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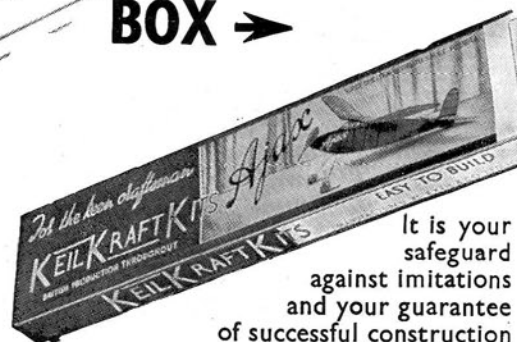
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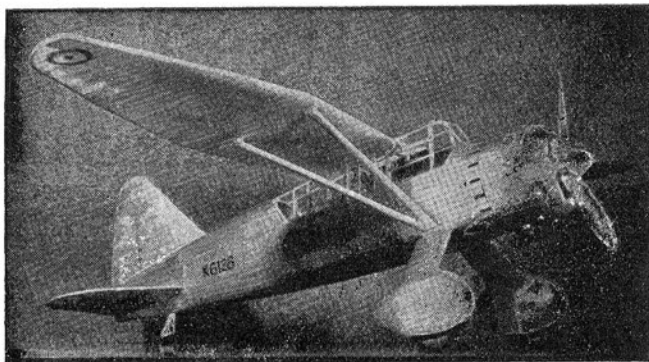
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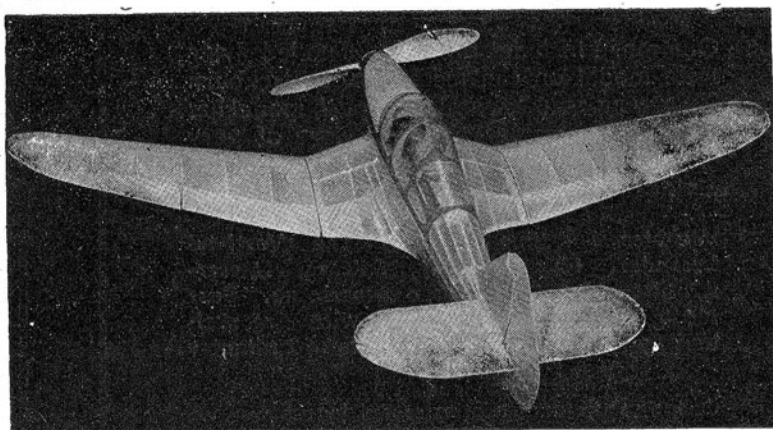
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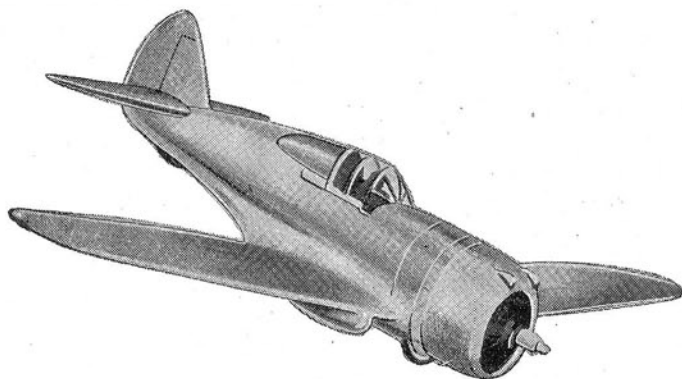
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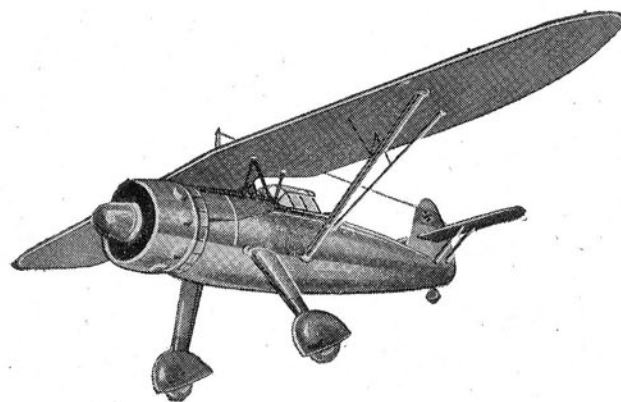
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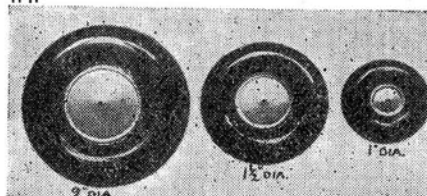
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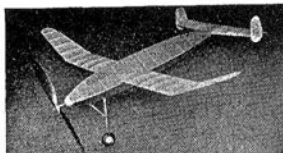
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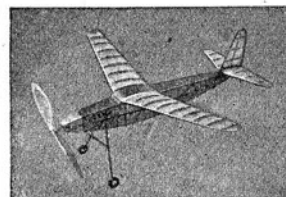
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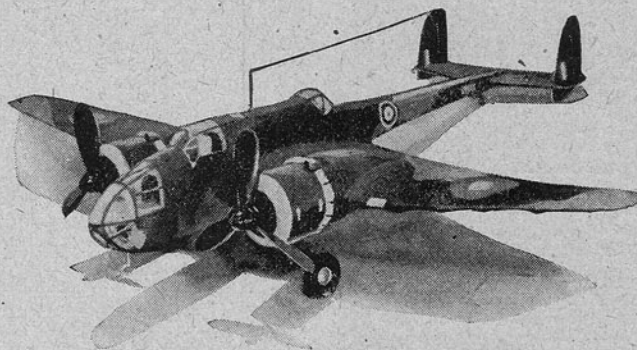
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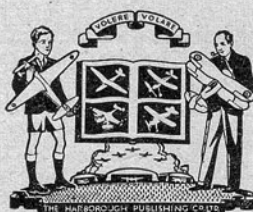
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# SCALE MODEL AIRCRAFT THAT FLY

BY

H. J. TOWNER and HOWARD BOYS



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## CHAPTER I

## "RAISON D'ETRE"

## THRILLS OF FLIGHT. RECREATION.

WHAT is the urge that makes us want to build and fly model aircraft?

Deep down inside most of us there is a desire to imitate, and in our case the imitation is of some well-known aircraft. Some mechanical device of man's that thrills our imagination, not only in the pleasure we derive from seeing a wonderful piece of mechanism or hearing the roar of the well-tuned engine, but also that perfect thrill of seeing this graceful object of man's inventiveness performing wonderful evolutions in the air and controlled by a perfect and measured sense of rhythm.

Now in our particular hobby, not only do we gratify our desire to imitate, but we go further, we imitate in miniature; anything in miniature always has an appeal of its own, whatever it may be, whether accuracy of detail or delicacy of outline.

Having completed our model, and spent many a happy hour of our winter evenings in doing so, we can stand back and admire our achievement, and the accomplishment of a thing well done gives a great satisfaction.

We must interpose a little note of warning just here. However well the job may be done don't be completely satisfied, but let it urge you on to greater achievements and perhaps more complicated designs, each with its attendant urge to do still better—that is the way to succeed.

But to return to where we were gazing upon our finished work with pride; we now step right out of the imitative sphere, which holds the large majority of people, and rise above them in attempting to impose our will upon Nature; so that our model shall be borne upon the wings of the wind and perform evolutions at our will. Not just a hectic few seconds of undulation in the air, but consistent, steady flight

after a snappy take-off from the ground under its own power, and then when the motor has run out, a long, easy, flat glide, a gentle touch down, and the model coming to a rolling stop.

These are thrills which only those who have achieved them can know.

It is because we have enjoyed these thrills that we wish to impart to others some of the knowledge gained both in the workshop and on the flying field, and hope that in so doing we may give many pleasant hours of relaxation to young and old alike.

Then there is the always open field of design, where we can actually design our own models, and, maybe in experimenting and scientific research, introduce to the world some hitherto unknown or undreamt of addition to the sphere of aeronautics.

Remember from the earliest days of human flight those great pioneers first of all experimented with models.

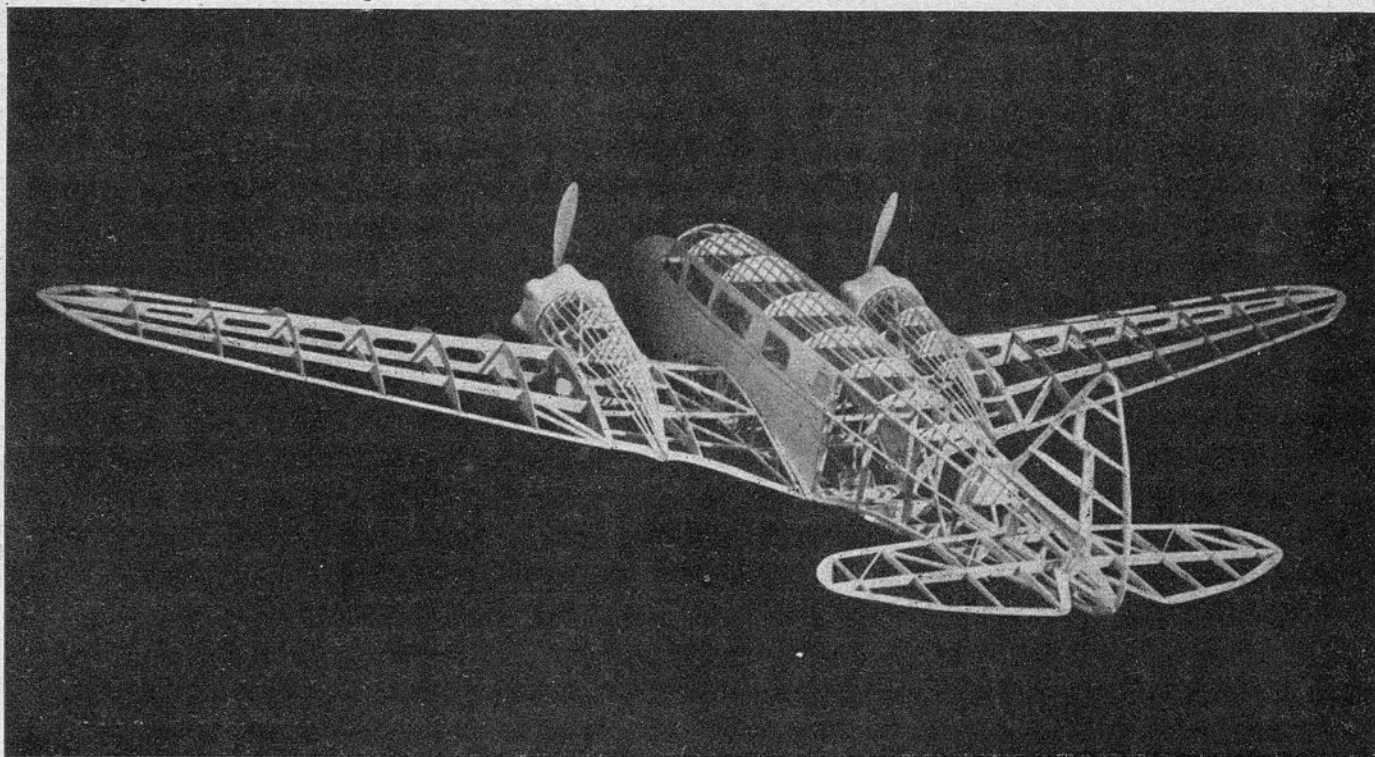
In normal times, too, we have our model aircraft clubs under the auspices of the Society of Model Aeronautical Engineers, who govern the model aircraft movement in this country. With these clubs we have our social side, where all are pals, irrespective of creed or class, each one helping the other, and at the same time a healthy competitive spirit pervading the whole, urging us on to do still better.

What a hobby! What a training for the schoolboy and the young man for after life—not forgetting that the ladies too are keen model-builders—what a recreation for the older man when he seeks to cast aside the trials and worries of workaday life!

Such, then, are the reasons why we build and fly model aircraft.

H. J. TOWNER.  
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*Built by Mr. H. J. Towner, this 1 in. to 1 ft. flying scale model is one of the finest examples of the aero-modeller's skill. Span of the 'plane is 54 in. and length 34½ in. The model will rise off the ground and fly quite a long way.*



## CHAPTER II

## DEFINITION

## SCALE. DETAIL IN MINIATURE. BROADER TYPES.

It may seem at first sight strange to suggest that we should propose discussing the design of scale model flying aircraft.

Surely, says the reader, as the model is a scale reproduction of some particular prototype all the designing was carried out on the actual full-size craft. All we have to do is to reproduce that full-size craft at one-twelfth or one-eighteenth the size, or whatever scale we should decide upon.

We trust, however, that if the reader will peruse these pages he will realize that the design of a scale model is full of all sorts of pitfalls for the unwary, and in fact often is a far greater problem than designing the more usual duration type of model one sees at every model meeting.

And here let us state most emphatically for the benefit of the uninitiated that although we can get splendid realistic flights of quite a high order of duration, yet, owing to the restrictions imposed upon us by a given outline and shape, we are not yet, at any rate, able to compete with the out-and-out duration class of model in length of time and distance flown.

It has already been taken for granted that we have an idea of what a scale model really is—that it is a reproduction of a full-size aircraft only built to a considerably smaller size. For instance, a model built to a scale of one inch to the foot would in reality be one-twelfth the size of the real job in length and wing-span, and so on.

It will readily be seen, however, that it is impracticable to reproduce every detail and every small part in their correct proportion, and so we have to leave the final decision of detail to the builder himself.

Now there are two main types of model both within the scale model category.

Firstly there is the type in which the builder

desires to build the most perfect miniature that he can, including parts that are seen and parts that are not seen; every detail that can be incorporated being fitted, even perhaps to a complete motor under the cowling.

Secondly, there is the type of a bolder conception, a type that pleases the eye and expresses the character and individuality of the actual job in a few distinctive parts without all the fuss of detail.

It is "art," only in a different sphere.

We have admired beautiful pen and ink etchings, with every detail the master mind could produce, and we have seen the artist with a few bold strokes of a brush create a picture full of life and vigour.

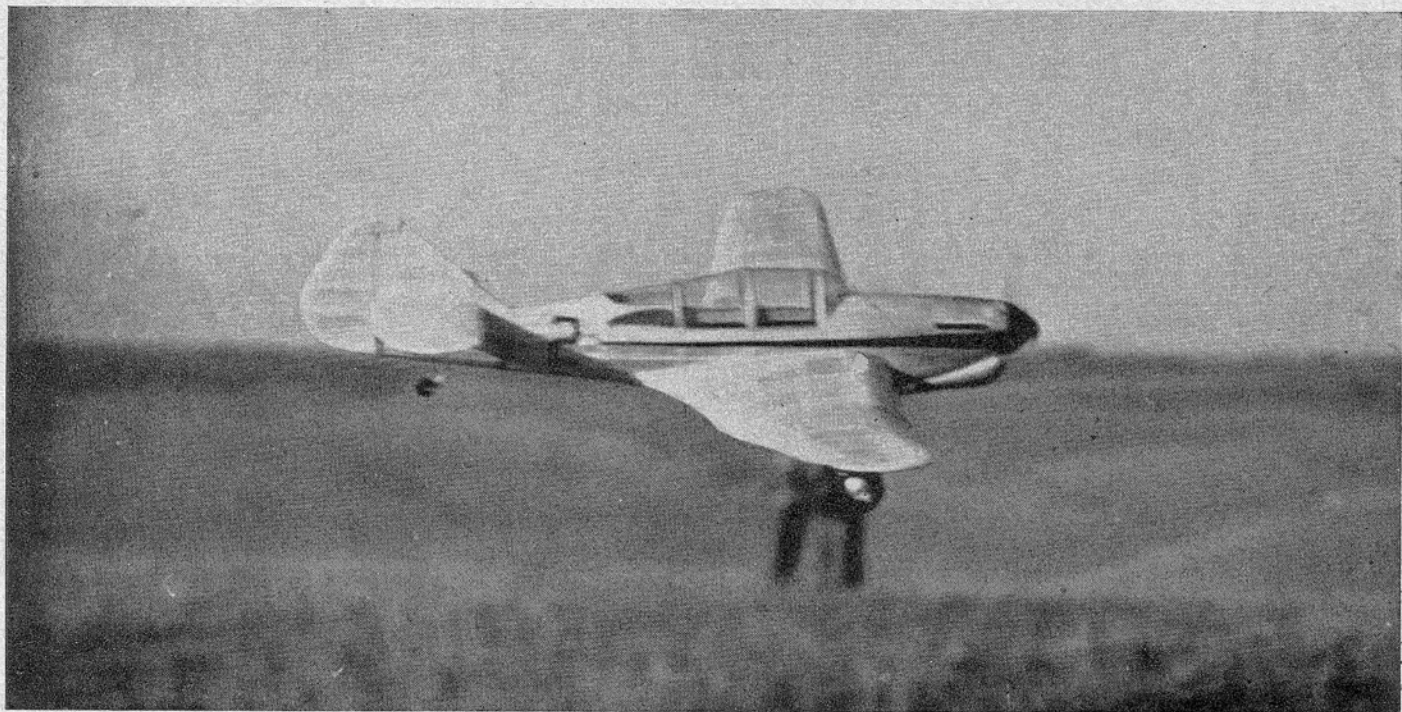
The one common ground to both these types of expressing our ideas is that our boundary line shall be the same, a wing of a certain plan form, the diameter of an engine cowling or the overall length of the model must be in true proportion to the original.

To those of you who do not possess that instinctive art to know what to put in and what to leave out we would say "leave it out." It will have a much cleaner appearance and look perhaps less like a Christmas tree!

The following method helps. Draw on a piece of cardboard the outline of the model you propose to build, making it the correct size of the finished job—cut this out. You then have a silhouette of the completed job if you hold it up before you.

Now suppose you could see the actual prototype sitting pretty on an airfield. You could walk up to it, holding this silhouette of yours in front of you until you arrived at a position when this card of yours exactly covered the real thing. *Now what you can see of the details of the actual job is what you should incorporate in your model.*

## THE MILES "KESTREL" TRAINER



*This fine "action photo" shows another of Mr. Towner's models. Span is 39 in. Plans are on page 65.*

Don't delay building your model if you are unable to see the actual thing, but this just gives you a shrewd idea of how much to leave out.

Now both these types of model, the fully-detailed and the impressionist type, can be divided again, depending entirely on the builder's wishes. He can build with a view to its exhibition qualities as being pre-eminent, with its flying qualities as a secondary con-

sideration, or he can place performance first and exhibitive qualities second.

Probably the true flying scale model is one in which neither one nor the other quality is subservient. A model in which every characteristic, whether it be likeness to form, style of flight or reasonable duration in the air, are all harmoniously blended in an even proportion, so that we shall not hear such remarks as "a fine performance but a poor finish," or "a wonderful finish but a poor performance."



## CHAPTER III

## AERODYNAMICS

## WING SECTIONS. AIRFLOW. C.G. STABILITY. THRUST. TORQUE.

WHEN you see the title of Aerodynamics at the head of this chapter please don't turn over a few pages until you come to something more interesting, or what you may imagine will be more interesting! After all, we are dealing with scale model aircraft "*that fly*," and so we must at least know the essentials of flight.

We do not propose delving deeply and mathematically into the subject, so don't be frightened, and, to those of you who have already dug into the subject before, perhaps you *too* may learn something!

As you are all aware, it is the wing that supports the aeroplane in the air. The distance from wing tip to wing tip is called the "span," and the distance from the front or leading edge to the rear or "trailing edge" of the wing is called the "chord." Now if we multiply the "span" by the average chord we get the "area," that is to say the amount of surface available to lift our model, although we must subtract from it the area presented by the body or fuselage, where no lift can occur.

Now suppose our model has an effective wing area of 1 sq. ft., and the model complete weighs 1 lb., we shall have a wing loading of 16 oz. per sq. ft.

Now this figure is far and away too high for our purpose. In fact we should never exceed 8 unless we are designing a machine for speed purposes only. Actually the most suitable ratios lie between  $3\frac{1}{2}$  oz. and  $7\frac{1}{2}$  oz. per sq. ft. The heavier the wing loading, that is to say the higher the figure, the faster our model will fly. This must be borne in mind when originally laying out our designs if we are to succeed in arranging for our model to fly at a scale speed. Therefore most service type models will be heavier on the wing than light civil and private types.

Now our wing not only has area but it has thickness, and this thickness we design in different shapes, called wing sections.

Each different wing section is designed for a definite purpose, and it is not always possible to discover which wing section is used on any particular prototype, and so we generally use a choice of three or four which we know from experience are suitable for model work.

Now the basic idea underlying all these different wing sections is to create a sufficient lift to fly our model, and at the same time to eliminate as far as possible wind resistance or "drag."

Drag is divided into two parts, "induced" and "parasitic." Induced drag is the price we have to pay for lift, and parasitic drag is due to skin friction, interference between parts close together, projections, and parts not properly streamlined. We cannot get away from induced drag, but the others can be decreased by really smooth surfaces and careful streamlining.

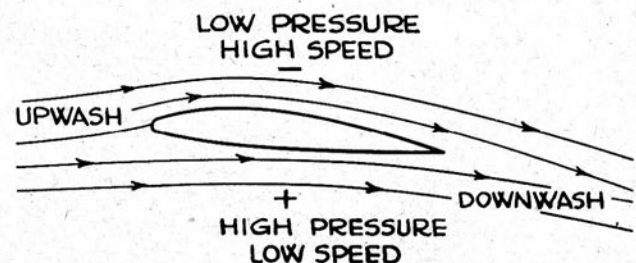


Fig. 1.

Fig. 1 shows a typical wing section, with the air flowing over and under it. You will see that underneath the wing the air pressure is high and the air speed low, while on the top of the wing the pressure is low and the speed high. The air actually has to flow faster over

the top surface than under the bottom, as it has farther to go in order to meet the underneath stream of air. It is this low pressure above the wing from which we obtain the greater part of our lift.

Referring again to Fig. 1, we note that the wing section is tilted at an angle to the air flow.

This angle we call the angle of incidence.

Now if we increase this angle we shall get more lift, but at the same time we shall get more drag as well, but usually we arrange for our angle of incidence to lie anywhere between about 3 degrees and 7 degrees incidence.

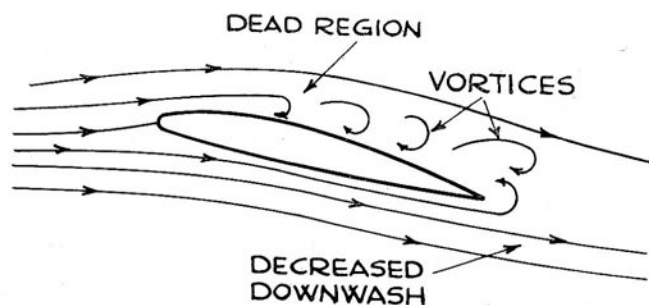


Fig. 2.

When this angle is considerably increased we get an effect as shown in Fig. 2. Here we see that the air flowing over the top surface has broken its flow and does not continue its journey smoothly over the rest of the wing. Here, then, is what we call a "stall." The low pressure has disappeared, and with it our lift, and consequently the wing is not able to support our model in the air, and will not do so until the wing has attained a more normal angle, and even then it will take some time to get into its even flow again.

There are two main types of wing, or aerofoil section, the "high lift" and the "low lift," and they generally correspond to low speed and high speed respectively. That is, the low lift aerofoil has a lower drag at high speed, and therefore assists speed, while the high lift type will carry the same weight at a lower speed, or a greater weight at the same speed, though requiring more power.

Clark Y has always been a favourite with

model makers, chiefly because of its shape and its having a flat underside, which is easy to build on a flat surface. The high lift type has become more popular of recent years, especially the section known as R.A.F. 32, particularly for duration models. It is undoubtedly a very good section, and it seems to be the general opinion that its use will result in a flatter glide. Unfortunately it has a slight "undercamber," which makes it more difficult to construct, in that the covering material has to be stuck to the underside of each rib.

"Undercamber" is a term generally used to denote a wing section with a concave bottom surface.

One of the writers prefers this type, while the other writer prefers a lighter model with a lower lift wing section, such as R.A.F. 34 or Gottingen 436. R.A.F. 34 wing section, instead of our "undercamber," has a convex underside, which keeps the centre of pressure down to a narrow limit of movement, and consequently aids stability.

In explaining centre of pressure, it is that point on the wing section where the lift has its greatest effect. Fig. 3 shows how increasing the angle of incidence causes the C.P. (centre of pressure) to travel towards the leading edge, and vice versa.

It can readily be seen that flying on a "bumpy" day, or with only a small amount of wind, the model will be flying through air that contains local disturbances, and the angle of incidence will vary continuously, with a backward and forward movement of the C. of P., and consequent loss of stability.

One comforting thing to know, however, is that if we use a section similar to the prototype we shall be able to make the model fly quite well, though it is possible that a different section would give a slightly better flight. Thick wings are not as good as thin ones from a model point of view, but we need not worry unduly.

Before continuing further, we must deviate to lend a hand to our friend "gravity" and



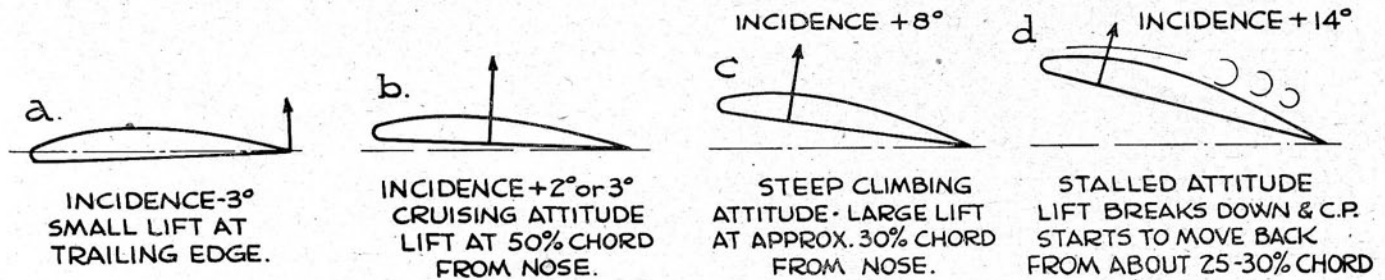


Fig. 3.

bring him into the picture. We may somewhat loosely define the centre of gravity as "that part of the model where gravity has the greatest effect." That is to say, if the C. of G., or centre of gravity, were at the nose of the model, the model would come to earth in a vertical nose-dive; or, if at the tail, the model would come to earth tail first. So you see it is very important where this centre of gravity of ours is placed.

At the same time we should note that the machine will rotate about three axes passing through the C.G., as shown in Fig. 4. The machine can be rotated by disturbances in the air or by the controls. Rolling is corrected with the ailerons by raising or lowering the wings; pitching by the elevators; and yawing with the rudder. Occasionally rolling can be corrected with the rudder. This is done by turning it so that the lower wing is on the outside of the turn, and thus goes faster, which increases its lift.

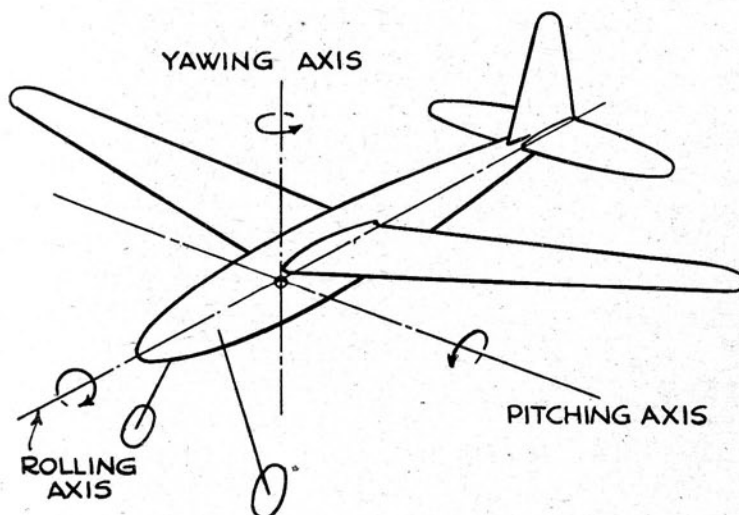


Fig. 4.

The usual method adopted to maintain stability is based on placing the C.G. in such a way that the wing moment is always positive (climbing) or negative (diving).

Let us take the latter case first. Fig. 5a shows that the wing moment, which is negative (diving) can be balanced by a tail moment that will raise the nose (a climbing or positive

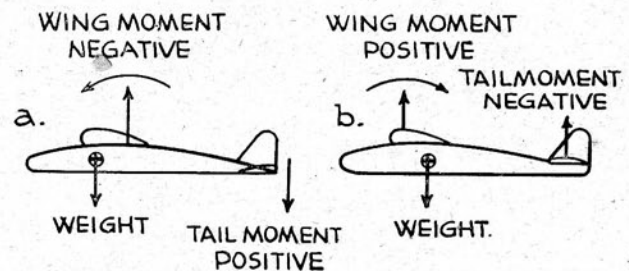


Fig. 5.

moment). In other words, if we place the C.G. at from one-quarter to one-third of the mean chord from the leading edge, and mount a tail-plane fitted with a symmetrical section placed at a small negative angle of incidence, which will experience a down load, we can achieve stability.

Now take the former case. Fig. 5b shows that the wing moment, which is positive (climbing) can be balanced by a tail moment that will depress the nose (a diving or negative moment). In other words, if we place the C.G. at the trailing edge and mount a tail-plane fitted with a normal section so that it will produce lift, we can achieve stability.

Actually the only arrangement used on normal full-sized aeroplanes is the symmetrical section, and if we are to

conform as nearly as possible to the real thing this is the type of tail to use. The symmetrical section (sometimes called non-lifting), like R.A.F. 30, is used to give sometimes a positive and sometimes a negative moment.

However, there are times when the C.G. may become too far back, owing perhaps to bad design, faulty workmanship or badly chosen prototype; when the fitting of a (lifting) section like Clark Y may get us out of our troubles.

Having arrived as far as the tail, let us consider the functions of the fin.

The well-known weathercock shows the general principle, which is based on the fact that it always places itself parallel to the air-stream. This is achieved very simply by arranging more area behind the turning axis. The same argument applies to the aeroplane, full-size or model. We want the model to head into the relative wind (which is not neces-

If the area is not distributed so that its centre is situated well behind the hinged line the model will not show this weathercock action and the slip will not be corrected, with the result that it will probably stall and spin into the ground.

On the other hand, if the area behind the centre of gravity is too great there will be a danger of the model being forced into a spiral which gradually tightens until it dives into the ground. Obviously it will be caused by a fin that is too large.

We have included this brief treatise on the fin as, although on the full-size craft the size is determined for us, yet it is sometimes advisable to increase this area somewhat. Where, however, the shape of the fuselage is of the box type variety the fin as a rule is quite adequate in area, but where the fuselage is of a round or oval section the side area behind the hinge line or turning axis does not offer such an effective weathercock effect, and so the fin has to be increased slightly, say, by 7 to 10 per cent.

With regard to the tail or elevator, this can sometimes remain the same area as the prototype, although a slight increase can be of advantage to counteract the pitching movement which normally would be controlled by the pilot himself.

So far we have merely considered the model as gliding, but when we come to power our model two more factors step into the picture, "thrust" and "torque."

Thrust is the force that pulls the model through the air. In the case of the rubber-driven model it has a maximum value at the beginning of the flight, and decreases fairly rapidly as the motor runs out. It is obvious that the thrust will supply a moment round the C. of G. in all cases when it does not pass through it.

Now let us study the sketches in Fig. 7. In case "a" the C. of G. lies high and the thrust line is placed low, as shown by the full line; the thrust will tend to raise the nose of

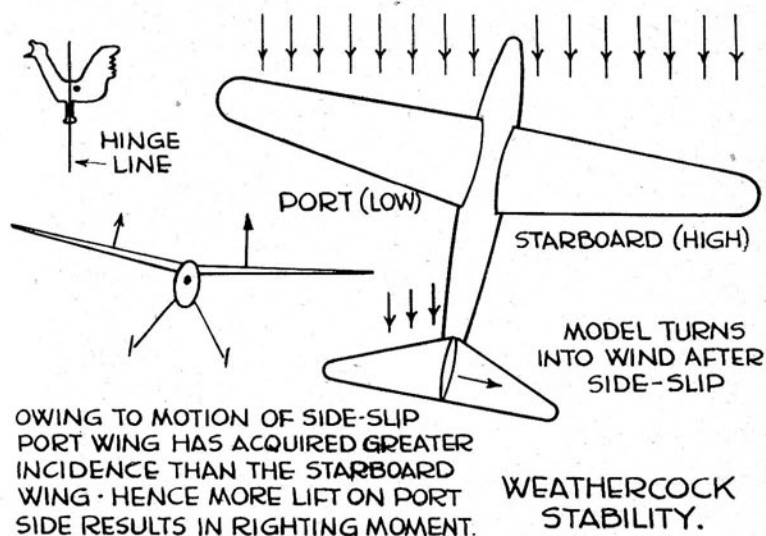


Fig. 6.

sarily the direction of the wind as seen from the ground). This is particularly important when the model starts a side-slip. In that case one wing will be lower than the other and the model will skid in the direction as shown in Fig. 6.

The air will now strike the rudder or fin at a small angle, which turns the model into the wind.



the model and make it climb.

This can be demonstrated by drawing a similar figure and fastening it by means of a drawing pin through the C. of G. If one pulls in the direction of the full line the nose will tend to rise, that is, it will increase its angle of incidence.

This may be too much and the model will stall; therefore we try to choose the thrust moment in such a way that it will just supply the amount of climbing moment that we want without stalling. In order to do this we apply what is termed "downthrust," that is, we tilt our thrust line downwards slightly by one or two degrees so that the initial burst of power from our motor will not raise the nose too high.

We will now turn to case (b), Fig. 7, which is the opposite to case (a). The thrust line, running as in the full line, will make the model dive with the motor on, and so we employ upthrust. It would be still better to rearrange the lay-out so that the thrust does not supply quite such a large diving moment.

Now this is very important. In the glide we arrange for stability and direction by means

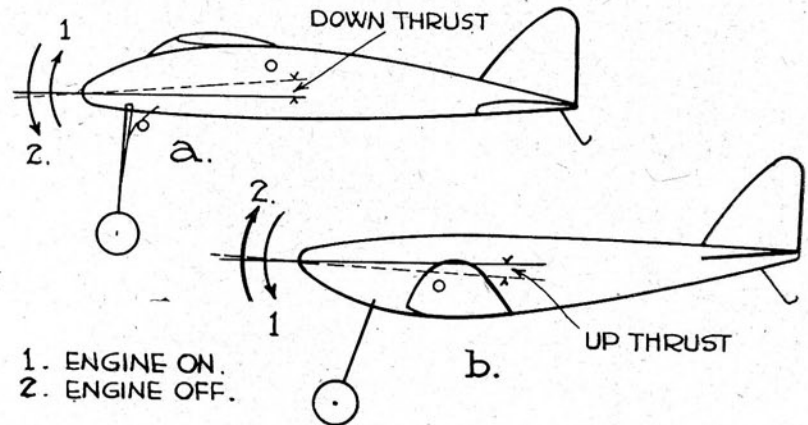


Fig. 7.

come into their own and bring the model safely down.

The torque of the airscrew is the equivalent of the drag of the wing, and is opposed to the direction of motion. In other words, if an airscrew runs clockwise *when seen from behind*, the torque will be anti-clockwise and the model will tend to lower the left wing (Fig. 8). We must look for a means to counteract this torque, for it may put the model into a tight bank, so that it will be prevented from climbing, or may even dive into the ground. (Fortunately for us, however, we are only dealing with scale models, which haven't such a terrific amount of torque to be controlled. The duration

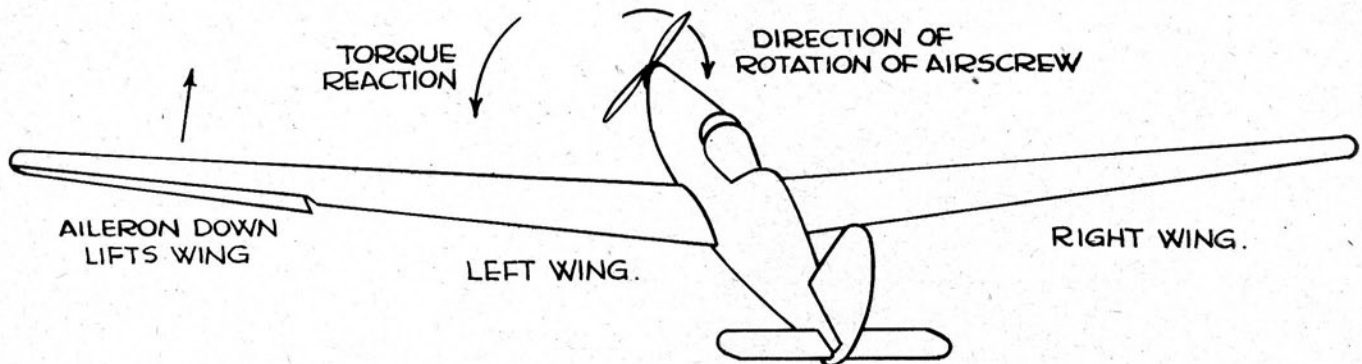


Fig. 8.

of the elevator and rudder, and this trim must not be changed.

Climb and power flight must be obtained by the proper use of downthrust, so that when the power has run out the gliding characteristics

people have to deal with very large propellers and much more power!)

As the torque supplies a rolling moment it will be logical to counteract it by another rolling moment; in other words, if we use

"aileron" control we correct this bank, but as the power decreases the model will be banked in the opposite way. However, if we use a light "aileron" control, i.e. depress the left wing aileron to raise the left wing very gently and then allow the model to circle with the torque, that is to the left with the power on,

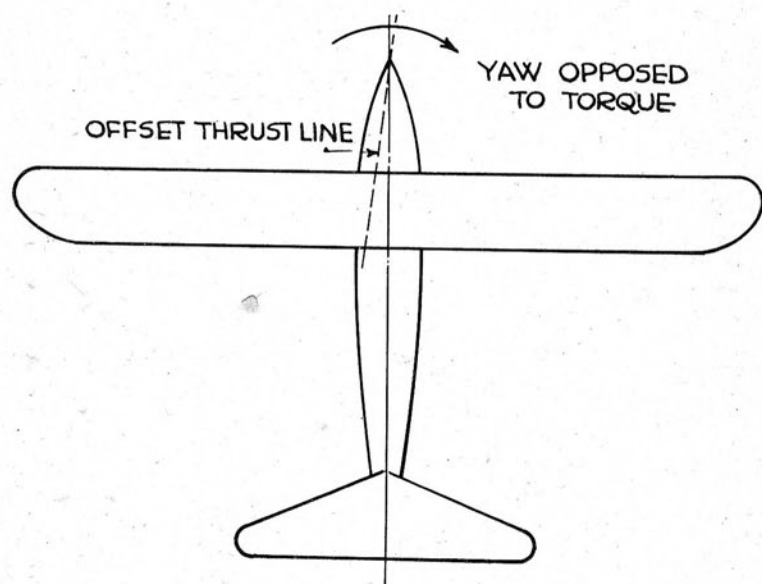


Fig. 9.

the sting will be taken out of the torque, and when the power dies away the model will gently bank towards the right.

However, probably the best method of all is to offset the thrust line slightly so that the thrust tends to pull the model to the right, and when the power dies down the model takes up its normal flying direction. See Fig. 9.

Now in this treatise on aerodynamics there is also the question of dihedral to consider.

Dihedral is the "V"-shaped angle between the wings as viewed from the front or behind; in other words, the wing tips are higher than the base or root of the wings.

The theory of this dihedral is the fact that when one half of the wing drops owing to some disturbance in the air the model will start a side-slip or skid.

The lower wing will now have a greater incidence to the air stream than the other wing.

The lift on the former will therefore be greater, with the result that the lower wing will now rise and the model be brought back to an even keel again.

Too little dihedral will cause the model to slip and skid all over the sky, whereas too much dihedral will cause the model to rock from side to side.

Now dihedral is incorporated to a greater or lesser degree in most full-size aircraft, but from the aero-modeler's point of view we shall generally have to increase it slightly, especially if the model happens to be a low-wing type or the motor develops a lot of torque.

The "first-timer" is advised to increase tail areas anything up to 10 per cent, and dihedral a few degrees, say up to five, but with experience these can be reduced even to scale dimensions in some cases. As a general guide, these increases are more necessary in high performance and high-speed prototypes than in the case of light aeroplanes of the private owner class.

It must always be remembered in model-work that we have no pilot to correct the machine in flight, so we have to arrange for the model to be more stable and less sensitive than the full-size aircraft; although, of course, there are real aircraft that will almost fly themselves, and in fact fly *better* by themselves than when a ham-handed fellow takes charge!

Let us hope by now you have digested the foregoing chapter and have a fair idea of the reasons of it all; also that you will realise that the building and flying of scale model aircraft is not just a slavish copy of the real thing.

In fact the more we build and fly these miniature 'planes the more we realise that scale-model flying is a worth-while job where we can let our ingenuity play to the full in incorporating these ideas of stability without detracting from the appearance and scale of the original.



## CHAPTER IV

## DISTRIBUTION OF WEIGHT

## SIMILARITY TO PROTOTYPE. VARYING C.G. POSITION.

LET us suppose it were possible for an owner-pilot of a full-size craft to say to himself, "I am fed up with my engine and all its complications; I will scrap it. But in order to get motive power I will install a rubber motor like the aero-modellers do." Supposing it were faintly possible, let us see what would happen to his distribution of weights.

First of all he would take out his engine, a total weight of, say, three hundred pounds, from the front of the machine, and he would proceed to hook a tremendous number of rubber skeins to his propeller shaft and stretch them right aft to somewhere above his tail wheel; and what would be the result?

His distribution of weight is entirely altered. Even assuming that there would be the same amount of rubber motor in front of the centre of gravity as there would be behind, so that these two weights cancelled out, there would still be the fact that the three hundred pounds of motor was not where it was in the nose. Attempting to fly a craft in this condition would be like throwing an arrow or a dart with the feathers in front and expecting it to continue in that attitude!

The aeroplane simply would not fly.

But that is the approximate state of a model if we merely copied the prototype and did not rearrange the distribution of weights.

If we wished to suspend a correctly built model from the ceiling on a strong thread we should find that we should have to attach this thread to the 'plane at a point one-quarter to one-third of the way back from the leading edge of the wing along the centre line of the fuselage. The 'plane would then assume a normal flying position, that is to say, parallel to the ground.

Actually, of course, this only applies to a wing whose leading edge or trailing edge does

not sweep forwards or backwards. If either or both did we should have to find the "mean" one-third back from the leading edge of the whole wing. The whole point is that the centre of gravity should lie on this line. (See the chapter on Aerodynamics, Fig. 5a.

Actually, of course, the final exact position would have to be found by trial and error.

Our friend the owner-pilot, prior to discarding his petrol engine, would find that his 'plane, if suspended likewise, would take up its normal flying position in like manner.

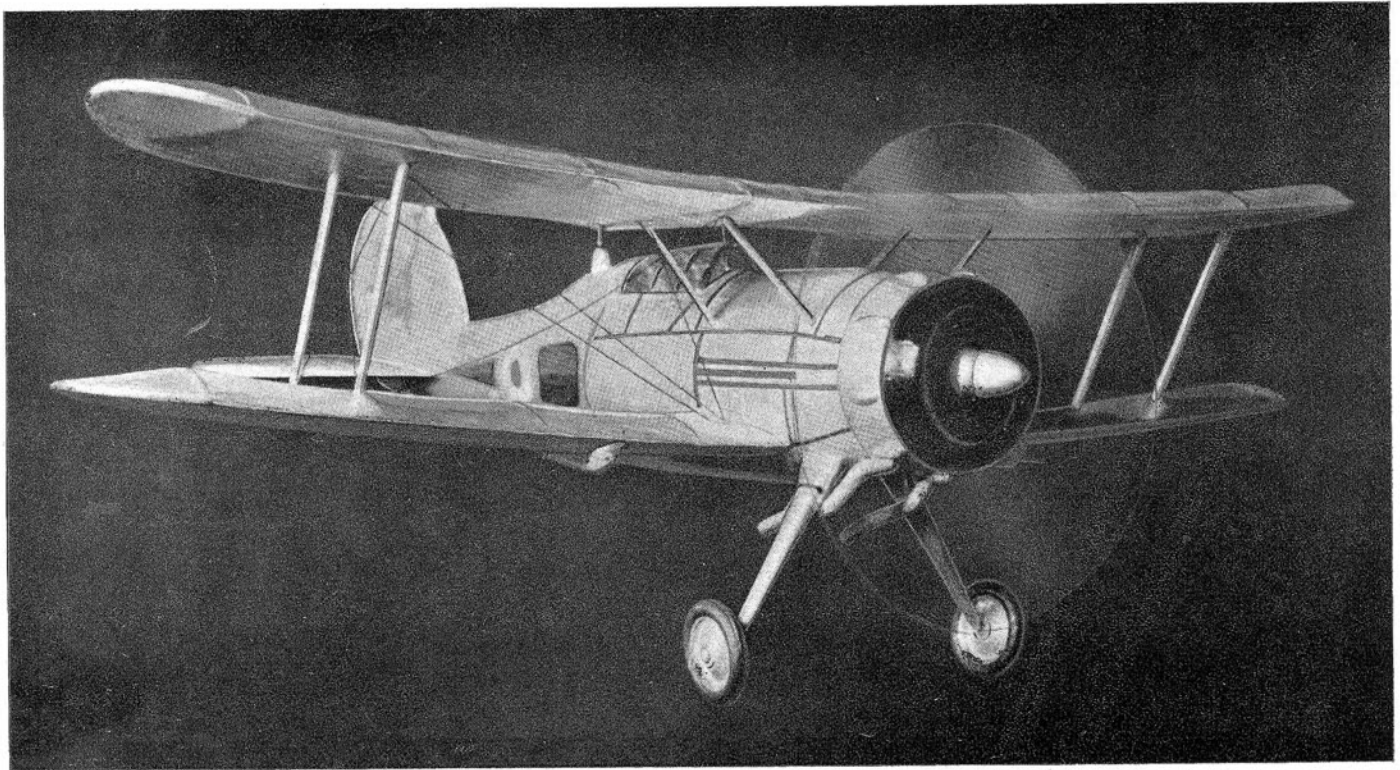
Now with an average type of duration 'plane we just slide the wing along the fuselage until the model balances correctly, and away it flies. But in our case the wing position is definitely fixed for us by the prototype, so we have to hunt around for other means of accomplishing this.

The first thing that comes to our mind is, naturally, to put weight into the nose, but weight unfortunately is also one of our chief worries, as the more weight we pile on the more power we require to lift it, and more power means more rubber! This means more weight, and so we go on!

Now as we are definitely tied to the outline shape of our model, we must look for something we can alter without disturbing the shape, and the first thing that strikes us as being completely different from the real thing but hidden inside is the motive power; so perhaps we can arrange this in some way to correct our weight distribution.

To get the greatest number of turns on our motor, and consequently the longest power run, we must have a long motor, and the generally-accepted principle is to thread our motor from the nose to the tail. With this arrangement we shall probably have about two-thirds more rubber behind the centre of lift than in front. This

## THE GLOSTER "GLADIATOR"



*Here is a fine photo of a very popular biplane. Span is  $18\frac{1}{2}$  in. Full-size plans are at the end of this book.*

means, of course, that not only have we relieved the nose of a lot of weight in the form of an engine, but that we have actually piled on a lot more weight to the rear of the centre of lift, exactly where we do not want it.

As the whole design is one big compromise, let us bring our rear hook well forward, so that the centre of lift of the wing lies half-way along the rubber motor. In this arrangement, as we have just seen, the front and rear portion of the motor cancel out, and provided we can make our tail unit light enough and a certain amount of lead or plasticine, or "what have you," is added to the nose, we can achieve our correct position for the centre of gravity.

Let us suppose when the motor was the full length of the fuselage we could put on six hun-

dred full turns, but with the shortened motor we can only put on about four hundred; the duration is less. But as we have to add less weight in the nose than we should have to do in the first case we shall not want such a powerful motor, and so we can actually use *fewer* strands of rubber. This will slow up the speed of our airscrew and will lengthen our motor run. It may perhaps equal or even *exceed* the duration of the first example of six hundred turns.

But there is still, in the majority of cases, dead weight to be added to the nose, and this is where a gearbox comes right into its own on a scale model. The gears and their shafts have of necessity a certain amount of weight, and we can place this right forward, just where we want it!



## CHAPTER V

## GEARBOXES

## FUNCTIONS OF GEARS. EFFECTS ON MOTOR.

THERE is a maxim in aircraft design that one should design a component to serve as many uses as possible in order to save further parts and cut down the weight.

Now fortunately a gearbox fulfils five very important functions, viz.:

- (a) Weight in the right place.
- (b) Longer motor run.
- (c) More even torque.
- (d) Less torsion in the fuselage.
- (e) Use of smaller propeller.

The question of weight we have dwelt on at some length, but it seems it cannot be emphasised enough. People one would expect to know all about it seem to slip up on this point, or perhaps they are so concerned with the looks of the model that they can't afford to compromise! But whatever it may be, however well the model has been built and finished, if the centre of gravity is in the wrong place the model is no longer in the flying scale category and should be classed as an exhibition model only.

Now the longer motor run achieved by using a gearbox is a very great boon, especially as we propose shortening our motor to effect trim; and it comes about this way.

Suppose we require eight strands of rubber  $\frac{1}{4}$  inch wide and 20 inches long to fly our 'plane, and these are made up into one motor, the total number of safe turns we can put on is in the region of 580, depending on the freshness of the rubber, whether it is well lubricated and well stretched, etc.

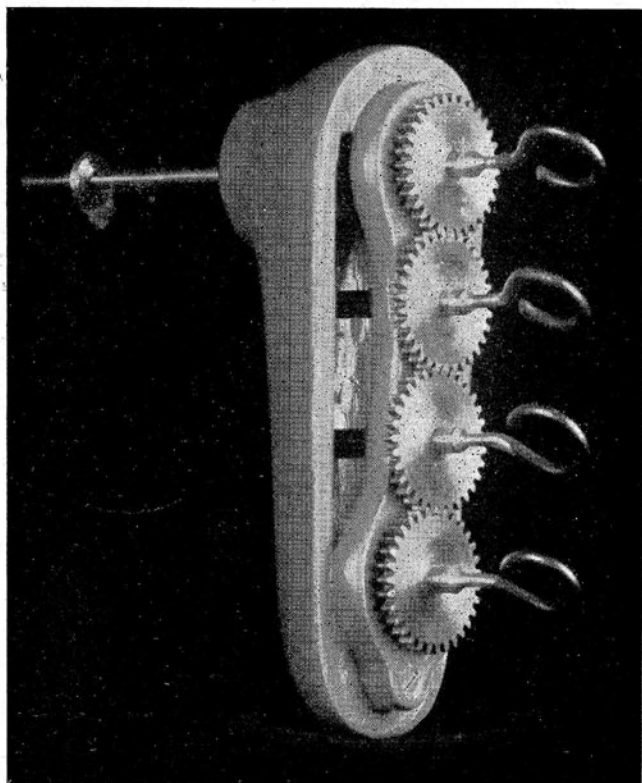
When this motor is fully wound and tightly knotted it is obvious that the stretch of the rubber motor is taken up in wrapping itself around itself in the form of knots, and that if we divide our eight strands into two lots of four equal strands geared together we shall be able to get a greater number of knots on each skein, and hence a longer motor run but the

same total power output. Of course, there is added friction between the gears and shafts and bearings to account for, but taking the twin skeins only into account, where 580 turns were put on in the single skein we can now actually wind up to 817 turns on the twin skeins.

Moreover, should we use *three* gears and a third skein, then we can increase our total turns to 1,000. Still further, if we use a gearbox of four skeins and four gears then we can increase our number of safe turns to 1,160! It must be borne in mind that by using two skeins we do not double the number of turns, but it increases in accordance with the square law. That is to say, two skeins will take 1.41 times the number of turns of a single skein, three skeins will take 1.73 times and four skeins will take twice, and so on. The use of gears evens out the torque, and consequently the thrust or pulling power of the airscrew. In order to explain this, let us examine the single skein motor, and wind to full turns; as we are winding it becomes harder and harder to do so. Now in the reverse process, as the rubber is unwinding, the greatest power is delivered to the airscrew during the first few seconds. As the motor runs out so the power dies away, until the last few turns are of no value at all. This all means that we get an initial burst of power that takes the model rushing upwards, and then a gradual slackening off until the power is exhausted.

From the duration man's point of view this is excellent, as he is enabled to get his "ceiling" quickly, accompanied by a long, floating glide; but for the scale modellist this is all wrong.

We have already decided that the model should not only be to scale, but the style of flight should be correct. That is to say, a replica of a small light 'plane should not rush up into the sky any more than a scale version



of a high-speed fighter should come floating in on a slow glide.

Fortunately, with the use of multi-skeins not only have we lengthened our motor run, but, as we still have the same amount of weight in the rubber, we still have the same amount of power. This same amount of power has to be expended over a longer period of time, and in so doing the initial burst of power is lessened, and the power more evenly distributed over the whole duration.

By using three- or four-gear motors this effect is still more pronounced, and, in fact, with a four-skein gearbox we can utilise nearly the whole of our turns for flying and almost do away with the useless turns at the finishing end.

Some fellows who have tried gearing will tell you that they know it gives a longer power run, but they don't get the climb. *This slow climb and long power flight is exactly what we want for scale flight.*

The illustrations show various types of gear-boxes. Fig. 10 is a four-spindle box shown applied to a Gipsy type cowling. Fig. 11 is a three-spindle box enclosed in a Kestrel or

Merlin cowling. Fig. 12 is a simple two-spindle box fitted to a light 'plane with a horizontally opposed engine, and Fig. 13 is the same twin spindle with the propeller geared up to go two or three times as fast as the rubber shown fitted to a Pobjoy motor.

If we refer to the chapter on aerodynamics where we discussed downthrust and sidethrust to correct for torque, we see that by reducing the initial burst of power we have helped ourselves tremendously in achieving a stable flight.

Now let us consider function number four of our gearbox. Less torsion in the fuselage. Most of us have heard of reaction. Action and reaction are equal and opposite. That is to say, the turning action of the rubber in turning the airscrew has an equal and opposite reaction in the form of the motor trying to twist the rear of the fuselage about itself in the opposite direction to the rotation of the airscrew. This all means that the part of the airframe to which we attach the rear hook has to be strengthened

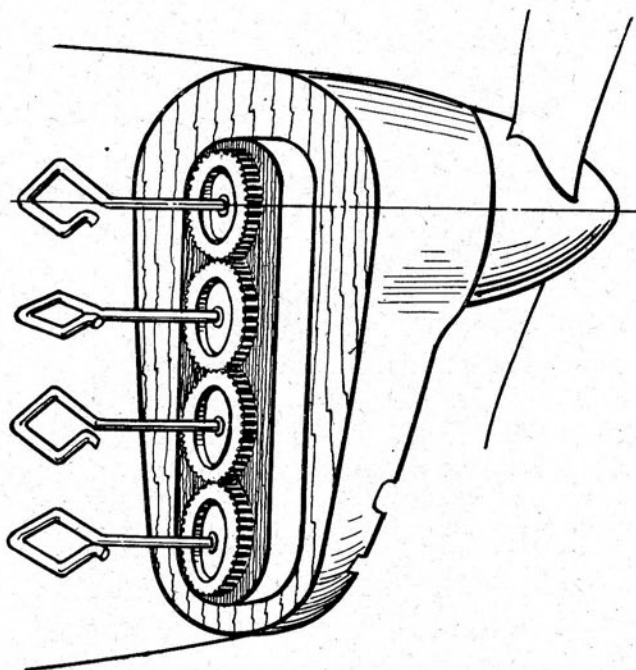


Fig. 10.

to withstand this load, and in fact the whole fuselage has to be strengthened, and consequently more weight must be added to the rear.



But if, on the other hand, we use two skeins of rubber geared together, then one turns in the opposite direction to the other, and the *torsion at the rear hook is cancelled out*, greatly to our advantage, since the fuselage is not twisted at all.

Naturally, a combination of an even number of skeins will always produce this result, while odd numbers will only make a difference in torsion of the one odd skein.

We now come to the last, but not the least, important factor of using a gearbox, namely, the use of a smaller propeller.

Going back to the single skein arrangement as exemplified by the duration model, we have to use a large airscrew and plenty of blade area to absorb some of the initial burst of power,

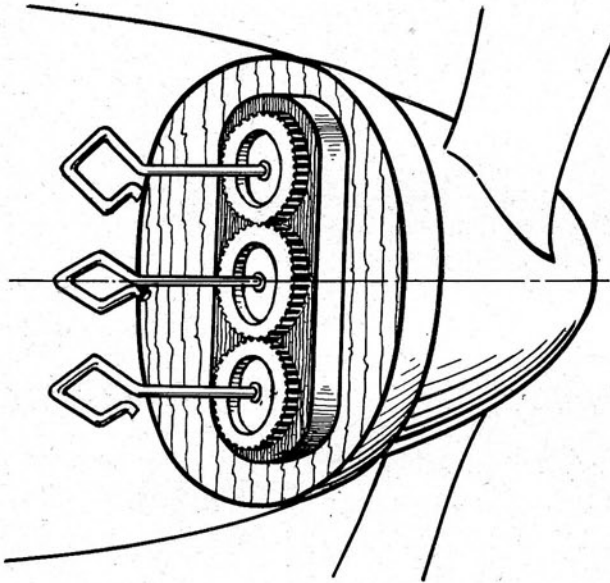


Fig. 11.

otherwise the motor would run out too quickly. But where we have a more or less even output of power, and spread over a longer period of time, we can use a smaller diameter airscrew, which means less blade area. A smaller diameter means a faster revving airscrew to deliver sufficient power to fly, but this means getting nearer to scale. (As a matter of fact, all S.M.A.E. records for scale models must be accomplished with a propeller of the correct scale diameter.)

While on this subject it would be as well to

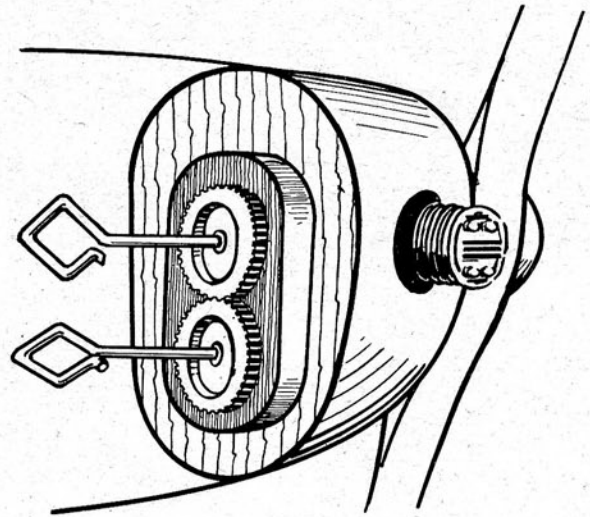


Fig. 12.

mention the practice of gearing up the airscrew, that is to say, arranging for the airscrew to revolve faster than the rubber motor. By this method a still smaller propeller can be used, but there is a limit to the size of propellers that can be used efficiently. Not only that, but if the airscrew is not designed correctly it will tend to go back to its old tricks again and give us a high burst of power and a long trail-away of useless turns.

So we can sum up the five uses of the gearbox and say that by its application we can achieve a long, steady output of power, maintaining a stable flight at a constant height for the longest part of the motor run, and giving us the exact effect of the prototype in flight.

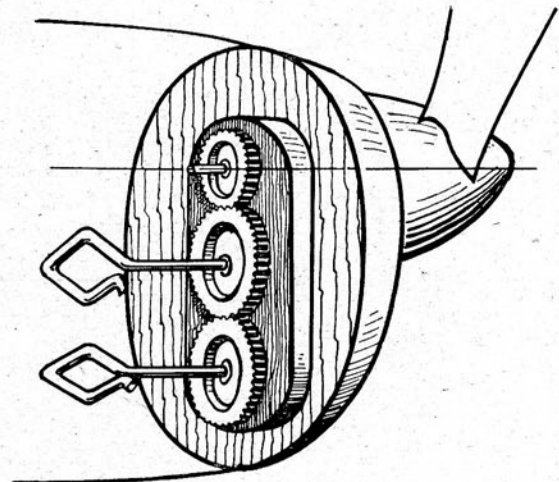


Fig. 13.

## CHAPTER VI

## DIRECTIONAL CONTROL

## RUDDER CONTROLS. COUNTERACTING TORQUE.

So far we have only considered longitudinal trim and the correct placing of weights to achieve it.

However, the question of movable controls will naturally occur. For those who wish to fit them, the simplest and most effective way is to have the hinged portions, such as the rudder, ailerons, elevators, etc., made separately, and then fastened to the main portion of the aerofoil by means of aluminium tabs in such a way that each control surface will remain fairly rigid in whatever position it may be placed.

However, from a purely performance point of view it is far better to leave all control surfaces definitely fixed and built integral with the model in a neutral position.

However well one may trim a job and mark the exact position of variable controls, the probability is that on a roughish landing the controls will all be put out of order!

Also, as these controls are very sensitive, especially on the elevator and rudder, it is a moot point whether they can be set accurately after each flight, and the chances are that in the heat of the moment and rush to make another flight these controls may be forgotten, with disastrous results.

Some form of semi-permanent adjustment is obviously necessary, and it is suggested that the "empennage," that is the stabiliser, elevators, fin and rudder, be made as a single unit, and detachable. This unit can be held in place by means of small wire hooks and rubber bands, and will take a knock safely. Not only that, but it is far easier for transport purposes, and transport amongst the aero-modelling

fraternity is generally a very serious problem.

But to return to the adjustment of the tail unit. It will readily be seen that it is quite a simple matter to pack the elevator up slightly, either positive or negative, by cementing small strips of balsa underneath, and to very slightly offset the unit sideways to obtain a circling inclination to one side.

Now this circling tendency must be only very slight, otherwise we shall have the model dipping a wing and spiralling to earth.

It is very important that these various semi-permanent adjustments be made for the glide only, so that when the motor runs out our model shall still be in complete stability and shall safely come to earth.

Of course, the turning tendency to the left is always present when the motor is running, owing to the torque or reaction of the airscrew, but this will be counteracted by offsetting the nose-block slightly to the right.

It is important that all superimposed adjustments while under power should be made to the nose-block, *and the nose-block only*. Not only should the direction of flight under power be adjusted this way, but also climbing abilities as well, by either giving a slight amount of upthrust if the model tends to be underpowered, or downthrust if the model should climb too steeply.

It will be realised that with the use of a gearbox to eliminate the initial burst of power there should not be excessive torque to counteract, but where a single-skein motor is used without a gearbox, then a certain amount of side- and downthrust is almost essential.