected from hand, there must be few who will gainsay that the addition of a screw and means to drive it add tremendously to the interest and instructiveness of a model, and turn an inert instrument into a real flying machine.

The construction and design of screws, especially the latter, present some complex problems which have hardly yet yielded to solution. Fortunately, however, the model maker can afford to be fairly lavish in power, hence he will not be called upon to carry his calculations very far beyond the decimal point, nevertheless screw efficiency and economy are no less to be striven for, and research into these matters with the aid of models well repays the trouble it entails.

It is a very good plan and a very helpful one to bear in mind that a screw is neither more nor less than a particular form of aeroplane ; it may, in fact, be regarded as a monoplane whose wing tips have been warped (see Chapter I.) to an altogether disproportionate extent. Its course, too, is not horizontal, but vertical ; not, as in the aeroplane, against gravity, but against the resistance of the air, and hence only against gravity indirectly.

Exigencies of " aspect ratio " apply to screws as much as to supporting surfaces, as also do considerations of stream-line form and plan form to give the least disturbance of the air. Fig. 44 gives a selection of plan forms, of which A is clearly the best, as it produces little or no disturbance. It is, however, not a strong form, and will not stand very many knocks. The author, on grounds of general experience, recommends the form shown at B. C produces too much disturbance, whilst D, unless made very heavy at those points, betrays a liability to snap off at the narrow parts close up against the boss.

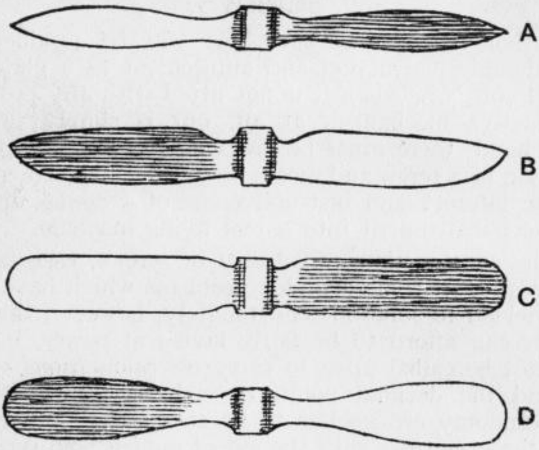


FIG. 44. Four different types of screw.

The aspect ratio of a screw may be, without disadvantage, a higher figure than that suitable for supporting surfaces.

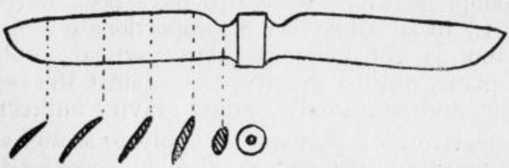


FIG. 45. Projection of one blade of a helical screw showing sections corresponding to different points along the blade.

The form or section of the blades varies according to the distance of the point taken from the centre of the screw. Of the screw B in fig. 44, which is repeated for the sake of reference, the sections should be approximately those as shown in fig. 45.

It is clear that the dipping front edge is as much an advantage in screw design as in that of aero-curves, and there is no doubt that its employment ensures a high efficiency. It is difficult, however, as will be gathered from subsequent details of screw construction, to embody that excellent feature in screws for model aeroplanes.

Pitch.

The pitch of a screw is the linear distance that screw travels theoretically in one revolution. In fig. 46A the short blade line represents the section of a screw at the end of its

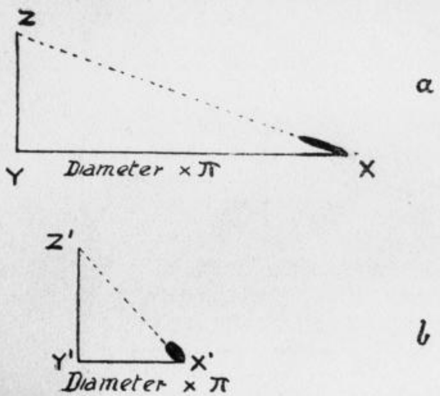


Fig. 46. Diagrams illustrating the pitch of a screw as being the theoretical forward distance that it travels during one revolution, the angle of the blade section varying inversely as its radial distance from the centre of the screw.

blade. The base line X Y represents a linear distance equal to the travel of the blade tip, *i.e.*, the diameter of the propeller × π. The dotted line indicates the theoretical course of the screw blade during one revolution, and the perpendicular line Y Z represents the consequent pitch.

Now in a theoretically correct screw the pitch must at all points be the same. If a point be selected at a smaller distance from the centre than the blade tip, the angle at that point must evidently be greater in order to obtain the same pitch Z Y with a shorter base line (fig. 46B). At

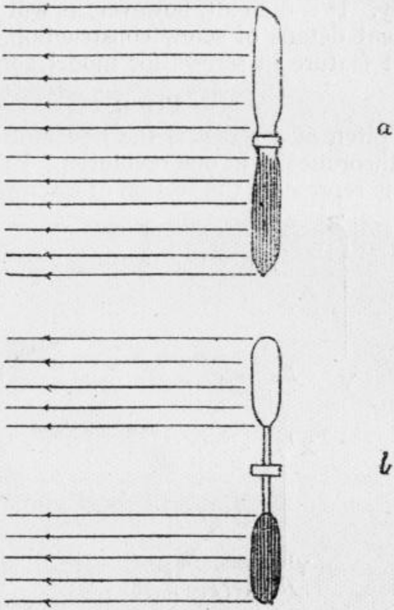


FIG. 47A. A truly helical screw delivers a cylinder of air. FIG. 47B. An incorrectly designed screw delivers a "tube" of air.

the centre of the screw the blade must clearly be at right angles to the plane of rotation, and this should obtain as nearly as may be in all screws. This practice, as suggested later on, may perhaps with advantage undergo slight modification.

It would appear that the portions of the blades adjacent to the boss of the screw do very little work. This to a certain extent is the case, but the point is that they offer no resistance in the line of travel. Some screws are made (see fig. 58 later) with the inner portions of the blades cut away to a minimum in accordance with this idea; but there is no doubt that their efficiency is seriously affected by this practice. Certain French designers adhere to this indefensible type of screw, which seems to account for the extravagant engine power with which some aeroplanes are endowed.

Fig. 47 is a graphic comparison of the correct and the incorrect forms of screw. A (a true helix with constant pitch) delivers a *cylinder* of air, which is acted upon by atmospheric friction on its outside only; whilst B produces a *tube* of air, which suffers loss of efficiency in two places, outside and inside.

Balance of Screws.

It is almost needless to say that the pitch on either side of the boss must be the same at all points equidistant from the boss; whilst the same applies to the weights of the blades, which, of course, must balance one another absolutely. Failure in either of these respects leads inevitably to considerable irregularity in running and to a vibration and "shivering" which is disastrous to the flight of any aeroplane, full size or model.

Speed of Screws.

Owing to skin friction small aerial screws are sometimes liable, when driven at very high speeds, to "cavitate." That is to say, they carry a quantity of air round and round with them, and thus the blades strike no unbroken or "solid" air at all; hence they lose some of their driving effect.

For this reason model screws should never be driven at much over 1,200 revolutions per minute; 1,000 r.p.m. is a still more satisfactory figure to work to. On this account the pitch of the screws should be kept fairly "coarse." The author's screws, with which he has been singularly successful, have the blades at a distance of half an inch from the tips set at an angle of 45° to the screw shaft, *i.e.*, at right angles to one another, thus affording a pitch of roughly three times the diameter of the screw. This figure is admittedly a large one, but the author can testify to the good results which follow in the train of its employment in models, at any rate.

It need scarcely be said that the screw should be throughout perfectly smooth and free from irregularity of any description. The edges of the blades should not be made *too* sharp, as they readily chip in those circumstances, and some efficiency is consequently lost.

A thoroughly well designed and carefully made screw will, when rotating, exhibit no signs of throwing the air out tangentially, *i.e.*, by centrifugal force. On the other hand, it will actually draw air in. This test can be made with tobacco smoke, thin strands of silk, or a lighted match.

Screws are of two sorts—tractors, those whose position is in front of the machine they drive; and propellers, those which are placed at the back of the machine, as in marine practice. At first glance there would seem to be no difference between a tractor and a propeller, except that of position; but experiment goes to show that the latter type is very considerably the more efficient.

The reason of this is that the machine preceding the propeller drags with it (due to skin friction and other causes) a considerable quantity of air, which in the region closely surrounding the rear portion of the machine is travelling as fast as the machine itself. It is in this air that the propeller works, and from this fact it derives considerable benefit, since it is tantamount to running with the wind. The same phenomenon occurs sometimes to a marked extent in ships. A numerical example will perhaps make the matter more clear.

A certain propeller gives a theoretical speed of thirty miles per hour; owing to "slip" the actual speed is only twenty miles per hour. The air in which it works is, however, travelling forward at ten miles per hour, hence the propeller gives a speed of thirty miles per hour, *i.e.*, it is apparently perfectly efficient. The author has himself observed results which have led him to the belief that it is quite possible to obtain in this manner figures which indicate an efficiency greater than perfection.

Such a paradox admits of a ready explanation, which is as follows: A large tractor would, it is clear, give the same results, according to the above, as a smaller propeller. The point is that they would both absorb the same *power* if the respective speeds they produced were equal.

In consequence of this, and also of the fact that a propeller is guarded by the machine, and therefore much less likely to come to harm than a tractor, it is certainly advisable, whenever and wherever possible, to employ the propeller type of screw.

CONSTRUCTION.

There are several ways of making model screws: (1) To cut the screw out of a single piece of wood, (2) to cut it out of a built-up piece of wood, (3) to bend it out of thin wood or metal, (4) to build the screw up, and (5) to make the screw of fabric.

These methods will now be dealt with in their order:

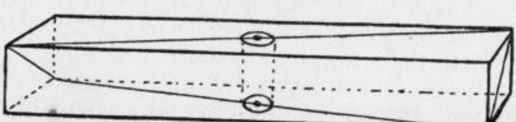


FIG. 48. Method of "laying off" a piece of wood from which a truly helical screw is to be carved.

(1) *To cut the screw out of a single piece of wood.*—This is a method not to be recommended for screws much over 8in. or 9in. in diameter with a width of 1in. and a pitch up to 10in. or 1ft. Fig. 48 shows that if a single piece of wood be used, the grain of the wood cannot possibly

lie along *both* the edges of the screw; thus breakage is extremely likely to ensue. However, single-piece screws work very well, and are little trouble to make.

A rectangular piece of wood square in section (or oblong according to pitch) is cut to the required length, and planed smooth and square all over. It is then marked out with lines as shown in fig. 48, and as much of the wood as is required cut away with a penknife, or roughly rasped out with a half-round rasp, until it assumes the shape represented in fig. 49—

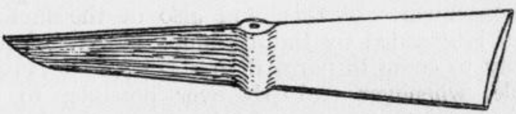


FIG. 49. A truly helical screw in the rough. Its form may be traced in the previous figure.

after which it is finished up to any of the shapes shown in fig. 43. A half-round rasp *must* be used in the roughing-out process, as a little thought will show that no part of a true helix is a plane, hence if a plane (flat) rasp be used, an incorrect screw is more than likely to result.

(2) *Cutting the screw out of a built-up piece of wood.*—This method, by which it is possible to get a *straight grain* everywhere in the screw, and in consequence great strength with lightness, is employed by pattern-makers in constructing patterns for metal screws on account of the fact that a screw so made will not warp so much as a single piece of wood.

After trying all manner of screws constructed in every conceivable way, the author prefers above all others a screw cut out of a built-up piece of wood. It is light, nice-looking, and extremely strong; and in his experience has never been known to break, although some hard knocks have been met with.

A further advantage will be observed to be incidental to this method of constructing screws, viz., the hole for the screw shaft is bound to be, for all practical purposes, true.

Any number of separate wooden units (each of which is, it should be remembered, a complete screw) may be used, but it is not advisable to have, nor is there anything gained in having, more than six to the inch, *i.e.*, if the screw be $1\frac{1}{2}$in. deep *at the boss*, not more than nine pieces should be used, but a smaller number is quite permissible.

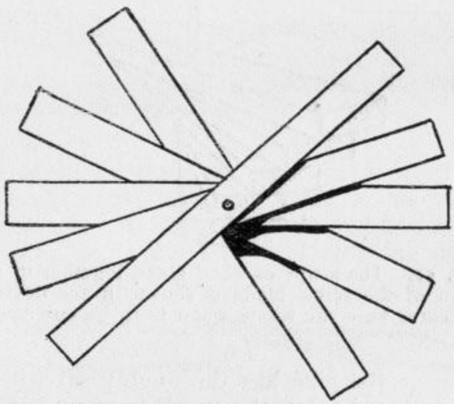


FIG. 50. Plan of method of building up a helical screw of several strips of wood which are threaded upon the screw shaft.

A plank of American white wood is taken and planed smooth on each side to a thickness of $\frac{1}{6}$in., or thereabouts, being then sawn into the required number of strips, the breadth of the strips being, roughly, one-sixteenth of their length. These strips are all of the same size, and are all drilled flatwise (with a hole to suit the screw shaft) through the centre.

They are then threaded on to a cycle spoke, as represented in plan in fig. 50.

A thin even coat of glue or seccotine is then laid on each slat top and bottom (with the exception of the end strips, which are glued respectively top and bottom only), and they are then separately brought into their required positions, according to pitch, an end view of the whole being given in fig. 51, in which the final section of the screw at the extremity of each blade is shown in dotted lines. The angle of "stepping" is, if the holes in the strips be central, obviously the same at either end.

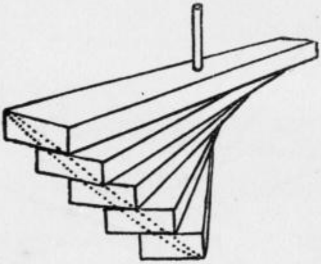


FIG. 51. The strips of wood glued together in position. A section of the screw blade is shown in the dotted lines, and indicates how the waste wood is to be cut away.

As soon as the glue has thoroughly set (this takes at least twenty-four hours), the rough ends are cut off square with a saw, and the section desired marked on the "steps" as a guide, after which the screw is roughed out and dressed with sandpaper until it is down to the required thickness, which for propellers less than 12in. in diameter may be safely carried as low as $\frac{1}{16}$in., or even less.

The glue will have fixed the dummy screw shaft fairly tight into the wood, but it can easily be driven out.

The finished propeller is shown in fig. 52.

It will be observed that this screw is (with the exception of the boss) a pure helix, *i.e.*, the angle at any point varies inversely with the diameter, so that the *resultant pitch* is everywhere the same. Close up by the boss the diameter is negligible, hence the angle is practically a right angle.

Experiments may be carried out with screws having an effective pitch at the boss—that is to say, the pitch is everywhere on the screw slightly smaller than it theoretically ought to be, such as that shown in fig. 53.

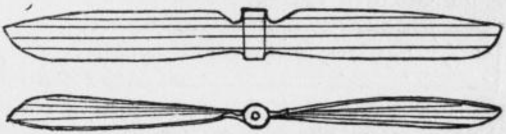


FIG. 52. Side elevation and plan of a helical screw built up of several pieces of wood.

This type gives, if anything, greater efficiency than the purely helical screw, although there is no very appreciable difference. However, experimentation along these lines cannot fail to be productive of interesting and valuable results.

FIG. 53. An alternative form of quasi-helical screw in which the pitch at every point is slightly less than would be the case if the screw were truly helical.

It is important that screws made from built-up wood, as above, should be given a coat or two of thin waterproof varnish, which prevents them "coming unstuck" in case of their getting wet.

(3) *Bending screws out of thin wood and metal.*—There are two methods of making screws in the above manner, neither of which results in a thoroughly successful screw, but they both commend themselves on the score of ease and rapidity of manufacture.

In each case a strip of metal, vulcanite, or thin wood (American white wood will serve in this case, but it is better to employ birch or ash if it be available) is taken and cut to the same shape and dimensions the finished screw would have if it were pressed out flat.

On this strip, in the first method, are marked a series of lines arranged symmetrically about the centre of the strip, as indicated in fig. 54.

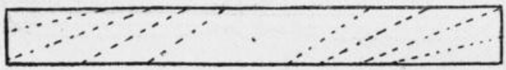


FIG. 54. Method of marking off a strip of wood which is to be bent into the form of a screw.

The strip is then bent (in the case of wood this is done under steam, whilst vulcanite can be readily bent after being immersed for a few minutes in boiling hot water) at each of these lines in turn until it appears somewhat as shown in fig. 55.

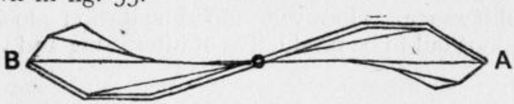


FIG. 55. Appearance of a bent wood screw.

The centre line of the bent-up extremity A should now be at right angles or thereabouts to that of the extremity B.

This type of screw, which is not so inefficient as it looks, cannot be mounted in the ordinary way with a cycle spoke, but requires a piece of wire—the screw shaft—to be bent around it, as in fig. 56.

FIG. 56. Method of attaching the screw shaft to a bent wood screw.

The second method, which is the easier, is to cut the material used to the shape shown in fig. 57. It is then bent to the required pitch along the dotted lines. This type of screw has the inherent disadvantage that the whole middle portion offers a big resistance to the air when the machine is travelling along, whilst at the same time, of course, it does no work.

Thin wooden screws can also be made out of a strip by steaming the whole and then placing one end in a vice and, holding the other between the fingers, steadily turning the latter until its centre line is at right angles, or beyond right angles, with that of the extremity in the vice. These bent wood screws are, however, unless precautions be taken, liable to warp back to their original form, especially in damp weather, whilst they also (the wood being under a severe strain) exhibit a deplorable tendency to crack on the slightest provocation.

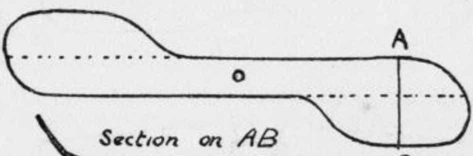


FIG. 57. An alternative form of bent wood screw, the section of a blade being shown alongside.

(4) *Building up the screw.*—This is also an easy and expeditious matter, though, as is the nature of easily made things, it is distinctly inefficient when compared with the more carefully and laboriously constructed article. It has also little capability for resisting hard knocks, this excellent quality being possessed by wood to a far greater degree than any other material.

Fig. 58 shows three kinds of built-up screws, of which C is perhaps the best. It is impossible in this mode of manufacture to obtain blades of anything like the correct form, although a slight improvement may be made by bending the metal blades of A to the section shown at

A1. B represents a vulcanite screw, the flat or twisted blades of which are inserted in a small piece of brass tube, the ends of which are pinched up flat at the required angle to one another, as indicated roughly in B1. In C is shown an extremely simple form of screw. A wooden boss C1 has angular slots cut in it, and in this are glued the wood or other blades.

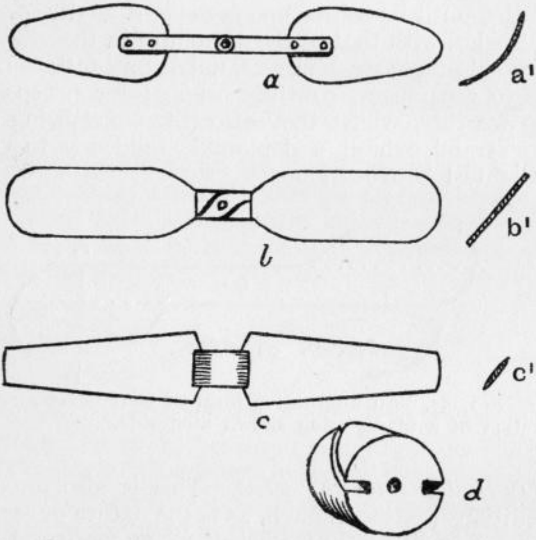


FIG. 58A. A built-up screw consisting of aluminium blades riveted to a central arm. FIG. 58B. A vulcanite or celluloid screw in which the blades are held in a piece of thin brass tube pinched at each end to the required angle. FIG. 58C. A wood screw, consisting of plain flat blades, glued into "saw-cuts" in a wooden boss.

(5) *Making the screw of fabric.*—In this connection thin sheet rubber, or a very elastic rubberised fabric, is required. Two pieces of the fabric are cut and folded, being afterwards solutioned down at the edges, as shown

in fig. 59—the result being a couple of bags as indicated at B in the figure.

Next a couple of pieces of split cane (beech or birch will serve in this capacity) are rounded into rods of the length required for the screw, and are drilled centrally and threaded on to the screw shaft, where they are held

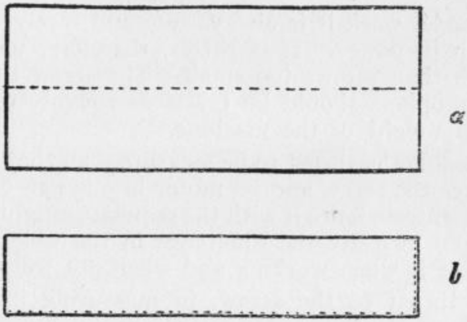


FIG. 59. The blades of a fabric screw are made by constructing two open-ended bags of the fabric.

apart by a tubular cane distance piece slightly longer than the fabric bags are broad. The rods are then set as shown in fig. 60, segmental distance pieces of stout brass wire being fixed across their extremities, and lashed to the inner edges of the rods.

FIG. 60. The framework of a fabric screw.

Over this skeleton screw the fabric bags are now stretched, and the result is, if the fabric be elastic and extensible, a very nearly true helix. This form of screw, though somewhat crude, is capable of giving excellent results, and is, furthermore, practically unbreakable.

There are, doubtless, other screws with which good efficiency can be obtained; but the above are the types which have been actually tried by the author. Readers will probably be able to improve on the above, or improvise fresh ones of their own.

SCREW THRUST.

In model work it is always safe and rarely difficult to be lavish in power. If is better, therefore, to fit screws too large than screws too small. The screw thrust for a model aeroplane should be taken as roughly one quarter the total weight of the machine.

To enable the thrust to be measured, all that is required is to place the screw and its motor in one pan of a pair of scales, counterbalance it with the requisite weights, start the screw, and measure the difference in the weight required to balance it when working and when not working.

The thrust of the screw, in measuring in this way, should be preferably a downward one.

CHAPTER V.

TAILS AND ELEVATORS.

Tails and elevators, in the light of Chapter III., present no difficulties. They may, if desired, be made of the correct curved section when they have to act as subsidiary supporting surfaces ; but in general very little is gained by using anything but a plain flat strip of wood or thin aluminium, or a piece of fabric stretched over a suitable frame, the procedure of construction being exactly similar to that adopted for fins (Chapter VI.)

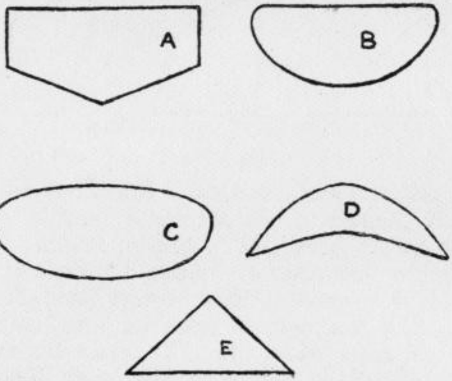


FIG. 61. Various forms of tail plane.

Tails and elevators, for the sake of simplicity, should be made of the plan-form indicated in fig. 61A. Other plan-forms are also shown in the figure, but they have nothing to recommend them except perhaps on the score of looks. On the other hand they possess no disadvantages ; their only drawback (if it be a drawback) is that they require a little extra labour over and above that required in making the one marked A. D and E should not, in any case, be used as elevators. They are more suitable for purely directional tails, *i.e.*, tails which are not called upon to lift their own weight.

The method of fixing employed with tails and elevators is exactly similar to that of attaching the main supporting surfaces. They are screwed or otherwise secured to suitably shaped bolsters, which, in turn, are lashed with elastic to the required point of the frame. Adjustment can be made either by increasing the angle of the bolster with the aid of a wedge, or by bodily moving the elevator (or tail) nearer to or farther from (as the case may be) the main supporting surface.

CHAPTER VI.

FINS.

Although birds afford us no precedent for the vertical fin or rudder by which the horizontal steering of an aeroplane may be aided, there is no doubt but that in some cases flying machines may be improved by their addition. Whether a vertical fin prove an advantage or not, this at least is certain—that if it be properly made and located it can do no harm, as the extra head resistance it entails is for all practical purposes negligible.

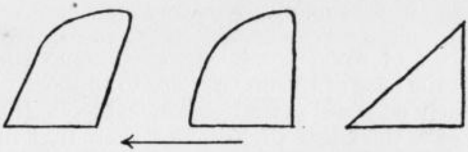


FIG. 62. Three forms of fin.

Just as the rudder of a boat is placed at the rear, so that of an aeroplane, when its use is desired, should be arranged in a similar position. If placed on an outrigger in front of the main "plane" it exercises, when caught by even the slightest gust of wind, a moment which results in the machine losing all sense of direction, and generally toppling over sideways. The fin when used for steering purposes should, therefore, be placed slightly in the rear of the main supporting surface, when its turning moment is not felt so violently, and when, consequently, its adjustments are not so sensitive, and easier to make.

It is advisable, as has already been pointed out, to allow the fin to stretch above and below the centre line of the machine, so that in the event of the latter being caught in a cross wind, the pressure is equal top and bottom, and the wind has, therefore, no tendency to twist the machine about its longitudinal axis.

Thin wood of one of the shapes shown in fig. 62, with nicely smoothed and chamfered edges, makes the best fin, but has the disadvantage that it cannot be, as aluminium can be, simply twisted to the required angle.

Thin aluminium may accordingly be used for this purpose, its mode of mounting on the frame of the machine being the same as that which is used for the wooden fin, which is as follows:

FIG. 63. Adapter for fin.

Two strips of wood are taken, each some ¾in. to 1in. longer than the base of the fin they are to support. Between them at each end are placed distance pieces ¼in. to ⅜in. long, and of a thickness slightly less than that of the fin. When these members are assembled by means of a small screw at each end, the fin-mount takes the form shown in fig. 63.

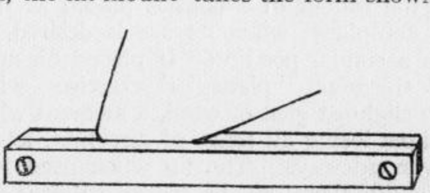


FIG. 64. Method of inserting metal fin into its adapter.

The bottom edge of the fin is slightly chamfered to enable it to be thrust into the space between the sides of the mount, where it sticks by mere friction.

With an aluminium fin the distance pieces in the fin mount may be dispensed with; then if the base of the fin be rounded at one end (fig. 64) and sharpened on the edge with a file, no difficulty will be met in forcing it between the side pieces.

The fin mount can be lashed to the frame at each end either with twine or elastic; the latter is preferable, as it allows the fin to be moved when necessary.

If a wooden fin is to be used as a rudder, the mount, instead of being attached to the upper or lower surface of the frame member, is lashed with elastic to the side of the frame member, where any angle may be imparted to it by inserting a wedge of a suitable size between the frame and the fin mount (fig. 65).

FIG. 65. The angle of the fin can be altered by inserting a wedge between its adapter and the frame.

Fins may also be made by covering a wire frame, bent to the desired shape, with some sort of fabric, which may be double in the form of a bag, as used in the fabric propeller (fig. 60), or may be single, and sewn to the wire frame all round. If stoutish steel wire be used, the spring of the frame will be quite sufficient to keep the fabric taut and even.

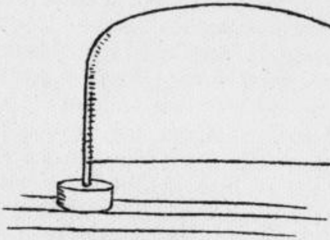


FIG. 66. An adjustable fin with wire frame.

This type of fin may be mounted in several ways, perhaps the best being that in which only one end of the wire frame is attached to the machine, adjustment being then made by simply twisting the fin round to the desired amount (fig. 66).

In a second method (fig. 67) both ends of the wire frame are bent to the shape shown, and are thus enabled to slide, when required, to any position, when a single frame is used. With this attachment change of direction is attained by bending the front upright of the fin one

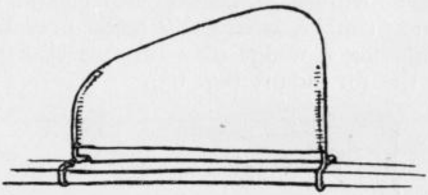


FIG. 67. Alternative form of adjustable fin with wire frame.

way and the rear upright the other way, according to circumstances. The fabric, if fairly elastic, will accommodate itself to this warping, which need never be very much if the fin be placed in the correct position, which must be ascertained by experiment.

CHAPTER VII.

DESIGN.

It will be a good course to pursue to commence with the simplest possible form of aeroplane, which requires the least mechanical skill in its construction, and proceed by easy stages to the more ambitious models which are a delight to the eye when stationary, as well as fascinating to watch when in flight.

Simplicity in the design of model aeroplanes is, as it is in the design of every other mechanical contrivance, a matter of the greatest importance, hence the aim of the flying machine constructor must be the elimination of unnecessary parts compatible with general soundness of design. Complication invariably spells liability to failure and increased resistance.

It is, of course, possible to make extremely strong girder and cantilever constructions marvels of lightness, and there is no reason why such arrangements should not be introduced into the model flying machine. In the author's opinion, however, a straightforward honest stick is preferable to a veritable spider's web of interlaced struts and trusses, even though the latter may be only half the weight of the former. There is no question at all as to which stands up to its work the longest, gives the least trouble, and offers the least resistance. However, there is reason and moderation in all things, and in the designs included in this chapter there will be found plenty of scope for nice work.

No dimensions are given in the following designs, but the parts are drawn as nearly as possible to scale.

The author thinks it best to suggest a simple framework construction for each machine, and leave any embellishment to the discretion of such builders as think sufficiently well of the general design to adopt it.

FRAMEWORK.

Since head resistance is a factor of great magnitude, the framework should be considered in its approximation, or otherwise, to stream-line form no less than the supporting surface and the screw. All square surfaces to meet the wind should be avoided ; round section is better than square, oval better than round, and that indicated in fig. 68 better than all three.

All framework should accordingly be made as near as possible this section, as far as is convenient to the particular arrangement adopted.

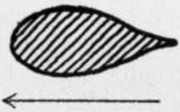


FIG. 68. Correct sectional form of uprights and other framework members.

Guy wires and stays should be avoided if possible. They give endless trouble, and are difficult to adjust to a nicety. Where such construction is required a thin strip of wood of the correct section is far preferable to either wire or twine, and is able to stand also a small amount of compression. In addition, wood need not be under heavy tension, and it has consequently little tendency to distort a framework.

Rigid triangular construction should be embodied as far as possible, and plenty of strength given to such parts of the framework as have to resist the powerful torque of an elastic motor, especially when such a power plant is unbalanced.

When a single propeller is used, a small lead weight must be affixed to the wing which receives the consequent upward torque, unless the main supporting surface be divided into two portions which are placed dihedrally (see fig. 19).

In all these models the "bolsters" of the main planes, elevators, and tails are attached to the framework by a lashing of elastic at each end. Upon the "plane" striking anything, the rubber "gives," and saves damage.

The author need hardly say that if any of these designs fly successfully directly they are made, it will be an occurrence bordering on the miraculous. Slight differences in details of angles, etc., variations in materials, the state of the atmosphere, all render experimental adjustment absolutely necessary. The models will, one and all, however, fly successfully upon the completion of adjustments, provided care has been taken to make them "according to the book."

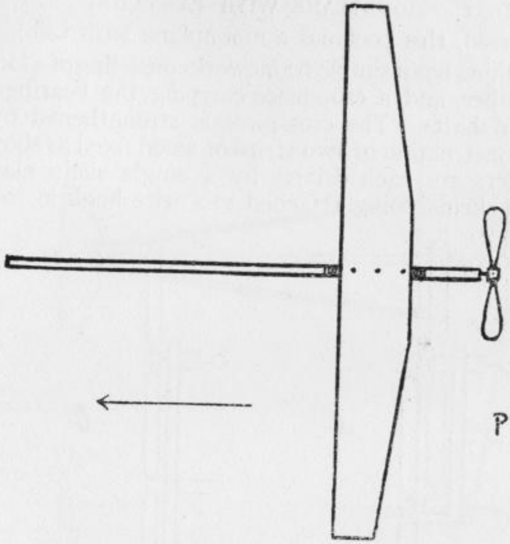
Nothing is more frequent than the fact that several people, widely divided, have the same or a similar idea all at the same time. It is more than probable that some, if not all, of these designs have been thought of and made by other experimenters. To those upon whose corns the author unwittingly treads he would express the assurance that every one of the designs, except the first, is original (as far as he is concerned), and has been arrived at by entirely independent experiment and research.

No. 1.—Simple Monoplane.

This machine has a single skein rubber motor driving a single propeller. Adjustment is made by sliding the supporting surface along the frame, which is a simple stick of suitable wood. The locus of the centre of gravity of the machine should be roughly the centre of the sustainer, as marked in the figure with a dot.

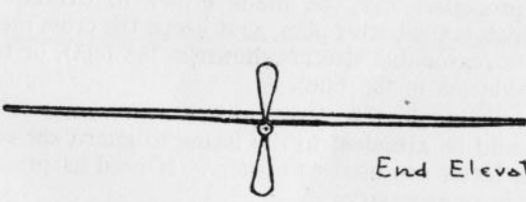
If desired, the elastic can be enclosed in a light tube of stiff paper, aluminium, or celluloid, this tube forming the main frame.

Tests of this machine running in either direction may be made by reversing the " plane," whilst a small elevator or tail may be added. The effect of a vertical fin placed at various points in front and behind the plane may be noted.



Plan

Side Elevation



End Elevation

No. 2.—Monoplane with Elevator.

(If reversed, this becomes a monoplane with tail.)

This machine has a simple framework consisting of a longitudinal member, and a crosspiece carrying the beaiings of the propeller-shafts. The crosspiece is strengthened by a triangular construction of two strips of wood fixed as shown. The propellers are each driven by a single skein elastic motor, both skeins being attached to a wire hook in front.

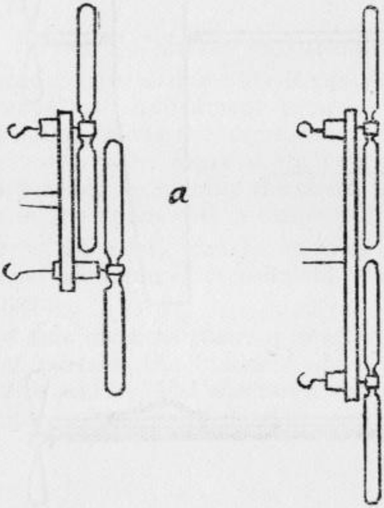
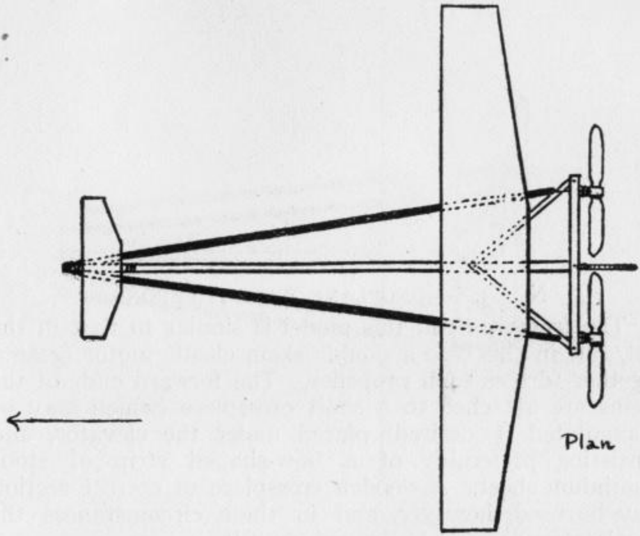


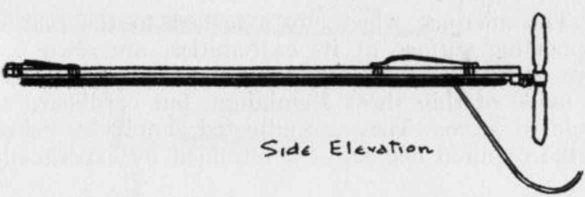
Fig. 69. Alternative methods of using a twin screw installation.

The propellers may be made either to overlap each other, which is the better plan, as it keeps the cross member down to a reasonable size (as shown in fig. 69a), or to run side by side (as in fig. 69b).

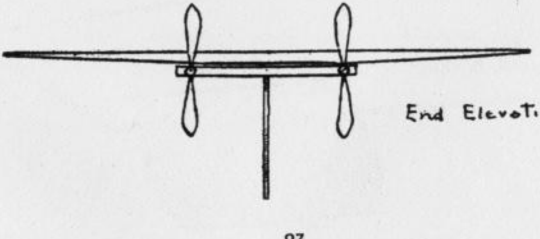
As indicated in the design a runner of cane or bent wood should be attached to the frame to guard the screws when the latter are used as *tractors.* If used as propellers a guard is unnecessary.



Plan



Side Elevation

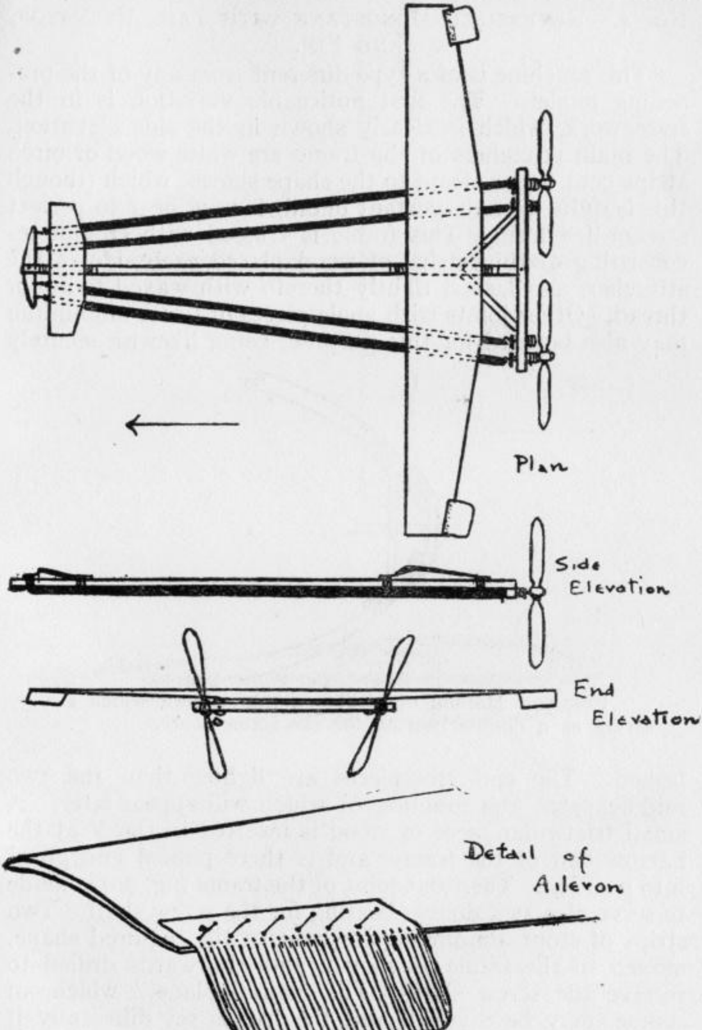


End Elevation

No. 3.—Monoplane with Ailerons.

The framework in this model is similar to that in the last, but in this case a double skein elastic motor (geared together) drives each propeller. The forward ends of the skeins are attached to a short crosspiece (which may be triangulated if desired) placed under the elevator, and consisting preferably of a bow-shaped strip of stout aluminium sheet. A wooden crosspiece of correct section may be used, however, and in these circumstances the elastic strands may be looped over it.

The ailerons, which are attached to the rear of the supporting surface at its extremities, are sewn on with wire or fixed in some other suitable way. They may best be made of thin sheet aluminium, but cardboard can be made to serve. They are adjusted simply by being bent to the required degree, as determined by experiment.


Plan
Side Elevation
End Elevation
Detail of Aileron

No. 4.—Reversible Monoplane with Tail, Elevator, and Fin.

This machine is of a type different from any of the preceding models. The first noticeable variation is in the framework, which is clearly shown in the side elevation. The main stretchers of the frame are white wood or birch strips bent under steam to the shape shown, which (though this is quite an unimportant detail) is very near to perfect stream-line form. This frame is trussed with crosspieces consisting of thin strips of wood placed each side of the stretcher, and lashed tightly thereto with waxed twine or thread. Other joints with angle pieces of tin or aluminium may also be used for this purpose, being likewise securely

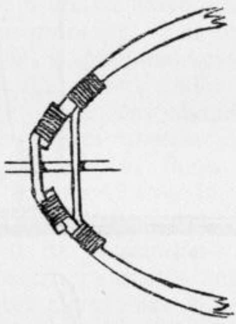
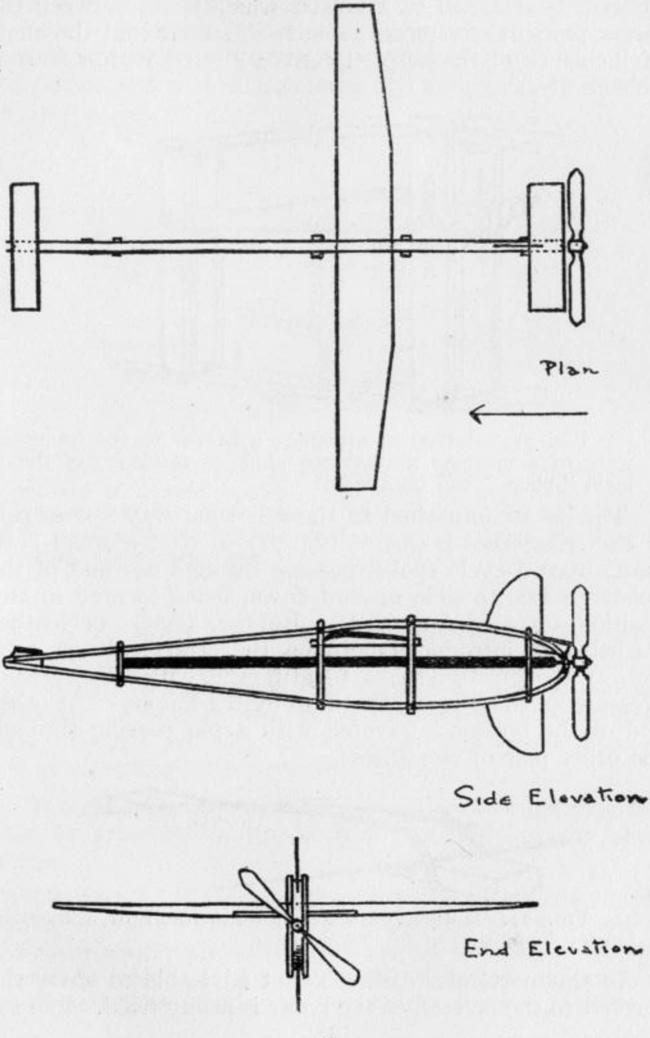


Fig. 70. Method of making a frame joint, which also serves as a double bearing for the screw shaft.

lashed. The end crosspieces are lighter than the two middle pairs, the function of which will appear later. A small triangular piece of wood is inserted in the V at the narrow end of the frame, and is there pinned and glued into position. The front joint of the frame (fig. 70) is made to serve also as a double bearing for the screw shaft. Two strips of stout aluminium are bent to the required shape, affixed to the frame as shown, and afterwards drilled to receive the screw shaft. The main "plane," which, of course, may be divided, and the halves set dihedrally if


Plan
Side Elevation
End Elevation

desired, is attached to a bolster which is set between the larger pairs of crosspieces in such a manner that the angle of incidence of the aerofoil can be altered within reasonable limits.

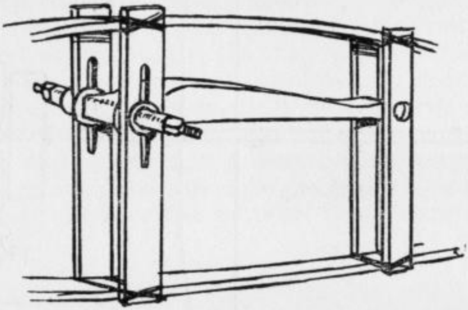


FIG. 71. Method of attaching a bolster to the framework of a machine so that the angle of incidence of the main "plane" can be altered.

This is accomplished in the following way: One pair of the crosspieces is slotted (fig. 71) so that a small bolt, made from a cycle spoke, passing through one end of the bolster is free to slide up and down, being secured in any position by a spoke nipple. Rubber, paper, or leather washers are introduced between the crosspieces on each side of the bolster, so as to grip well without excessive pressure when all is tightened up by the nipple. The other end of the bolster is pivoted with a pin passing through the other pair of crosspieces.

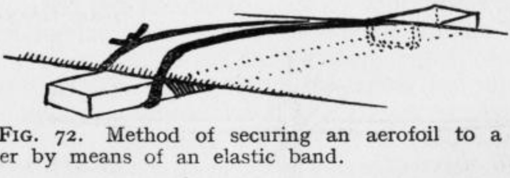


FIG. 72. Method of securing an aerofoil to a fixed bolster by means of an elastic band.

In this particular case it is not advisable to screw the aerofoil to the bolster, as the latter is firmly fixed. Instead a piece of stout elastic is passed under the bolster, over the "plane," under the other end of the bolster, back again over the "plane," stretched tight, and tied up. The aerofoil is thus provided with a means of "giving" if an obstacle be struck (fig. 72).

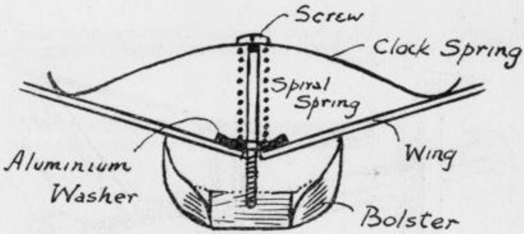


FIG. 73. Method of attaching a dihedral supporting surface to a fixed bolster. The latter is, as it were, two separate bolsters on the slant. The springs secure the wings in position during flight, but if an obstacle be struck they immediately come free.

Fig. 73 shows how a divided supporting surface may be fixed dihedrally to a special bolster. In this case, if the wings strike anything they come free, and no damage is done. The clips are preferably made of aluminium strip, though for the flat ones at the top a piece of old clock-spring acts very well indeed.

The elevator and tail are carried on suitable movable bolsters attached to the bottom stretchers of the main frame.

To reverse the machine the elevator and tail are simply turned round and remounted, whilst the pin and bolt of the main bolster are withdrawn, the aerofoil and its bolster reversed, and the pin and bolt reinserted in opposite positions. The fin also undergoes the same operation.

No. 5.—A Wright Type Biplane with Double Propeller.

For some inherent reason this type of machine does not fly quite so well, nor is it so stable, as its monoplane analogue, although it is capable of good distances, and is picturesque.

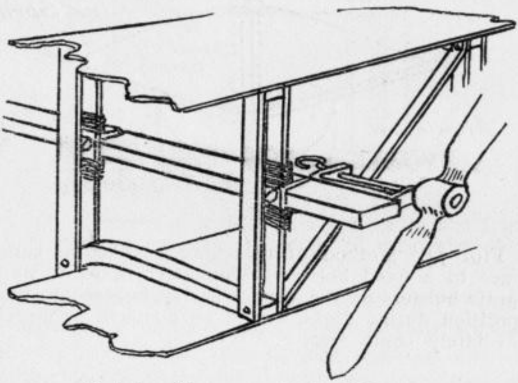
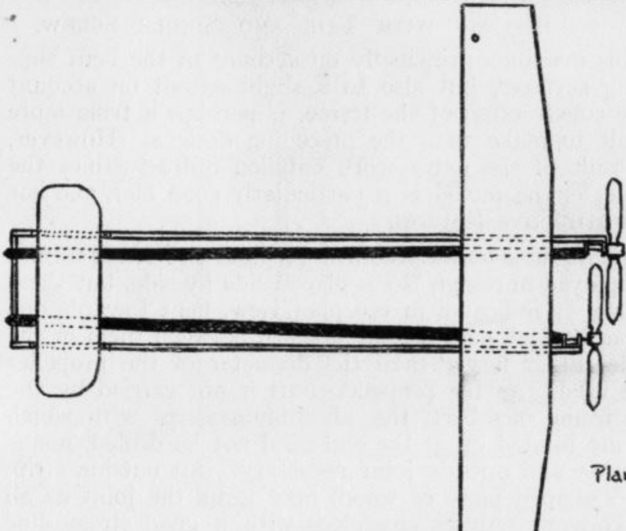


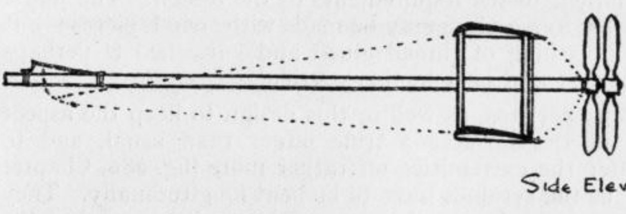
Fig. 74. Details of framework of a Wright type biplane.

The frame is shown composed of a couple of plain sticks, but it may be also made as suggested by the dotted lines in the side elevation. Fig. 74 shows a number of details in the construction of this machine, from which it will be seen that the skeins of elastic are set at the *side* of the frame members.

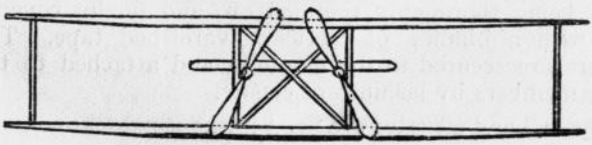
The triangulation of the middle pair of upright struts is easily accomplished, and is all that is required. The main "planes" are attached to their pairs of bolsters with stout elastic straps, as in the previous design No. 4. The elevator has double bolsters, each of which is secured to the main frame members in the usual manner



Plan



Side Elevation



End Elevation

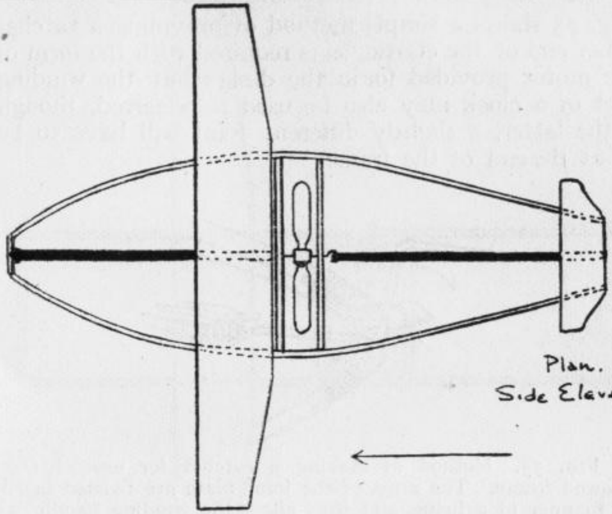
No. 6.—Biplane with Tail and Single Screw.

This machine, principally on account of the bent supporting surfaces, but also to a slight extent on account of the construction of the frame, is perhaps a trifle more difficult to make than the preceding designs. However, the result of the extra work entailed quite justifies the trouble, as the model is a particularly good flier, and has many attractive features.

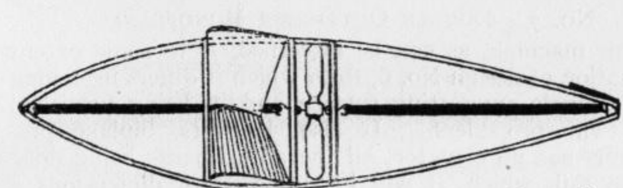
The frame is for all practical purposes two of the frames as employed in design No. 4 placed side by side, but these are also, as indicated in the plan view, bent towards one another at each end, leaving a space between them in the middle rather larger than the diameter of the propeller to be used. As the propeller-shaft is not carried by the main frame members, the aluminium strips with which they are jointed up at the end need not be drilled, nor is an inside and outside joint necessary. An outside strip, or a V-shaped piece of wood, may form the joint at all four corners. An ⌶ crosspiece with a good stream-line section throughout is employed to keep the frames the requisite distance apart, and also to carry the elastic motor, which is preferably of the type shown in fig. 16 (Chapter II.), although other forms of elastic motor may be adapted to the requirements of the design. The joints of the ⌶ frame piece may be made with strip L pieces; but a good lashing of thread glued and varnished is perhaps the easiest and best in this particular case.

It is, perhaps, as well in this design to keep the aspect ratio of the surfaces a trifle larger than usual, and to chamfer the extremities off rather more (fig. 28B, Chapter III.), as the aerofoils have to be bent longitudinally. They are sewn together at the extremities with brass wire, the joints being thoroughly rounded off, and finally covered over with a binding of fabric or varnished tape. The bolsters are secured to the aerofoils, and attached to the frame members by lashings of elastic.

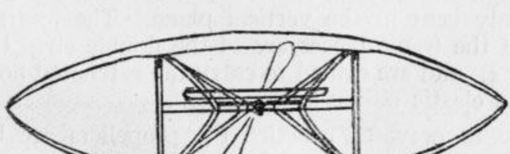
The tail and elevator are fixed in the usual manner.



Plan.
Side Elevation



Side Elevation



End Elevation

Fig. 75 shows a simple method of providing a ratchet at either end of the elastic, as is required with the form of elastic motor provided for in the design but the winding ratchet of a clock may also be used if preferred, though with the latter, a slightly different joint will have to be made at the end of the frame.

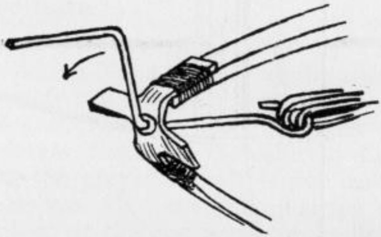


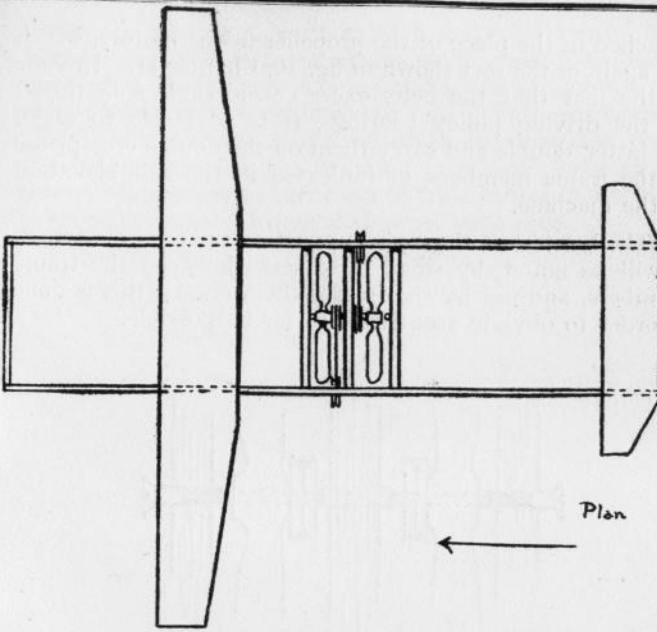
FIG. 75. Method of making a ratchet for use with a bowed frame. The arms of the joint plate are twisted in the manner of a helix, and thus allow the winding handle to pass in one direction only.

NO. 7.—DOUBLE OUTRIGGER MONOPLANE.

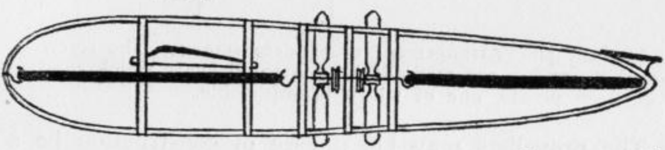
This machine, as can be discerned, is to some extent a variation of design No. 6, from which it differs in having only a single supporting surface and in being furnished with twin propellers. It also, like its biplane predecessor, has no elevator, all the adjustments being done by the tail, which, it will be noted, is of dimensions a shade larger than any previously employed.

The framework is double, each member being of the type used in design No. 4, and, it will be seen from the plan they are only bent in the vertical plane. The joints at each end of the frame pieces are of the double strip type (design No. 4), and are drilled to carry the ratcheted hooks whereby the elastic motor is wound up.

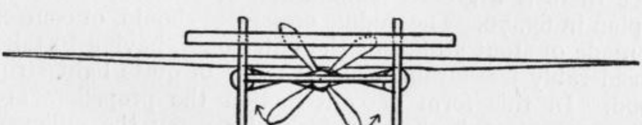
Contrary to previous practice the propellers are belt driven, *both* belts being crossed from aluminium pulleys



Plan



Side Elevation



End Elevation

attached in the place of the propeller in the motors, which are again of the sort shown in fig. 16, Chapter II. In view of the fact that the belts exert considerable side thrust on the driving pulley bearings, it is advisable to make the latter double and carry them on the double crosspieces of the frame members, as indicated in the side elevation of the machine.

The bolsters of the main supporting surface are carried, it will be noted, by small crosspieces between the frame members, and not by the frames themselves; this is done in order to obviate acentricity as far as possible.

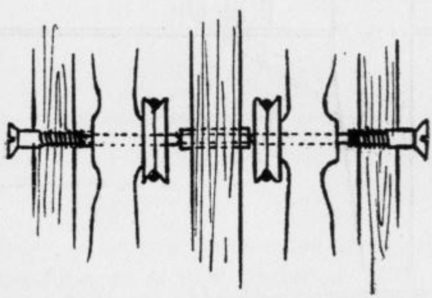


FIG. 76. Arrangement of tandem screws. The screw and its pulley are made fast on a small shaft which runs between pivots, one of which is adjustable.

The propellers may be, if ease of construction be a consideration, allowed to run loose on a shaft passing through a single crosspiece, with the pulley attached to the propellers abutting close up against this crosspiece. This is quite a satisfactory arrangement, but a better one, since there is a greater elimination of friction, is shown in plan in fig. 76. The middle crosspiece should, of course, be made of stout stuff, but the outer ones, having to take considerably less strain, may be made of quite light strip wood. In this form of construction the propellers are put on short stub shafts (which also carry the pulleys), which are filed to a point at each end, and run in fixed V bearings. The last-named are easily made by squaring the end of an ordinary brass wood screw of suitable size, and drilling a V hole into the end. This arrangement allows the bearings to be adjusted to eliminate shake, the bearing carried in the main crosspiece between the screws being either a short piece of brass tubing or a straight piece of brass wire drilled shallow at both ends.

No. 8.—Biplane with Double Tandem Screw.

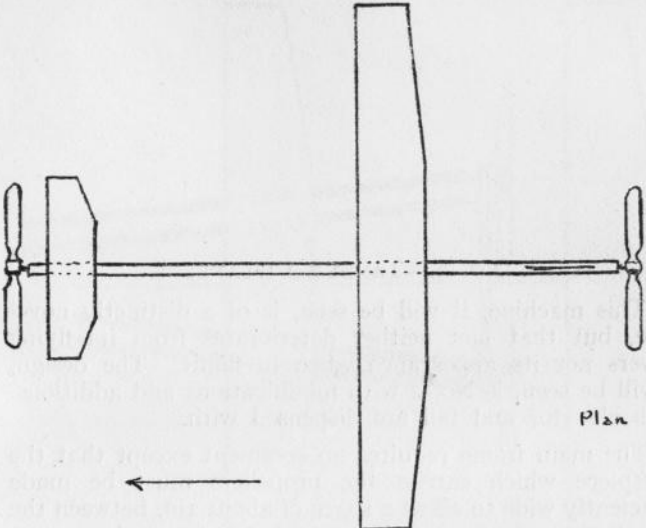
This machine, which is somewhat bizarre in appearance, is quite an easy one to make, and is rendered unusual by the mere fact that the screws are placed at either end of the machine, and the elastic skeins are "staggered" so as not to interfere with one another.

The bowed frame has, in consequence, joint bearings at both ends. Crosspieces and triangular stays secure the main supporting surfaces in position, and there are shorter and lighter crosspieces to secure the fixed ends of the elastic skeins.

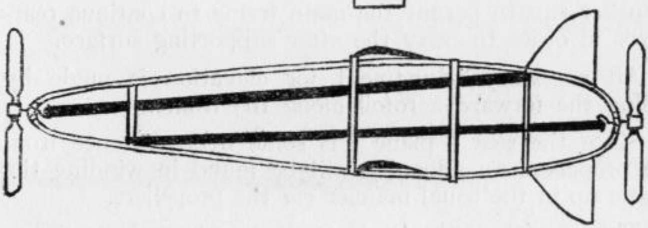
This arrangement of screws has the disadvantage that they cannot be properly balanced. Either the screws can be run in opposite directions, in which case the frame twists under the influence of the torque of the rubber, or else both screws are of the same hand and run in the same direction, when the frame is not so much twisted; but a weight has to be placed on one extremity of the aerofoil in order to counteract the thrust of the screws.

The elevator is fixed in the usual manner, but a tail, if desired, can be added.

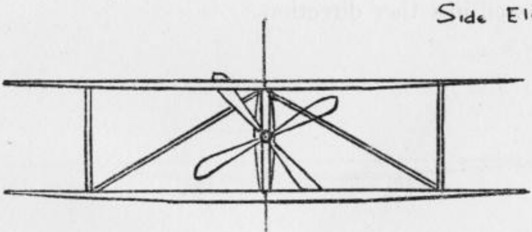
This machine should be provided with a vertical fin to act in a directional capacity at the rear.



Plan



Side Elevation



End Elevation

No. 9.—Tandem Biplane.

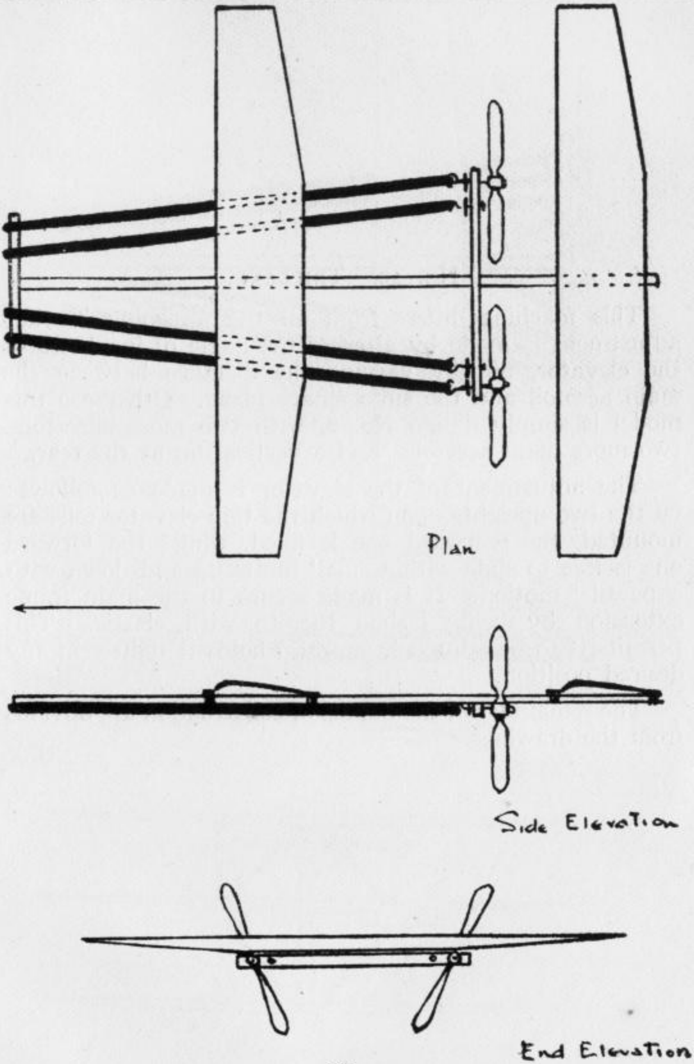
This machine, it will be seen, is of a distinctly novel type, but that fact neither deteriorates from its flying powers nor its appearance when in flight. The design, it will be seen, is No. 2 with modifications and additions. Both elevator and tail are dispensed with.

The main frame requires no comment except that the crosspiece which carries the propellers must be made sufficiently wide to allow a space of about 1in. between the propeller tips to permit the main frame to continue rearwards in order to carry the after supporting surface.

All necessary adjustment for elevation is made by sliding the forward aerofoil along the frame.

Since the rear "plane" is some little distance from the propellers no difficulty will be found in winding the elastic up in the usual manner *via* the propellers.

This model easily lends itself to reversal, and flies equally well in either direction.

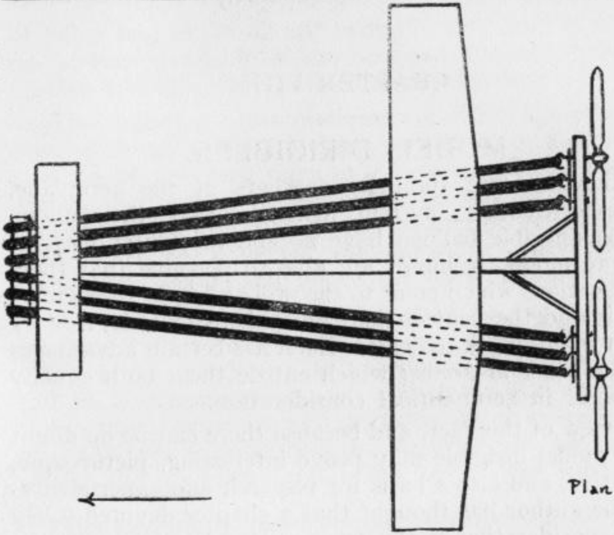

Plan
Side Elevation
End Elevation

No. 10.—Triplane.

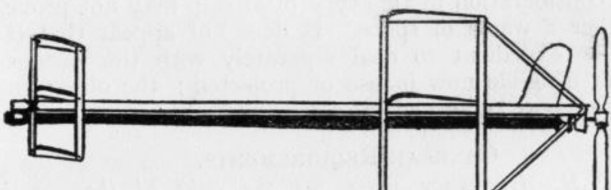
This machine differs from all the foregoing in that adjustment is made by altering the angle of incidence of the elevator, not by varying the distance between the main aerofoil and the subordinate plane. Otherwise this model is simply design No. 2, with two more elevators, two more main aerofoils, and a vertical fin at the rear.

The adjustment of the elevator is made as follows: Of the two uprights upon which the thin elevator foils are mounted, the rearward one is fixed, whilst the forward one is free to slide within small limits up and down with a parallel motion. It is made secure to the main frame extension by being lashed thereto with elastic. This permits it to be adjusted, and also holds it tightly in any desired position.

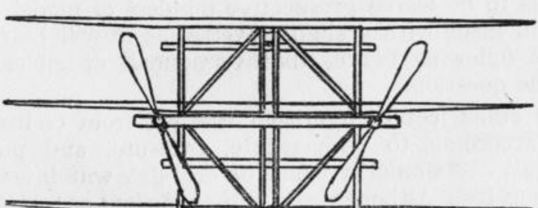
The remainder of the details of construction are obvious from the drawings.



Plan



Side Elevation



End Elevation

CHAPTER VIII.

MODEL DIRIGIBLES.

Although some staunch adherents of the aeroplane, or heavier-than-air, system maintain that the balloon and the dirigible balloon have no sphere of usefulness at all, more moderate minds are able to perceive that there are indications which point to the probability of the lighter-than-air and the heavier-than-air systems existing side by side for many years to come. Each has certain advantages over the other *at present* which entitle them both equally to a place in aeronautical consideration.

In view of this fact, and because there can be no doubt that a model dirigible may prove interesting, picturesque, instructive, and also a basis for research and experimentation, the author has thought that a chapter devoted solely to the consideration of this type of airship may not prove altogether a waste of space. It does not appear that it would be expedient to deal separately with the various types of dirigible now in use or projected; the object in view may best be served by a few generalities.

General Requirements.

N.B.—Buoyancy varies as the cube of the dimensions, weight as the square.

The first thing to be considered is the matter of size. Here it is to be feared prospective builders of model dirigibles will meet with a slight reverse, as it will be clear from the following figures that very small dirigibles are out of the question.

1,000 cubic feet of hydrogen will lift from 60 lbs. to 70 lbs., according to temperature, pressure, and purity of the gas. A similar volume of coal-gas will lift from 30 lbs. to 35 lbs. Although only half as efficient as hydrogen in providing buoyancy, coal-gas has the great advantage of being laid on in almost every house; and if not laid on, at least available within no great distance, unless the builder live in a very out-of-the-way locality.

The following considerations will show, however, that even with an airship of considerable size, matters will have to be cut very fine, and there will be no room for any slipshod work. It need hardly be said that the utmost care should be exercised in the making of joints in whatever fabric be used for the aerostat; they must be thoroughly sound, and above suspicion as regards leaks.

Exempli gratia, the aerostat shall be supposed to be 9ft. long with a diameter of 1ft. 6in., and of the *Zeppelin* shape, *i.e.*, a tubular central portion terminating at either end in a hemispherical cap. Best quality goldbeaters' skin is presumed to be used, and this has an average weight of .01 lb. per square foot, or, allowing for the increased weight due to seams and joints, .03 lb. per square foot.

The amount required for the envelope will be—

For the central portion	28.27 sq. ft.
For the two hemispheres	7.07 ,,
TOTAL	35.33 sq. ft.

or, to be on the safe side, 36 sq. ft., *the weight of which alone is* 1.08 *lbs.*

The actual volume of the aerostat is—

Of the central tubular portion, 6ft. long, with a diameter of $1\frac{1}{2}$ft.	9.6 cub. ft.
Of the two hemispheres	1.76 ,,
TOTAL	11.36 cub. ft.

Now 1,000 cubic feet of hydrogen lift 60 lbs., therefore the total buoyancy of 11.36 cubic feet is .681 lb., *or a trifle over* 10 *ozs.*

A 9ft. dirigible of the shape suggested (*Zeppelin*) is clearly out of the question altogether; for, even when hydrogen is used in the aerostat, the buoyancy is still considerably less than the weight of the envelope alone.

There are now three ways of setting about this difficulty: (1) The aerostat must be proportionately increased in size, made, say, 18ft. long by 3ft. in diameter, in which case it will have an effective buoyancy with hydrogen of 5 lbs.—that is to say, it would have a margin over the weight of the envelope (4.3 lbs.) of at least 8 ozs., which could scarcely be made to cover the weight of the interior supports with which an envelope of this size should be provided, apart from the motor and propeller which it is to carry.

(2) The aerostat may be kept the same length, but may be made "fatter." Let it be supposed that it be made 3ft. in diameter, its length being still 9ft.

In this case the weight of the envelope will be exactly double what it previously was, *i.e.*	2.16 lbs.
The buoyancy, however, will be obviously quadrupled, hence it will now be	2.5 ,,

Leaving a balance in favour of ascension of .34 lb., or less than $5\frac{1}{2}$ ozs.

(3) The two previous alternatives may be combined, and an aerostat be made 12ft. long × 3ft. in diameter, in which case the weight of the envelope will be exactly 3 lbs., whilst the buoyancy will be 3 lbs. $10\frac{1}{2}$ ozs., giving a balance in favour of ascension of $10\frac{1}{2}$ ozs.

This size of airship, viz., 12ft. × 3ft. in diameter, may be regarded as thoroughly practicable if hydrogen be used for inflation, the weight being made up as follows:

Cradle or *nacelle*	2 ozs.
Propeller, 12in. diameter	$\frac{1}{2}$ oz.
Elastic or clockwork	$6\frac{1}{2}$ ozs.
Sundries and ballast	$1\frac{1}{2}$,,

It is quite possible that with very good workmanship and careful choice of materials a 9ft. × 3ft. dirigible might be made workable, although 5½ ozs. is not a great weight to cover all that needs to be carried. In view of this fact, and also to some extent because the larger 12ft. machine will be little, if any, more trouble to construct, and will certainly have a finer appearance, the latter airship is certainly to be recommended.

Material.

The use of first-grade material for model dirigibles is imperative, and for this reason their construction is not likely to appeal to a great number of model makers, since the best material is naturally not the cheapest.

A number of people are under the impression that since it serves for fire-balloons, thin tissue paper will do equally well for the envelopes of hydrogen-filled aerostats. Owing to the great porosity of this material, however, its use is entirely out of the question—in fact, it would be little more efficient as a vessel for containing hydrogen than a fishing-net.

The materials available and their weights are—

Goldbeaters' skin	120 sq. ft. to the lb.
Varnished silk	80 ,, ,,
Prepared rubber fabric ..	40 ,, ,,
Varnished cotton	25 ,, ,,

The weights are somewhat deceptive, and would lead one to imagine that better results can be obtained than are practically possible. The joints that have to be made in all these materials add at least another forty per cent. to the weight, and in the case of goldbeaters' skin possibly as much as one hundred per cent., as it is not to be obtained in large pieces.

Construction.

Although the building of a model dirigible is certainly a more lengthy and intricate matter than that of the model aeroplanes already dealt with in preceding chapters, there is no reason why it should prove a difficult task. As regards the mechanical part or *nacelle*, as the French call it, this may be left very much to personal choice; but in any case it differs only in matters of degree from the mechanical part of the aeroplanes previously discussed.

As regards the balloon or aerostat, this is a matter that calls for particular care, cleanliness, light fingers, and patience; but it may be postulated that anyone who can build a passable paper fire-balloon can make the envelope of a dirigible.

Shape.

From Chapter I. it will have been gathered that the shape of the aerostat, *i.e.*, its approximation, or otherwise, to stream-line form, plays a very important part, not only in the speed of the airship, but also to a smaller extent in its navigability. The best shape, therefore, of an aerostat should be something like that represented in fig. 77, the direction in which it is to travel being indicated by the arrow. Capability of speed, however, is by no means the only point to be considered, there being two other equally important ones—lifting capacity and ease of construction.

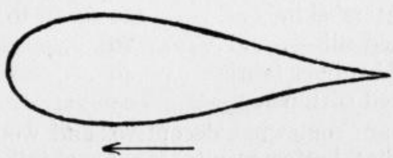


Fig. 77. Aerostat of approximately correct form.

As regards lifting capacity, it is obvious that the best possible form is a perfect sphere, which, since it offers the minimum of surface with the maximum volume contained, is clearly the shape which will give the greatest possible lifting power with the smallest weight of envelope. The sphere, unfortunately, is not at all adapted to be driven at any speed through a fluid, since its shape causes it to offer a considerable resistance, coupled with the fact that of itself it has no more sense of direction than a boat perfectly circular in plan would have. Those who in the days of their youth have essayed to convert the half of a barrel into a rowing-boat will have no difficulty in appreciating this lack of directional sense.

Thus, on the one hand, we have the desirability of a "stream-line" shape, on the other the necessity of good lifting capacity; and in the background the practical consideration of construction. In the opinion of the author, far and away the best course to pursue, as far as

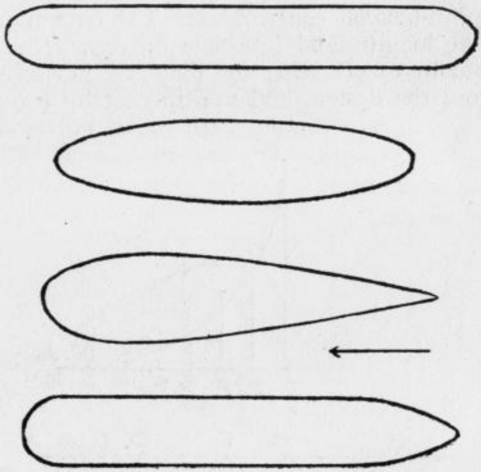


Fig. 78. Various shapes of aerostat.

the model dirigible is concerned, is to make stream-line form a secondary consideration, and adopt the design which affords good volume and little difficulty in the making.

Fig. 78 represents several good forms, the selection of which may well be left to personal choice

For the purposes of description the construction of an aerostat of the *Zeppelin* form will be dealt with; that of the others is subject to modifications, which will make themselves manifest as the matter is proceeded with. For the sake of illustration, let it be supposed that the diameter of the aerostat is to be 3ft. and its length 12ft. The aerostat consists, practically, of a tube terminated at each end with a hemispherical cap.

The tube presents no difficulty, and consists simply of a piece of material of the required length with a width of 3ft. × π, or 9.42ft. If the width be made a trifle more than tihs figure, there will be sufficient to form a single lap joint.

The caps are made in a manner similar to that obtaining in paper fire-balloon construction. The circumferences of the cap at longitudinal intervals of, say, $2\frac{1}{4}$in. are first worked out by ascertaining the diameter at each of these points from the design, and multiplying by π ($\frac{22}{7}$).

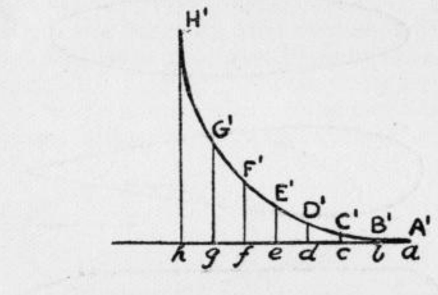


FIG. 79. Method of setting out the "facets" of a hemispherical cap for each end of an aerostat.

The caps may be built up of any number of "facets" or sides, but sixteen may be taken as a convenient number. The exact shape of the facet can be thus ascertained by the procedure about to be described.

To avoid mistakes it is just as well at this point to remind designers of the almost obvious fact that the length of the facets of a hemisphere which is 1ft. 6in. long *in* *section* is not 1ft. 6in., but is equal to $\frac{\textit{circumference,}}{4}$ which is actually about 2.36ft. Accordingly the centre line of the plan of a facet must not be marked off in lengths of 3in., but must be considered as a quarter circumference of a sphere marked off in 3in. lengths *in section,* and afterwards rolled out flat. Fig. 79 shows how the centre line is plotted out. A tangent to a quarter circle whose radius is equal to that of the hemisphere to be constructed is drawn, and on this tangent are marked lengths of 3in. each. Through these calibrations are then drawn lines perpendicular to the tangent, cutting the arc of the quarter circle. The distance between the points thus made on the arc are conveyed with a pair of dividers to the centre line of the facet in their correct order.

Thus in the figure the distance A B on the centre line A G of the facet is equal to the distance A^1 B^1 on the arc; B C on the centre line equal to B^1 C^1 on the arc, and so on.

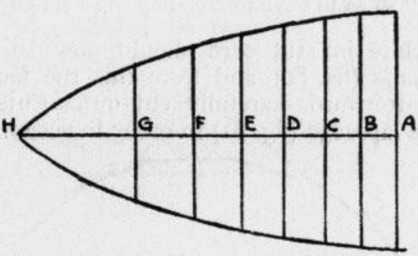


FIG. 80. Method of laying out facet.

Since there are sixteen equal facets the width of each facet at any point is one-sixteenth of the circumference of the cap at the corresponding point.

The diameter of the cap at A^1 (fig. 79) is 3ft., hence the width of the facet at A (fig. 80) must be $\frac{36\text{in.} \times \pi}{16}$ which is 7.07in. A line of this length is marked off at A taking care that the centre line (fig. 79) passes through its centre. The diameter at B^1 is, say, 35in., and the width B is marked off accordingly. In like manner the remaining lines C, D, E, F, G, H, etc., are laid off, a smooth, even-flowing curve being then drawn through their extremities (fig. 80). This now gives the correct form of the facet. As, however, sufficient material must be cut to allow a lap joint to be made (fig. 81), an extra width must be marked off *on one side only* of the facet for a lap joint.

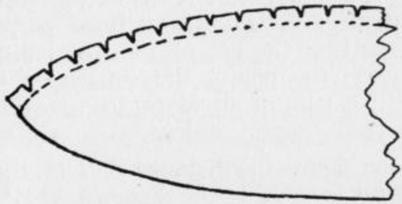


FIG. 81. The lap edge of each "facet" should be "scarfed," so as to obviate crinkling when set on the curve.

A template in stiff card should now be cut to the required shape (fig. 80), and from this the facets marked off, being afterwards carefully cut out. Cuts should be made in the lap edge (fig. 81) in order to accommodate this

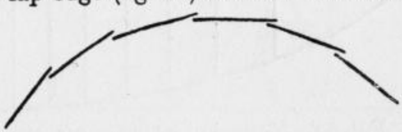


FIG. 82. Joints in the fabric are made by overlapping the "facets" of the envelope cap.

edge of the facet to curvature of the one next to it, thus obviating any tendency for the material to "hump" or "ruck up."

The caps are then built up with the aid of gold-size, being afterwards joined up to the main body of the aerostat. The joints at the tip of the cap being so close together are inclined to make it somewhat clumsy in appearance;

but this may easily be cured by covering up the end with a disc of material with segments cut out of its edges to allow it to take the curve required.

The Nacelle.

The design of the "nacelle" depends, of course, to a large extent upon the form of motor which it is to carry. In this connection it should be pointed out that, since high speed is not required, nor attainable, in a model dirigible, the motor will only be required to drive quite a small screw. For a dirigible with an aerostat 12ft. long × 3ft. in diameter a screw 12in. in diameter is amply large enough, hence a clockwork motor, if capable of being supported by the aerostat, may be used; whilst if weight be found to be the great consideration, a long skein of a

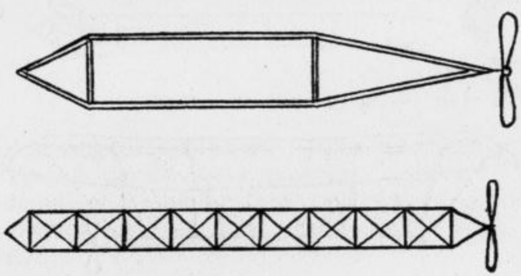


Fig. 83. Two types of "nacelle" for model dirigibles.

few strands of elastic may be used. An elastic motor suitable for a 12in. screw requires three strands of square section rubber or six of strip rubber, and will give about 200 revolutions for each foot run. With a motor 6ft. long, 1,200 or more revolutions will be obtained, and the propeller (according to pitch and weight) should run upwards of two minutes.

With a clockwork motor this time might easily be lengthened to five minutes if the mechanism were well adapted to its work. Fig. 83 suggests two forms of nacelle—

one for clockwork and the other for an elastic motor. Modifications and elaborations of these designs will no doubt suggest themselves to model dirigible enthusiasts. Thin strips of wood should be used for these nacelles, but umbrella ribs of U section would look and stand up very well if the aerostat could be made to sustain them.

The nacelle is attached to the aerostat by guy ropes, for which crochet cotton (No. 6) is very suitable. It is advisable to keep the number of these down as low as possible to avoid a tangle in case of accident. The ends of the guy ropes may be tied to the nacelle, but a permanent fixture of them should not be made to the aerostat, as there are several reasons why it is desirable to be able to detach the nacelle from the balloon when required.

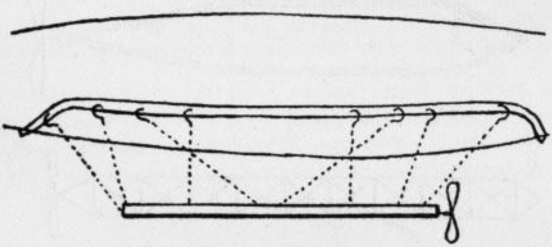


FIG. 84. Method of attaching the "nacelle" to a tape secured to the envelope of the aerostat.

A good arrangement which accomplishes this end is indicated in fig. 84, whence it can be seen that one edge of a piece of tape about 1in. broad is gummed or gold-sized along each side of the envelope of the aerostat. The ends of the guy ropes not attached to the nacelle are provided with small hooks made of thin steel wire, whereby they are attached to these strips of tape, marks being made upon the last-named to indicate the point at which each hook should be inserted.

The guy ropes must not be arranged in a parallel system or they will allow the nacelle to swing forwards and backwards. They must be triangulated as indicated in the figure.

Propulsion.

Similar screws to those advocated for model aeroplanes should be used for dirigibles.

Steering and Elevation.

Under normal conditions the dirigible should remain horizontally in the air and have just sufficient lifting power to support itself. A small receptacle for ballast should be provided in the centre of the nacelle, into which small lead shot or other weights may be placed as required.

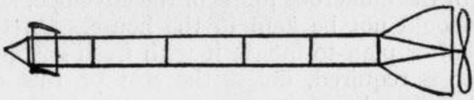


Fig. 85. "Nacelle" with elevating planes and rudder.

For steering in a horizontal plane a rudder should be rigged up just ahead of the propeller; whilst for vertical elevation one or more adjustable planes should be attached to the forward end of the nacelle (fig. 85), and set as required.

Filling the Aerostat.

It is neither desirable nor advisable to make one's own hydrogen for inflating the envelope of a model dirigible, as the home-made gas will be far less efficient (due to impurities), and it will be a matter of some difficulty to force it into the aerostat under sufficient pressure for satisfactory inflation. The preparation of hydrogen on a small scale is, moreover, neither convenient, cheap, nor altogether free from danger unless in expert hands; hence it is much the best plan to obtain commercial hydrogen compressed in steel cylinders, which can be obtained through any chemist at a not unreasonable charge. With hydrogen in this state there is no difficulty in filling the aerostat, as, after the necessary connections are made, all one has to do is to turn a tap on and wait till the desired degree of inflation is reached. In this connection it is hardly necessary to point out that before being filled, the envelope of the aerostat should be pressed flat, so as to expel every possible particle of air it contains, and that the operation should not be conducted in the immediate neighbourhood of naked lights.

Before attempting to fill with hydrogen, every seam and joint in the envelope should be very carefully gone over, and remade if there be any doubt about its strength and gas-tightness.

Unless there be absolutely no doubt about the gas tightness of the numerous joints of the envelope, an inflated aerostat should not be kept in the house. On the whole it is the better plan to inflate it with fresh gas every time the airship is required, unless the cost of this operation be considered prohibitive.

If desired a safety outlet tube to accommodate the increased volume of the gas due to rise in temperature may be filled *at the lowest point* of the aerostat when the last-named is in its normal horizontal position. This tube should be 6in. or 8in. long, and should hang down vertically, its orifice being left open.

The above are the bare outlines of the points that should be observed in the construction of a model dirigible airship. As already laid down, it cannot be too often insisted that the envelope of the aerostat *must* be made gas-tight, and every joint examined for leaks carefully and often. If that be done, and reasonable mechanical skill exercised in cutting weight down everywhere as far as possible, no great difficulty attends the making of a successful and highly realistic model airship.

CHAPTER IX.

MODEL HELICOPTERS.

In view of the fact that no particular type of helicopter has met with any success, the author considers that it would be idle to suggest any but the vaguest lines along which experiment may be conducted. There can be scarcely any doubt, however, that the helicopter or direct lift flying machine has a tremendous future before it if it can be made controllable

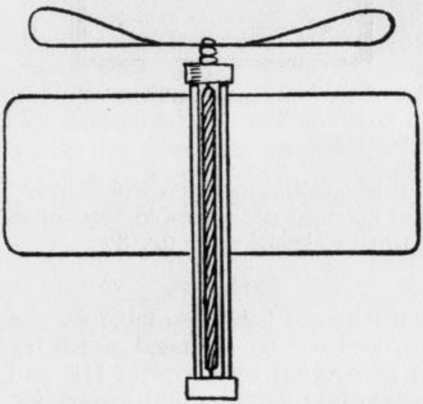


FIG. 86. A simple form of helicopter.

In considering helicopters the same remarks apply as to propelling screws, and the helicopter must accordingly be looked upon as an aeroplane in another phase. Each lifting helix is virtually an aeroplane having a spiral path, and its dimensions and adjustments obey the same laws as apply to aeroplanes.

A point that must be borne prominently in mind in the design of helicopters is that all forces must be balanced, otherwise the machine cannot be expected to retain its equilibrium; and in this connection it should be remembered that it is better to balance a force by another force acting in the opposite direction than to oppose it with a resistance. Thus the simple form of helicopter shown in fig. 86, in which the torque of the screw is resisted by a vertical plane, is much improved by substituting for this inert fin a second screw working in the opposite direction to the first.

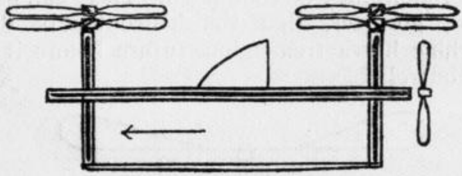


FIG. 87. Suggested experimental helicopter machine with four lifting screws and one for driving the apparatus in a horizontal direction.

By way of suggesting a design which may form a basis for study and experiment, a simple type of multiple helicopter is shown in elevation in fig. 87

HELICES.

The construction of helices suitable for use with direct lift machines need not be discussed afresh here, as it will be found to be covered by Chapters III. and IV., which deal with supporting surfaces and screws for aeroplanes.

As regards design it is perhaps unnecessary to state that a good propeller is a good lifter, and *vice versa*; but whereas in an aeroplane the thrust of the screw needs to be about one-quarter of the total weight of the machine to be driven by it, in a helicopter the thrust of the screw or screws must be obviously greater than the whole weight of the machine. That being the case, every device must be made use of which is likely to produce even the slightest gain in efficiency. Lightness, correct form, and also correct speed of rotation are matters of paramount importance.

From time to time the helicopter machine has been condemned as theoretically impossible; and it has been maintained that no engine has sufficient power to sustain itself in the air for any length of time.

The following statement of fact shows that this contention is absurd: *Walker and Alexander obtained in* 1899 *a thrust (lift) of* 74.7 *lbs. per horse-power,* the test being made with a screw 30ft. in diameter rotating at twenty revolutions per minute. Even the crude petrol engines of the present day can, for a weight of this amount, be made to give at least 25 h.p., so that the helicopter machine is certainly sound theoretically.

Although a tremendous amount of research work has been carried out on the helicopter machine, much more still remains to be done, and it is therefore to be hoped that original experimenters, many of whom are to be found in the ranks of model makers, will not lose sight of the advantages which the direct lift machine, or possibly a combination of the helicopter and the aeroplane, must have over the last named as we know it to-day.

CHAPTER X.

ORNITHOPTERS.

If little be known about helicopters, still less is known about ornithopters, or machines which depend for sustentation upon wing-flapping. Here again, however, no doubt exists as to whether an ornithopter be possible, for experiments have already proved beyond question its feasibility. In 1904 the late Mr. Hugh Bastin contrived a flapping wing machine, which, driven by a steam engine, successfully lifted and propelled itself without external aid. This machine had two pairs of wings one behind the other, and they were given a motion as nearly as possible that of a bird's wing.

FIG. 88. Section of a bird's wing in extreme positions showing how the wing acts exactly like the blade of a screw propeller.

As bearing on the question of ornithopters it may be recalled that Mr. Lawrance Hargraves, an Australian, constructed a small aeroplane machine in which the place of the screw was taken by a pair of simple flapping wings, which showed themselves very nearly as efficient as propellers as a screw. These wings were given a plain up and down motion, and were so made that whilst the front edge was rigid the rear portion of the wing was able to bend, and thus adapt its angle according to the upward or downward beat of the front edge, which alone was driven. Thus, as shown in fig. 88, the wings gave propulsive power on both beats, and acted exactly the same as would a screw propeller if it were oscillated instead of rotated and if its "hand" were alternately left and right at each oscillation.

As regards sustentation by flapping wings, it is clear that if a direct lift be required, the wing must be made to exercise a maximum resistance on the down stroke and a minimum resistance on the up stroke. It has been suggested, and it seems probable, that the wing of an essentially wing-flapping bird is so constructed that the air on the down stroke cannot pass through the feathers, whereas on the up stroke it can. Thus the wing acts like a valve. In support of this theory it has been pointed out that it is quite easy for one to thrust a finger through a bird's wing from the *upper* side, but that this cannot possibly be done when attempted from the *lower* side.

FIG. 89. Suggested form of flapping wing to flatten out on the down stroke, and fold on the up stroke.

It is also possible that some birds alter the curvature of their wings according to the direction of beat, so that on the up stroke the resistance is small compared with that offered on the down stroke. Thus in fig. 89 A shows a section of the wing on the downward stroke, and B a similar section on the upward.

For propulsion and sustentation at the same time—that is in ordinary flapping flight—the wings are made to perform both offices simultaneously. In other words, a bird in horizontal flight, exactly like an aeroplane under similar conditions, is continually flying up an imaginary hill (the steepness of which is in proportion to the ratio of weight of machine to supporting surface), the inclinational of its flight being reduced to a horizontal path by gravity.

In the case of horizontal flight a bird utilises its momentum to sustain it whilst its wings make an up stroke; whilst when lifting itself upwards from rest, it utilises its inertia.

It might be possible to arrange an ornithopter machine so that after it had made a downward or lifting stroke it were automatically caused to glide forward, using the wings on the upward stroke as supporting surfaces pure and simple. In this case the flight path would be something like that shown in fig. 90, the sharp corners of which would automatically "damp" themselves out as the gliding angle decreased with increased speed of forward motion.

FIG. 90. Flight path of an ornithopter glider.

Such a machine would not require to have a very complicated wing motion, and should, on that account alone, commend itself to experimenters who pin their faith to the ornithopter type of flying machine.

In the opinion of the writer the ornithopter is not so far removed from the pure aeroplane as a casual consideration of the subject would lead one to assume.

CHAPTER XI.

WINDING APPARATUS FOR ELASTIC MOTORS.

Those who have had experience with a twisted elastic motor, especially one which takes any number of turns over 500, have realised that they expend an enormous amount of energy compared with the small amount of power they obtain in return. They wind, as it were, for an hour, and the screw runs for a minute.

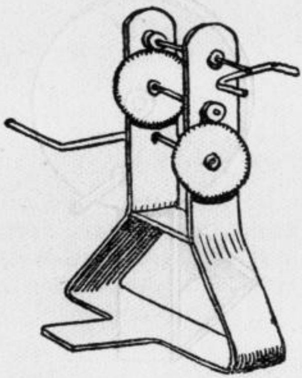


FIG. 91. Winding apparatus made of clockwork. The foot of the operator is placed in the stirrup at the base of the apparatus in order to hold it steady.

Much trouble and unnecessary labour can be saved by the construction of a winding apparatus in which the use of a high gear permits an elastic motor to be wound up in a very short time. For this purpose a gear of 20 or 30 to 1 is not too much, and may be obtained by the use of either gear wheels or pulleys and belts.

For small motors a winding apparatus can easily be made out of the works of a cheap American clock. Fig. 91 shows the arrangement, which is so simple as to require no comment, except an explanation of the lower portion of the contrivance. This is a stirrup made of a strip of sheet metal. When the apparatus is to be used, the operator kneels on one knee, and places his foot through the stirrup, thus holding the machine firmly, whilst his hands are left free—one to hold the machine and the other to wind.

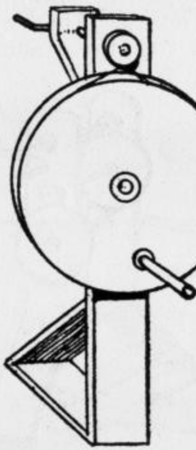


FIG. 92. Belt-driven winding apparatus

For larger machines a more ambitious apparatus is required, and unless gears of suitable strength and size be obtainable, had best be belt-driven, as shown in fig. 92.

In both machines a couple of pegs are used to clutch the blades of the screw whilst the winding-up operation is in progress.

Fig. 93 shows a form of winding machine that is more efficient than it looks. It consists merely of a fair-sized flywheel (a wheel-barrow wheel will do) held in plain bearings, and carrying a peg clutch similar to that used

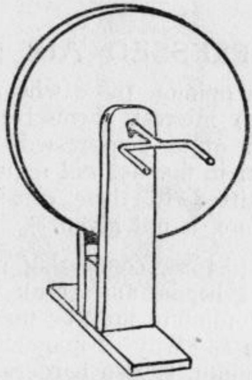


FIG. 93. Flywheel winding apparatus.

in the winding machines previously described. The flywheel is given a good initial " whizz," and is kept " whizzing " by further periodic " whizzes." It is astonishing how quickly an elastic motor can be wound up with its aid.

CHAPTER XII.

A COMPRESSED AIR MOTOR.

In the author's opinion those who are of a sufficient mechanical bent to interest themselves in, with a view to the construction of, a compressed air engine of the type of that shown in fig. 95, will require no explanation of the design submitted to their consideration. A full explanation, therefore, is not given.

The cylinders, pistons, connecting rods, valve chests, base-plate, cylinder heads, and crank web are all made of magnalium. Aluminium may be used, but it does not work anything like as easily as magnalium, which, whilst lighter than aluminium, is also harder.

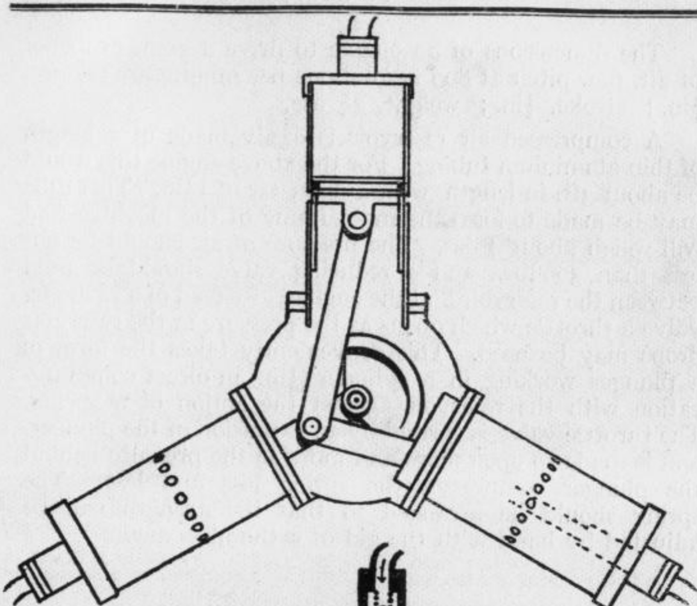
The crankshaft, valve tappet, valve (a small bicycle ball), gudgeon pin, and crank pin are of steel.

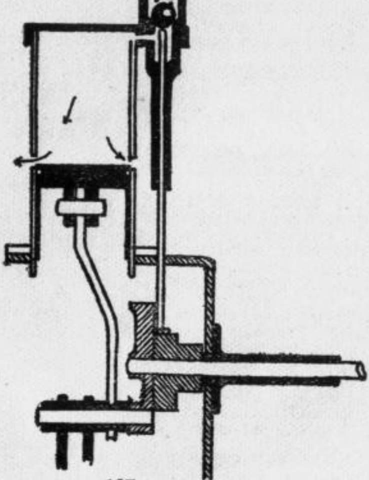
Gun-metal brasses are fitted to both ends of the connecting rods, which are, it will be noted, staggered to avoid each other. The main bearing is also of gun-metal in the form of a tube with a shoulder, which enables it to be secured by screws to the base-plate.

The last-named is marked off on, and cut out of, a sheet of metal, and the three arms are then bent at right angles to the plate to form flanges to carry the cylinders.

Joints throughout are made either with special aluminium solder or solder supplied for use with magnalium. In neither case is the operation very difficult.

A balance should be attached to the crank web of sufficient weight to counterpoise the weights of all three sets of reciprocating parts. The exhaust takes place at the end of the stroke.





The dimensions of an engine to drive a 10in. propeller of 2ft. 6in. pitch at 800 revolutions per minute are: Bore, ½in.; stroke, ½in.; weight, 2½ ozs.

A compressed air reservoir is easily made of a length of thin aluminium tubing. For the above engine this would be about 3ft. in length, with a diameter of 1½in. This tube may be made to form the main frame of the machine, and will weigh about 4 ozs. The pressure of air should be not less than 300 lbs., and a reducing valve should be used between the reservoir and the engine. Instead of a reducing valve a throttle which opens as the pressure in the reservoir drops may be used. This conveniently takes the form of a plunger working in a cylinder (¼in.) in direct communication with the reservoir against the action of a spring. The throttle valve is carried by an extension of the plunger, and is made to open more and more as the pressure behind the plunger compresses the spring less and less. The spring should be arranged so that its strength can be adjusted by hand with the aid of a thumb-screw.

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