CHAPTER VII

WING FIXING

RIGIDITY. DETACHABILITY.

THERE is another point directly affecting stability in flight, and that is the " rigidity " of all parts, and when designing wing fixings, tail fixings, undercarriage fixings and so on, this must be very carefully borne in mind.

We go to great lengths to get our trim exactly right after having studied—and, we hope, applied—the lessons learnt in the chapter on aerodynamics; and then if, during flight, the tail unit is not a fixture in the sense that it is rigid, and slight lifting of the elevator or turning of the rudder by a sudden gust occurs, all our good work is upset. Even should the model right itself in the air we do not know when the next disturbance will upset it again, and the whole flight is watched with our hearts in our mouths, wondering when the model will crash. Consistent flights mean consistent setting of the controls, and therefore no flapping part can be tolerated.

In considering the type of wing fixing it is as well to consider the problem of transport as well, as it may be advantageous to design our model to separate into more than the usual three parts — fuselage, wings and tail. Naturally, the size of the model also has a bearing on the subject, and here let us impress upon you the fact that most people build their models too small. Should storage space be a deciding factor, then we must perforce keep our size down, but even then, cleverly designed models that will take to pieces at home but will not fall to pieces in the air are a great asset; and it is suggested that builders should try, wherever possible, to keep to the S.M.A.E. formula of one inch to the foot for all normal models. Perhaps for the smaller prototypes of, say, 30 ft. span, we can build to a scale of one-and-a-half inches to the foot, which will give us a model with a span of 45 inches—a nice handy size, and something that will not want such a dead calm day to fly in!

Generally speaking, a high-wing design, that is, with the wings fixed on or near the top of the fuselage, is fairly straightforward, as the roots of the wings can be either hooked on the top of the cabin sides or else dowel pins pushed into paper tubes can be used, as shown in Fig. 14. These wings are then generally held by struts reaching from the bottom of the cabin sides of the fuselage, supporting each wing panel perhaps half-way out from the root. These struts, of course, brace the whole wing and make it rigid. Should these struts be attached to the base of the fuselage in the same way as the wings, by dowels and paper tubes or by the use of press studs, the whole wing will knock off on a bad landing and perhaps save a bad crack-up.

Press studs are quite suitable for small parts,

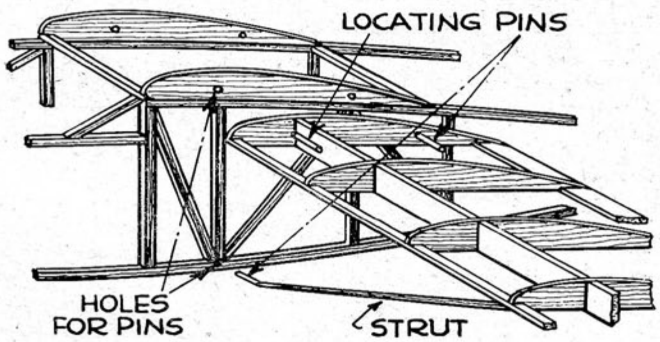


Fig. 14.

and where no great strain is to be taken. Of course, heavier types are available, but generally they require such a pressure to snap them together that quite a lot of damage can easily be done to the surrounding parts if these are not purposely strengthened. It is often difficult to fix these fasteners firmly to the structure without their pulling out. As a matter of fact you will be surprised how strong they will be if you just " sew " the fastener into place with an ordinary needle and thread and a spot of cement or glue to make all firm, as shown in Fig. 15.

Where paper tubes and hardwood dowels are used, these should generally be about ⅛ in.

dia. up to, say, $\frac{1}{4}$ in. for the larger and heavier models.

This $\frac{1}{8}$ in. dia. dowelling can easily be purchased at any wood store, and is usually made of birch.

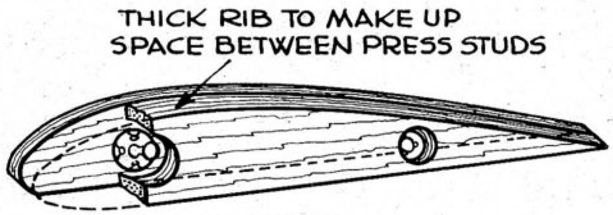


Fig. 15.

In order to keep the wings firmly butted against the airframe, rubber bands are generally used. These form the easiest method of holding the wings into position, but also allow a slight movement should the wings come into contact with a solid object. The rubber bands can be fitted in two ways. Firstly, small steel wire hooks protrude from each wing root and are connected together by a rubber band in tension passing right through the cabin-top in such a way that the rubber band pulls both wing roots tight against the fuselage. This is no doubt the neatest method, but not too easy to fit on the flying-field.

The other method is to use external rubber bands, one on each leading and trailing edge, and each one separately attached to suitable steel hooks on the fuselage. If these are neatly fitted and the colour of the rubber band is chosen to harmonise with the adjacent colour they will not be too prominent; a very easy device is assured, and from experience gained in the flying-field we recommend this as the better method of the two.

These rubber bands are only used to keep the wings in position and to prevent the dowels from coming out of the paper tubes, and they do not take any of the lifting loads.

The wing fixings of a low-wing model, a model whose wings are attached to the bottom of the fuselage, do really present a difficulty, because these wings are usually what are termed " cantilever " wings. A cantilever wing is one that is self-supporting and has no outside struts to support it.

Therefore we have to design a fitting that will be definitely rigid and will not allow wing flutter, but at the same time must be capable of withstanding normal landing shocks.

From a purely scale point of view the wings on a low-wing prototype are generally attached to a centre section which projects quite a distance either side of the fuselage, and from a transport point of view it may be advisable to make this centre section removable. If this be so, then our separate wing panels can be firmly plugged into the centre section and the centre section itself can be flexibly mounted to the fuselage by means of vertically placed rubber

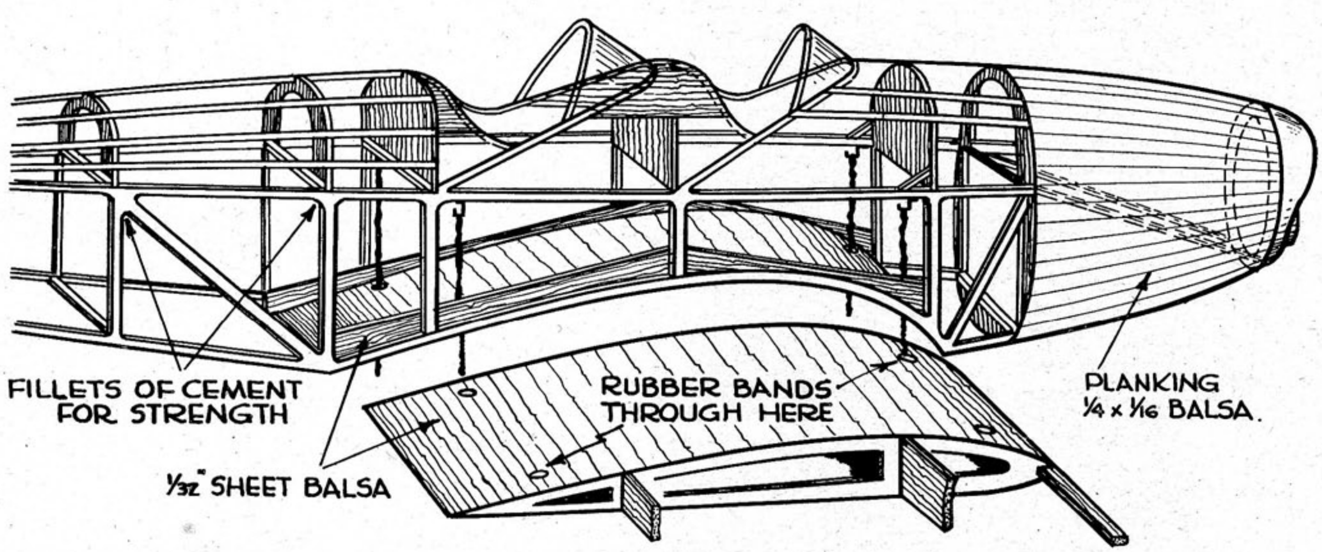


Fig. 15*a*.

bands inside the fuselage, and the centre section located by the arch formed under the fuselage to accommodate it. On any of the smaller powered prototypes this is quite a good method. Fig. 15a is a suggestion for a " Moth Minor " on these lines.

However, when a high-speed and high-powered job is under consideration the centre section is usually very well faired or streamlined into the fuselage, and here it is desirable as a rule to combine both together into one unit, and it is in this case that the wing fixing calls for a lot of thought.

Should the dowels be rather long in order to get rigidity, the dowels may rip out quite a lot of framework on a bad landing. On the other hand, if they are short, in order to enable them to slip out quickly, then the wing will not be rigid and will probably have a variable dihedral and consequently an unstable flight. When building large models of, say, over four feet span, it is advisable to make detachable wing tips of about four or five inches down the span, and plugged in by whichever method is desired. This will help to save a wing in a crash.

Then there is a further method which the writer used successfully on the " Airspeed Envoy." This method consists of two aluminium " U " pieces attached to each side of the centre section on the outer ribs. These " U " pieces fit over the root ribs of the wing panels, and balsa dowels are pushed right through the " U " pieces and through suitable holes in the wing panels. These dowels are made strong enough to hold all together rigidly, but in the event of a crash the dowels break and a fresh dowel is inserted, pushing out the broken pieces. These dowels or shear pins can be likened to a fuse in an electric circuit, or safety valve in a steam engine. No rubber bands are needed at all in this type of wing fixing.

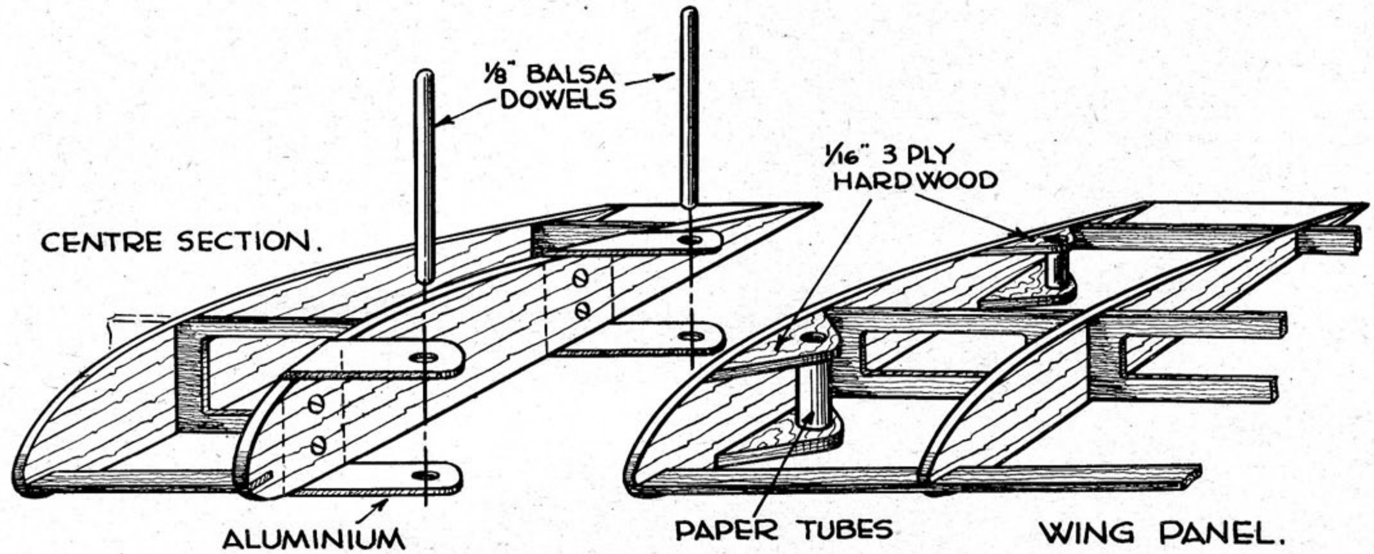
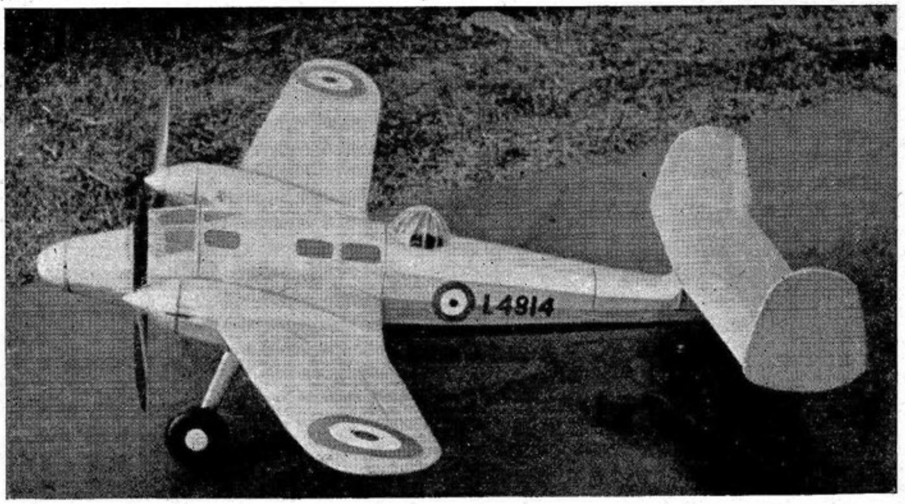


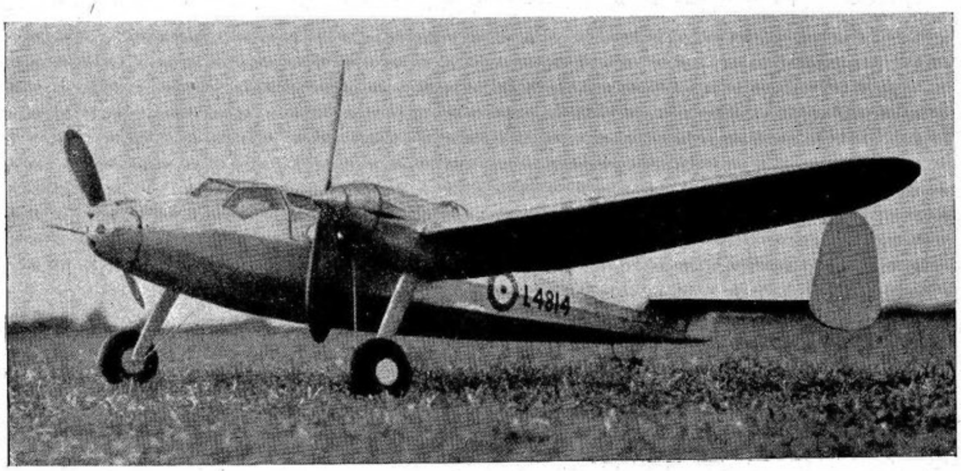
Fig. 16.

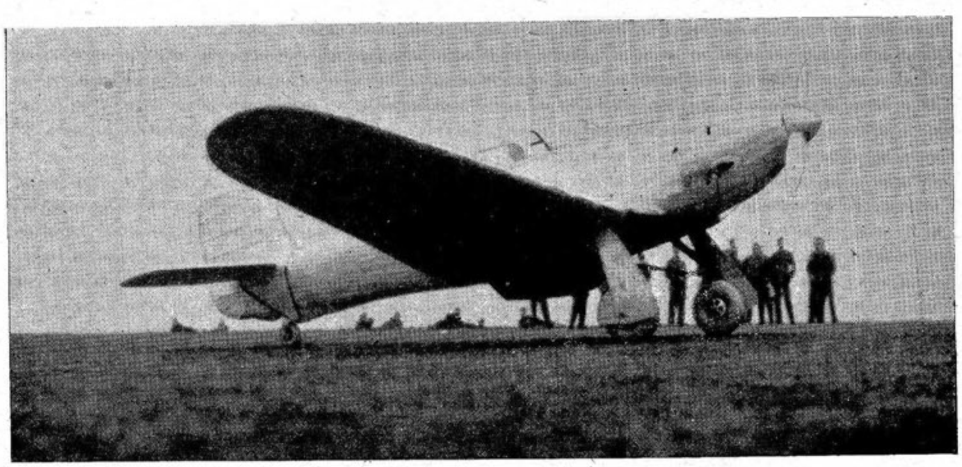
It should be borne in mind that a certain amount of " spring " should be incorporated in each wing, otherwise it will be liable to snap. In order to determine how much spring to allow, a wing panel of, say, 20 inches from root to tip, when fully covered and tightened, should be able to " bow " or spring about one inch; if not, the construction is too heavy or not properly designed.

(There is a definite practical illustration of this in the building of tall factory chimneys. You may have noticed in a strong wind how two tall chimneys close together will slightly sway. One can see the two tops coming closer together, and then going apart again. This is allowed for in the construction, to prevent them snapping off if they were too rigid.)



Though not strictly to scale, the model shown in the top and middle photos might easily be thought to be a model of one of Britain's latest twin - engined bombers! Designed and built by Mr. C. Rupert Moore, the model incorporates many novel features, is of most advanced design, and capable of a very fine performance. It is made as a scale model of an original design.





This model is to scale! It is of a Hawker "Hurricane," and is powered with a $\frac{1}{5}$ h.p. petrol engine. The photo was taken at Cranwell Aerodrome, and by careful positioning of the camera the cadets were introduced into the background to make a most realistic photo!

CHAPTER VIII

LANDING GEARS

ACTIONS. RETRACTILE TYPES. TRICYCLES. FLOATS AND BOATS.

THE " undercart," as the flying folk call the landing gear, will probably cause the aero-modeller furiously to think. How to incorporate it in his model and at the same time make it strong enough to withstand landing shocks and look like the real thing!

It is only proposed here to deal with the *functions* of the model undercart, as the construction will be dealt with in a later chapter. But so important are the functions of this particular part that the writer has seen fit to devote a chapter to it alone.

The chief reasons for the undercart being there at all are, of course, to support the air-frame whilst stationary, at take-off, and to absorb the shocks on landing. Otherwise it is a nuisance, in so much that on most very efficient 'planes it is made to tuck away out of sight, as it offers a most serious resistance to the air whilst in flight.

Taking the prototypes first, the undercarriage legs are either spring or hydraulically loaded. The latter type depends for its action on a piston in a cylinder pushing a certain amount of liquid through a small aperture. It will at once become apparent that on a small model we cannot use the latter method, but the spring method does offer possibilities. However, we must be very careful if we decide to use a sliding action of any sort, as a roughish landing may bend a leg, with the result that the sliding action is jammed.

Where it is decided to use this type, it is strongly urged that the builder, instead of the usual tube for the leg to slide in, uses a flexible tube, such as part of an expanding curtain rod or a Bowden outer covering.

On the other hand, of course, the whole leg can be a dummy, supported by a steel spring wire, or wires, attached to the fuselage in such a way that the legs as a unit spring slightly backwards and outwards to absorb the shock.

Probably the type that springs outwards is the easier to construct, and has a definite advantage over the type that swings backwards. It is this wise:

The landing wheels should be in front of our old friend the Centre of Gravity, otherwise the 'plane would tip over on its nose when stationary. But you will observe on the full-size aircraft that the point of contact with the ground is just behind, or actually in line with, the leading edge of the wing. Now if we adopt the spring-back method we may, on landing, get our line of contact with the ground pushed beneath the C. of G., or even slightly behind it, with the result that over goes the 'plane on to its nose.

Actually, of course, the positioning of the undercart is very important, but unfortunately for us it is fixed by the design we are copying.

For safety's sake it is advantageous if possible to have the undercarriage fairly well forward, so that the tail does not tend to come over on landing.

Unfortunately, however, for a take-off we want to get the tail up quickly, and so we must have the undercart fairly well back. There's a nice problem if ever there was. However, should the builder be prepared to sacrifice a certain amount of scale, it is suggested he can do a lot worse than by moving his wheels forward a little. This can easily be achieved by keeping the position correct where the undercart is attached to the fuselage or centre section; but the actual angle it makes with its fixing is altered slightly, so that the bottom of the legs are farther forward.

It must also be borne in mind that if we should be using a special airscrew to give us duration, and we have to exceed the original scale diameter, we shall have to extend the *length* of our undercarriage to prevent the tips of the blades hitting the ground. Here also it is advisable in nearly every case to deviate slightly from scale and add a little amount to the length of the legs, because, even when taking off on the smoothest of ground, the tail is likely to bump up and dig the propeller into the ground, or at least try to, with dire consequences for the propeller!

The undercart must be made sturdy, which introduces a certain amount of weight, but, as it happens, a certain amount of underslung weight adds enormously to the stability of our aircraft, and on the very small models of, say, 18 in. span and downwards, hardwood wheels to give weight will produce a very steady flight on a quiet day.

Retracting undercarts are quite possible and practical to the mechanically-minded builder, and are great fun to build. However, it must be borne in mind that wheels that retract inwards, like the Heston "Phœnix" and Hawker "Hurricane," or outwards, like the Blackburn "Skua" and "Spitfire," do not affect the C. of G., but all undercarriages that retract *backwards* into the engine nacelles shift the centre of gravity in so doing, and therefore must have counter weights to keep the balance correct.

Retracting undercarts can either be made to retract manually, that is, a small knob or lever can be made to operate them, or else they can be either locked in the up or down position.

There is, of course, the automatic type, which can be worked either by the tension of the rubber motor slackening off as the turns die down (although this method is not advised) or they can be worked by a mechanical contrivance, as shown in Fig. **17**, or a timing gear, as used for petrol model 'planes for switching off their ignition after a given length of run, can be used.

Some of the most successful models that the writer has built have proved that the safest way of bringing a model down is to keep the legs retracted.

With a braced or solid underpart to the engine cowling, and a propeller made to easily knock out, the model will land on its "tummy" very satisfactorily, and end up by just sliding along the ground—and it will always finish the right way up. One model, in fact, was designed so that its legs were detachable, and were taken off for flying! Of course, it necessitated a hand launch, but in flight it gave the exact appearance of a job in flight with the wheels fully retracted, and on all its many landings without an undercart it never came to grief.

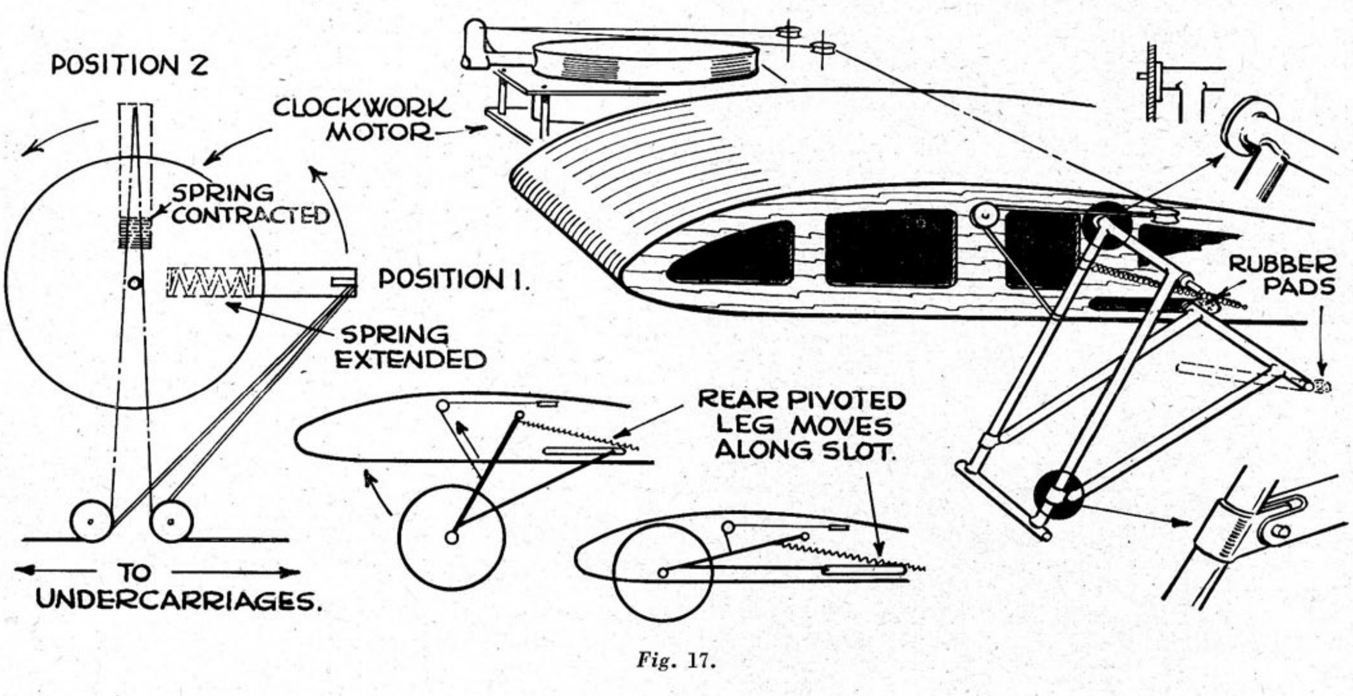
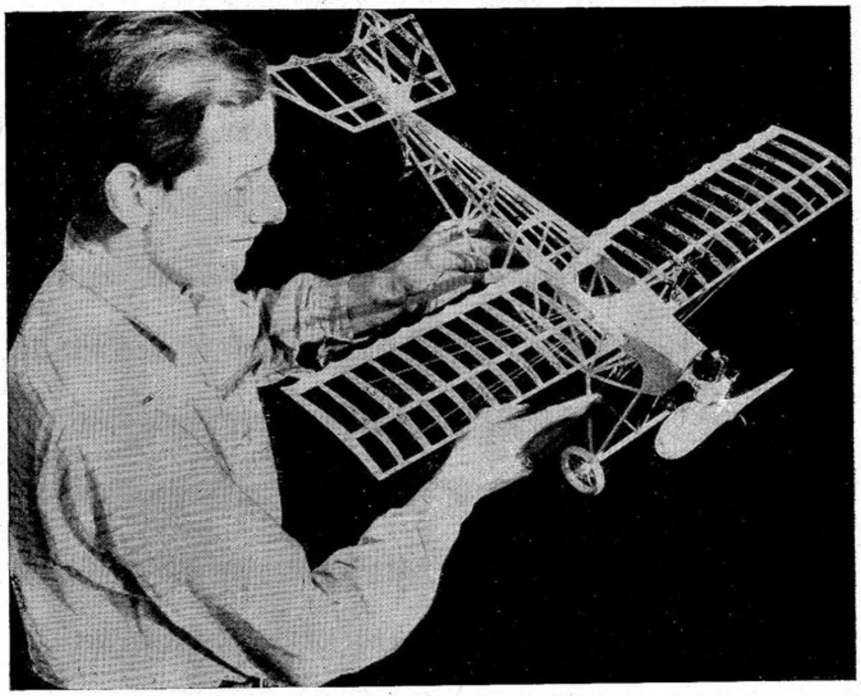


Fig. 17.



The construction of models of " old-time " 'planes is very popular. This photo shows Mr. G. W. Day with his model of a 1911 Caudron.

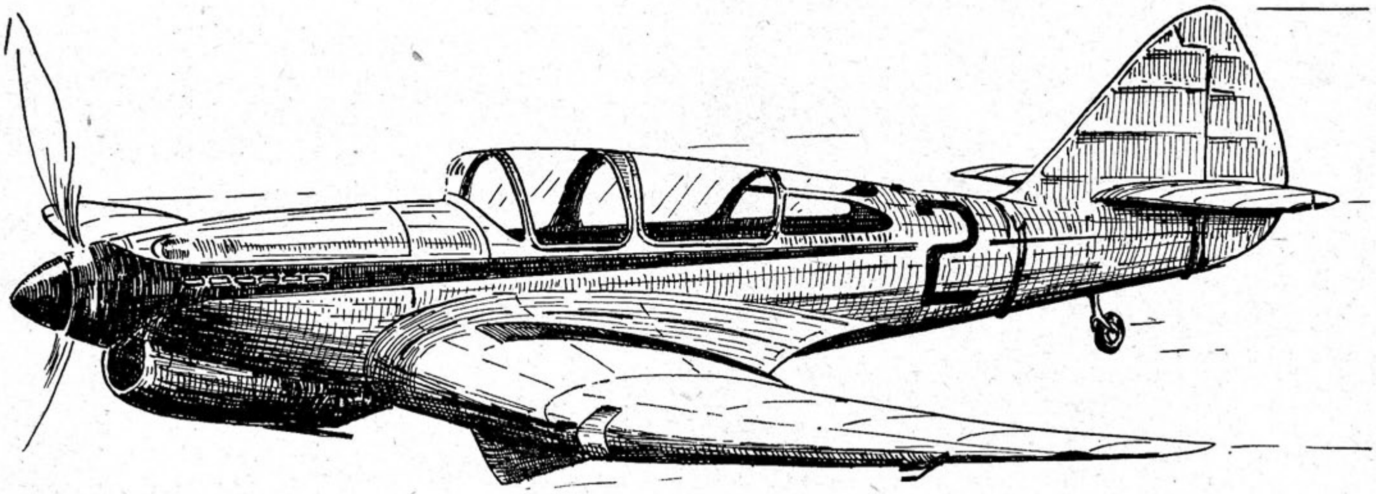
This, of course, leads up to the modern method of tricycle undercarts.

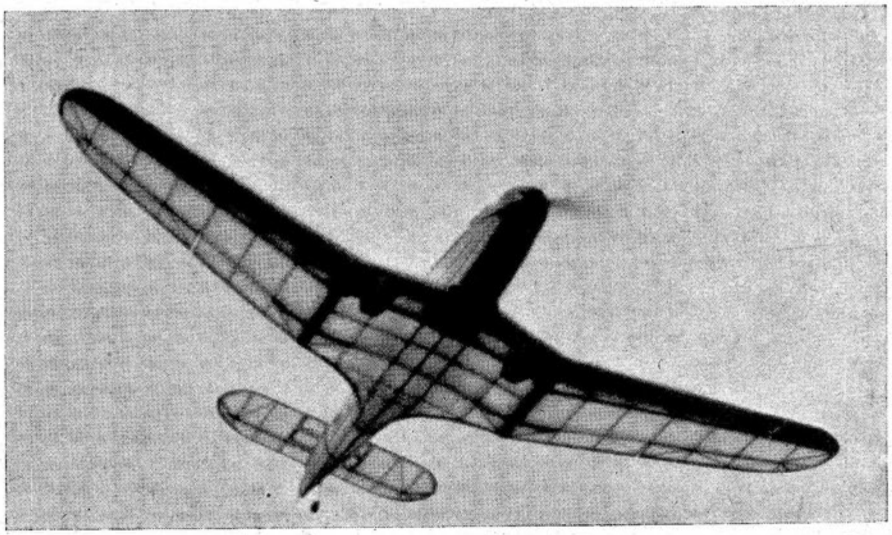
A tricycle undercart is the ideal landing gear for a model, because on landing the 'plane can be flown at its gliding angle on to the ground, the nose wheel taking the shock and the two rear wheels just taking the weight of the 'plane. Actually, this is the way a model comes down, as it has no pilot to flatten it out on landing.

The nose-wheel, too, helps to protect the airscrew from hitting the ground.

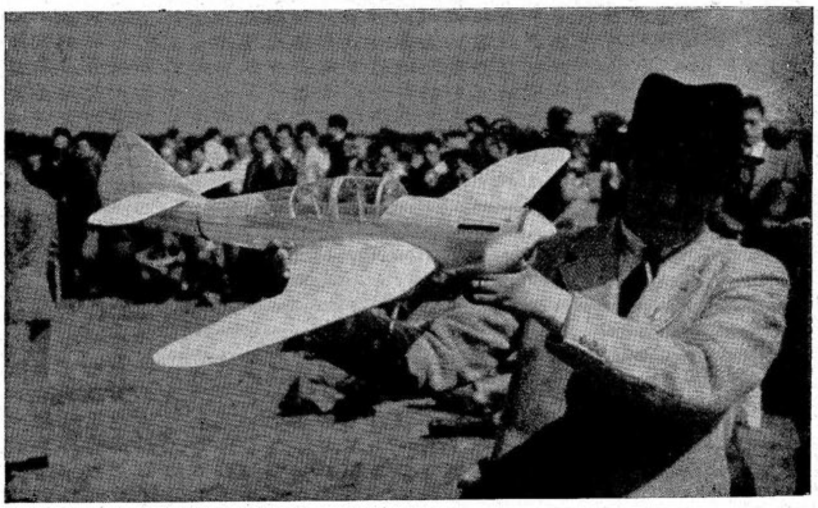
The chief difficulty is to get the nose-wheel to stand up to landing shocks, but as we probably want some extra weight in the nose here is an opportunity to use it to advantage. A parallel link motion can be used to give an up and down movement to the forks of the front wheel, or else they can be made of spring wire very firmly embedded to a strengthened underpart of the cowling. The pair of rear wheels, situated somewhere near the trailing edge, can be very lightly built, as they have very little load to carry.

Models have been fitted with " skis " for taking-off from snow, and these can easily be fitted, as the springs from the undercart are still available, but where floats to take-off from water are required it is another proposition, as scale floats would be generally fitted with a pair of legs each and braced with thread, the whole being a fixture. The snag here is that they are apt to be wiped off on a landing, and are really not worth while from a flying point of view. However, amphibians and seaplanes with boat-shaped hulls are quite popular, the chief difficulty being to " unstick " these from the water. They require a lot of power to get them on to the " step " before rising, and it is just as well to fit an air vent between the top of the step and the outside of the hull, to prevent any suction occurring, which would tend to hold the model down instead of letting it take off easily.





Here is Mr. H. J. Towner with his model of the Miles "Kestrel Trainer." In centre the 'plane is shown in flight, and top is a sketch by the builder of his model.



CHAPTER IX

RUBBER MOTORS

QUANTITY. ARRANGEMENT. TURNS.

We have considered this subject to a certain extent under the chapter dealing with gear-boxes, so it is only proposed to give a general description of the sizes and amount of rubber most suitable to our scale model.

The amount of power we can store in a motor is directly proportional to its weight, that is to say, we can expect to get twice as much power from two ounces of rubber as we should from only one ounce. Hence it would appear that the more rubber we can store in a model the more power we shall be able to have.

But remembering our redistribution of weight and wing loading, it will readily be seen that there must be a limit to the weight of rubber we can carry, as we cannot move our wing about to obtain trim. In determining the amount required it is as well to start on the low side, always remembering our trim, and add a loop of rubber at a time until we have attained a steady level flight.

Rubber is made in different sizes and thicknesses, but probably the size most useful is $\frac{1}{4}$ in. wide by 1/30 in. thick, and it is suggested as a guide with a 10 in. propeller on a 1 in. to 1 ft. scale, and a weight of about 6 oz., that, without a gearbox, six loops of the above rubber would make a good beginning, and with a gearbox of two gears, that three loops could be employed on each. It may be found that four loops on each will be better, but this must all be tried out on the flying field. When trying out, do at least find the softest stuff for the model to come down on, because we must remember that as we vary our motor so we must slightly alter our trim accordingly.

The length of our motor, too, is important, and, naturally, the longer we make it the more turns we can put on, and so a practice has arisen of using a motor actually longer than the distance between the rear hook and the hook on the propeller shaft. When a few turns have been put on it is quite taut, but the trouble starts when the motor is run out in the air, and, being loose inside the fuselage, it may flop about, and even bunch into knots, perhaps at the tail end, thus upsetting our weight and causing the model to stall and come down in a succession of dives. To overcome this, various methods of tension devices are used, such as explained in the chapter on construction dealing with nose-blocks.

Where, however, a gearbox is used, an extra loop of rubber can be put on to one particular skein and that skein given a few turns in the opposite direction before attaching to the motor hook.

This opposite winding is called " prewinding," and when the motor comes to rest it will attain a balance of so many prewound turns on one skein and so many unwound turns on the other skein, with a consequent even tautness on both and the slack of the motor taken up.

It must always be borne in mind, however, that the fewer strands we use the more turns we can put on, but, naturally, with fewer turns the power output will be less.

By a suitable arrangement of strands with a gearbox we can get a variable power output with the same weight of rubber and the same number of total strands and no deviation from trim.

As an example, the writer's Heston " Phœnix," of 1 in. to 1 ft., with a wing area of 196 square inches, a total wing loading of $8\frac{1}{4}$ oz., and a gearbox with four gears, the following combinations were used: $\frac{1}{4}$ in. × 1/20 in. rubber 27 in. long, driving a 10 in. dia. airscrew with 13 in. pitch, was arranged in the form of four gears with three loops of rubber on each, i.e. 12 loops in all, and in still air this gave a duration of 25 sec. power and 5 sec. idling at the end, on 600 turns.

This was suitable for a quiet day, but on a roughish day, when more power was required, the motor was rearranged, using four loops on only three of the gears, thus still using the original 12 loops but differently arranged.

This combination on 600 turns gave a power output of 20 sec. and 5 sec. idling.

It will be noticed that although the same power is available in both cases, yet in the latter case the power runs out sooner, and so is greater during the effective time of motor run.

Six hundred turns were not the maximum turns available, but gives a good indication of what to expect from a motor.

You will notice the expression " idling," that is to say, when the motor is nearly out, although the airscrew continues to revolve, there is not sufficient power for sustained flight, and therefore these turns are practically useless.

The safe number of turns we can put on a motor is a variable factor, depending upon the freshness of the rubber, the way it is treated and lubrication used, but assuming everything to be in tip-top order we can take as a safe average the following for 1/30 in. thick rubber.

No. of strands.	4	6	8	10	12	14	16	18	20
$\frac{3}{16}$	42	36	30	27	25	23	21	20	19
$\frac{1}{4}$	38	32	28	25	23	21	17	16	15

Taking this table, a motor of four strands $\frac{3}{16}$ in. wide could be wound 42 turns per inch of unstretched motor. Therefore if the motor was 20 inches long already made up in its six strands we should expect to be able to wind on 42 turns multiplied by 20 inches long, equals 840 turns.

Also, with a gearbox, we can take one individual skein or motor, and the number of turns we can put on this is the total for the whole gearbox.

Unfortunately this table does not cover all thicknesses and sizes of rubber. Then again, different makes of rubber sometimes vary slightly in size, so if in doubt, and we have the energy, there is a formula which can be used for working out the number of turns for any size of rubber.

It looks a bit awful at first, but we can sort it out fairly easily. The formula, then, for the number of turns that will just break the rubber is $\frac{5 \times L^{1 \cdot 5}}{\sqrt{W}}$ We do not want to break the rubber though, and if we want the rubber to last a long time without breakages it is not safe to give more than 80 per cent of the breaking turns. At the same time, the last few of the possible turns increase the torque enormously, and if we do without them we shall have a much smoother power run. The formula, then, for best results all round is $\frac{4 \times L^{1 \cdot 5}}{\sqrt{W}}$

Now let us see how to apply this to the rubber. First we must measure its length. The length we want is that of the folded skein. We fold the rubber into the number of strands required for the motor, lay it out on the table and find its length. Then we want its weight, and we want to find the square-root of the weight in ounces. Now that is not very difficult, is it? The next part, $L^{1 \cdot 5}$, is practically as easy, since it is the square-root of L cubed. In other words, we find the square-root of L and multiply it by itself three times. L must be in inches.

The lubrication of rubber is very important, and the entire motor should be well covered, and any excess wiped off, great care being taken to see that no foreign particle is on the rubber, otherwise on winding this particle may cut into the rubber and break it.

The rubber should be kept in a cool, dark, air-tight container between use, and direct sunlight should be avoided as much as possible.

When tying the ends of the rubber together to complete a skein, it is not necessary to tie them into a knot, but get someone to overlap both ends and stretch them tight while you bind them together with a fine thread—say, six or eight turns will do—this will stand up to all the power you are likely to put on it.

One more point. When winding, stretch the motor as far as you can without putting any undue strain on the fuselage, and wind in this condition. A much more evenly wound motor is the result, with a corresponding more even running of the motor and a better flight.

CHAPTER X

DESIGN OF AIRSCREWS

HOW THEY WORK. PITCH AND DIAMETER. SETTING OUT BLANKS.

IN writing this book the main underlying purpose is to present the subject of scale model aircraft in as simple a way as possible consistent with scientific investigation, and therefore we have carefully avoided any mathematical formula.

However, when we discuss the design of airscrews we are dealing with a subject which could involve us in a maze of wonderful figures. And even suppose we designed our propeller accordingly, the chances are that the finished article might not be the very best choice for our job.

So what we propose to do is to give the reader a simple method of laying out his own propeller in accordance with the best accepted principles, and then, by a system of trial and error, eventually evolving the best propeller for the particular model under consideration.

If the builder keeps to the same scale in building his models he will, after a time, have an assortment of various propellers of approximately the same size, and by interchanging them it may be possible to find the best one for any particular aircraft.

It must always be borne in mind that however well the model has been designed and built, and however much rubber has been stowed in the fuselage (and the rubber is the motive force), if we cannot convert this energy efficiently our flights must perchance be of a poor order.

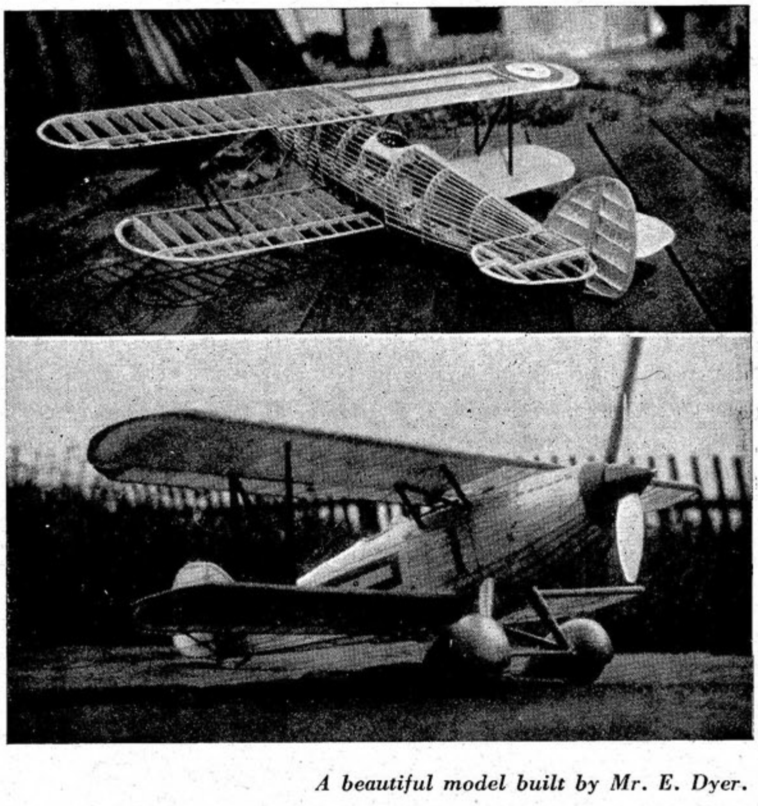
It is the propeller alone that converts our power within the model to powered flight. Therefore, however nice a particular propeller appears on a model, if it does not deliver the goods it is no use to us!

Although we generally term a propeller a propeller, it is a very loose phrase, because a propeller in reality should be placed behind the main-plane and act as a "pusher" or "propeller." The propeller in front, as is the more general position, is really termed a "tractor," or one that pulls.

However, to suit our purpose we often use the word "airscrew," which embraces both types, although even this word is a relic of earlier days, when people imagined that its blades "screwed" their way through the air similarly to a screw worming its way through a nut.

Actually, however, we must imagine each blade to be an airfoil or wing, and in revolving through the air it is developing lift or thrust, giving forward motion and drag in the form of torque. And just as in our wing we have incidence or angle of attack, so we must have this angle of attack in our airscrew. This angle, too, must be kept within reasonable limits, otherwise our propeller will stall.

The "thrust" or pulling power of the airscrew is used to overcome the drag (or



A beautiful model built by Mr. E. Dyer.

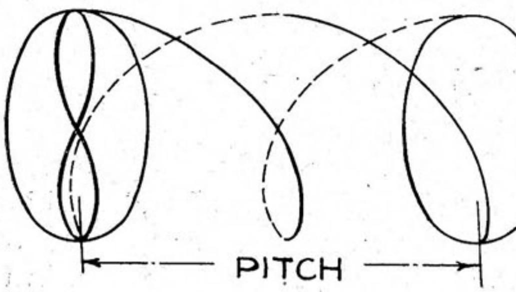


Fig. 18.

wind resistance) of the aeroplane, and the thrust depends on the diameter and speed of rotation. It also varies with the forward speed of the machine. With the model flying at a certain speed, then, there will be a certain speed at which the airscrew must revolve, and from this speed of rotation and the forward speed and drag of the machine we should be able to determine the best airscrew. The design of an airscrew on scientific lines, however, is rather out of the question, since there are so many forces on the model we are unable to measure. By far the best plan is to try two or three different pitches, since the diameter is fixed by the scale, and a strand or two, more or less, of rubber on the motor will vary the speed of rotation.

The " pitch " of an airscrew is the distance it travels forward (theoretically) in one complete revolution. See Fig. 18. However, there is a certain amount of slip, usually at least 25 per cent, so we seldom have an airscrew that is more than 75 per cent efficient. The pitch business can be likened to a gearbox on a car. A high pitch is like the high or top gear; it travels a long way in one revolution, but requires a lot of power, whereas a low pitch, like low gear, can do with less power per revolution, as it does not travel so far, but it will turn over faster. If the pitch is too large the airscrew will stall and not generate sufficient thrust to pull the machine through the air. On the other hand, the pitch must be high enough to suit the flying speed of the aeroplane. There is quite a wide margin between too large and too small a pitch, which is another reason for trying different pitches to find the best.

We now want some guide as to what pitch to try, and since we have a number of different diameters, this is best done by a pitch to diameter ratio. One writer is of the opinion that this should be from 1 to 1·3. That is, if we have a pitch/diameter ratio of 1·3 we should have a pitch of 13 in. for a diameter of 10 in., or a pitch of 7·8 in. for a diameter of 6 in. The other writer considers that pitch/diameter ratio should be lower, and might usefully vary with the ratio of diameter to wing-span. He thinks that if the diameter/span ratio is, say, one-seventh, as with the B.A. Swallow, the pitch/diameter ratio should be one-half to two-thirds, and where the diameter/span ratio is, say, one-quarter, the pitch/diameter ratio could be about 1/1. Here, then, is another reason for experiment.

Blade area, too, plays a part, and is varied by the width, since the diameter will be fixed. This again has some connection with the pitch, since a wider blade will give more thrust and will stand a larger pitch.

This width should not be too great or it will look ugly. A larger diameter would be much better, though not to scale. Looks and efficiency would be a big improvement on scale diameter with very wide blade.

If we are building an advanced model with two airscrews, we could work out the pitch as above, and then multiply it by 1·4, i.e. the square-root of the number of airscrews.

If we consider Fig. 19, this will give us a good average arrangement suited to most purposes. Although it is drawn full-size for an airscrew 12in. diameter and 12 in. pitch, the figures we require can be substituted. Should we wish to make an airscrew that is to scale in width (we can fly a model successfully with one), the lengths a, b, c, d in Fig. 2 should be taken from the full-size airscrew. These dimensions would be taken across the flat face of the blade, ignoring the effect of the twist.

Most probably, however, our propeller will be about 10 in. dia., with a pitch of between 7 in. and 13 in. Assuming we are

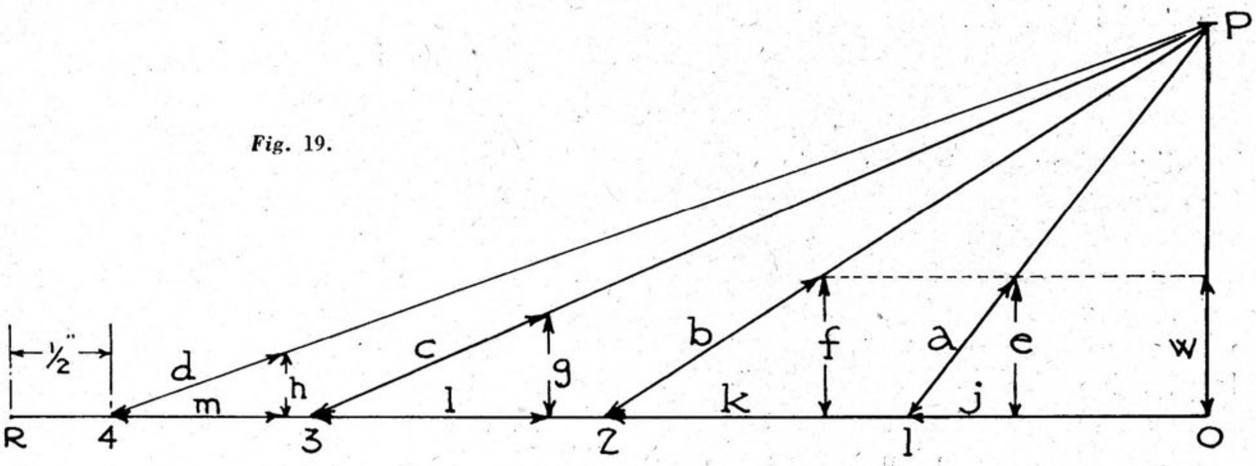


Fig. 19.

Fig. 19*a*.

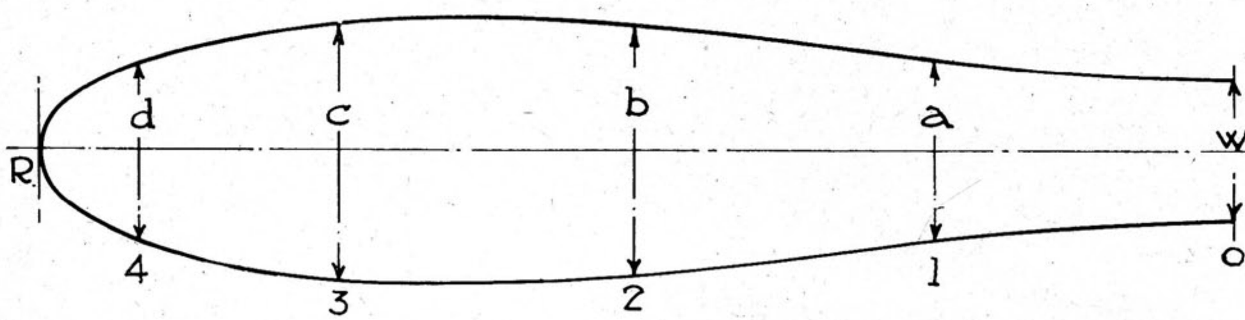


Fig. 19*b*.

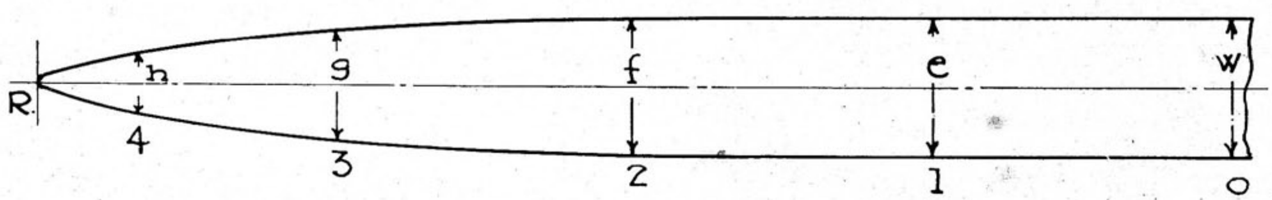


Fig. 19*c*.

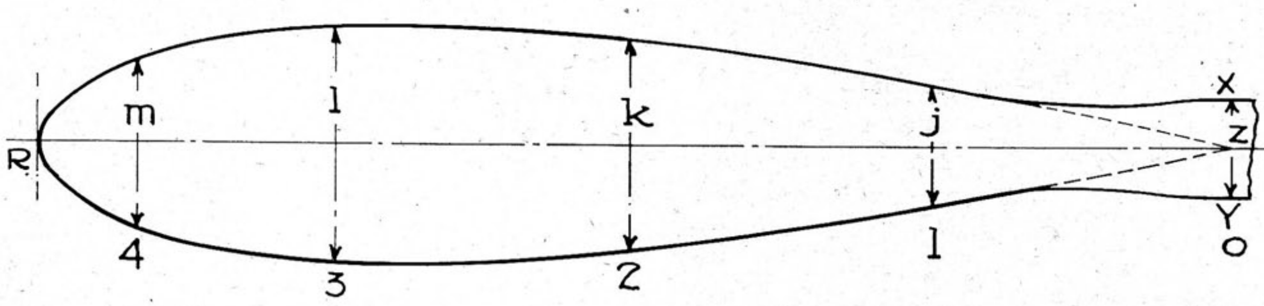


Fig. 19*d*

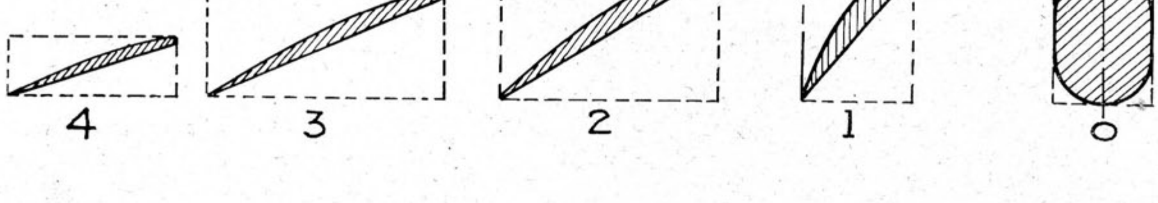


Fig. 19*e*.

building a model of 1 in. to the foot scale.

Decide on the size required, and, referring to Fig. 19a, draw the radius of the propeller OR, then draw OP, which is equal in length to the pitch divided by 6. Divide OR into four equal spaces, marked 1, 2 and 3, and mark another point 4 at ½ inch from the end R. Join these points to P. Next draw the centre line for Fig. 19b and mark off the lines 1, 2, 3 and 4 to correspond with Fig. 19a.

The lengths b and c are now put in, and should be equal to the diameter of the propeller divided by 9. Mark off the lengths b and c, Fig. 19a, and draw a line shown dotted from the end of b.

This gives the lengths d and w, which should be marked off in Fig. 19b.

Draw a smooth curve round all the points, and from this curve measure the length of d. Put in the length of d in Fig. 19a.

Draw the centre line for Fig. 19c and the lines 1, 2, 3 and 4 as before, and mark off the lengths W, E, F, G and H corresponding to the length of these lines in Fig. 19a. Draw in the curves as indicated, and we have a side view of one blade.

Draw a centre line and lines 1, 2, 3 and 4 in Fig. 19d, and the length of the lines j, k, l and m from Fig. 19a.

Draw in a curve through these points and point Z as indicated.

The centre XY is determined by the size of the boss or spinner, and should be made accordingly.

It is advisable to make the airscrew out of a good close-grained hardwood, such as walnut, as it will probably get quite a lot of knocking about, and the slight extra weight involved will be in the right place.

Where a three-bladed airscrew is considered, the total blade area will be approximately the same as a two-blader, so the width of each blade will be less.

On examining the different sections in Fig. 19e it will be noted that the angle of the blade increases towards the hub. As the airscrew is revolved it will be seen that the tip of the blade has farther to go in one revolution than the root of the blade, although in a forward direction the distance is the same, hence we get the twist effect when looking end on to the airscrew. The most effective part of the propeller is between a quarter and one-third of the radius from the tip, so we are careful in making this part the widest and the truest to pitch. Actually the pitch at the root is not correct, but we make it as near as we can, or even fair it off so that it makes as little disturbance to the air as possible in the form of a boss or spinner.

We can always take a little off the width of the blades if we find that, with the power available, the propeller is too slow, although, as we shall see in the chapter on "motors," another loop of rubber may cure this trouble. On the other hand, a propeller that whizzes round with not much speed to the model probably has not enough blade area, assuming the pitch and workmanship to be up to standard, unless it happens to be very small in diameter compared with the wing span. A little experience here is the best way of learning, but we must not expect to fly before we can run.

CHAPTER XI

GENERAL DESIGN

GRADES OF BALSA. TRIANGULATION. GENERAL NOTES.

As the materials we use are so bound up with the question of general design, it is proposed here to give a short description of their qualities and suitability for specific parts.

As balsa wood is the chief material used in the construction of model aircraft, we will take this first.

Balsa wood comes chiefly from South America, and comes to us in a very dry, light state, but in different grades, and it is in our choosing the right grade that the efficiency or otherwise of the model will largely depend.

We can divide the grades chiefly into two groups—hard and soft. The hard can be distinguished by a much closer grain than the soft, and also, of course, by gently pressing with the finger nail.

Unfortunately, however, the hard balsa is much heavier than the soft; in fact, it probably will weigh about twice as much, as the weight of balsa will range from about 3½ lb. per cubic foot for the very soft up to about 12 lb. per cubic foot for the hard.

Then these two grades of soft and hard balsa are divided again into three more categories, depending on how the strip of wood has been cut from the tree.

There is the strip with the grain running straight and lengthwise, suitable for all spars, longerons, stringers, etc., and all tubular and circular parts, such as the construction of circular engine cowls with the grain running fore and aft. It also can be used for top decking: but, naturally, anything of this nature behind the C. of G. will be of the lighter and softer grade.

Then there is the cut of balsa with a scallopy appearance. This will not bend so easily as the straight-grained section, and should only be used where stiffness is required, such as formers, ribs, bulkheads or sides of fuselages.

Then there is a third type, chiefly found in thick sections, such as one-and-a-half inches square, and so on. When observing the block of wood from the end, the grain runs diagonally.

This type of block can be used for any part that requires carving, and in fact any solid part. It is also very suitable for propellers.

Now, bearing these particular types of wood in mind, it can be seen that we can build the strongest model with the least amount of wood by exercising our imagination in choosing the right kind of balsa for any particular part.

There is one common fault that most constructors make. The idea is that, in order to achieve strength one must use thick wood.

Of course, there are cases where this is true, but in our search for lightness we must ap proach the subject from a scientific angle.

Probably the most important of all is the triangulation of parts to achieve rigidity; and to explain this simply, let us take a look at the frame of an ordinary cycle. The frame itself is in the shape of a triangle, with the loads taken at each corner, viz. the saddle, the crank and the steering column. Attached to the saddle corner and to the crank corner is another triangle (although this is sub-divided), with the back wheel attached to its third corner. The whole locks together perfectly rigidly, and it will be observed that the loads are taken down the lengths of the tubes; that is to say, the tubes are in compression.

If, on the other hand, the load was applied between the corners, that is, along the straight part, the whole frame would very easily buckle.

It is the designer's job to split the airframe up into a suitable number of triangles and take great care to see that the loads that are imposed put the respective legs of the triangles in compression and not in tension. Of course, we must not forget that when the covering is applied it will brace everything together, and where no extra load is involved this covering may be quite sufficient.

Where, however, we wish to impose a load, say on a stringer between two formers, such as is imparted by the tightening of the covering when doped, it is far better to use stringers of a deep section than a square section. That is to say, a stringer is far better made of a section $\frac{1}{16}$ in. × $\frac{1}{4}$ in. rather than $\frac{1}{8}$ in. square, although the total cross-sectional area is the same.

Actually, the sizes used will probably be smaller than this, but these figures have been used for simplicity.

This method of using the wood—or metal, for that matter—on edge is the great secret in building to give the maximum strength for the minimum weight. A balsa tube, made of $\frac{1}{32}$ in. wood bent around a quarter of an inch diameter former, which is then withdrawn, will support all the load you will probably wish to apply to it *on end*, provided its straightness is not affected, and it will be ever so much lighter than a solid piece of balsa of the same diameter.

Towards the front of the model, where a little weight is required and loads are imposed from all directions, such as the pressure of the fingers in holding the model during the process of winding, thicker wood can be used to advantage, but even then to use the " on edge method " for bracing is much stronger.

Imagine where the pressure of the hand will be, for instance, and arrange your deep stringers accordingly.

Where formers are attached to the outside of a frame to support stringers, as in the case of an oval fuselage built around a square frame, the writer has successfully used 1/64 in. formers, provided the depth does not exceed about $\frac{1}{4}$ in.—another example of material on edge.

There are times when it is necessary to depart from using balsa, such as the main beam through a fairly large centre section. It will be found that a good piece of hardwood three-ply $\frac{1}{8}$ in. thick, suitably fretsawed out to give radiating legs of about $\frac{3}{16}$ in depth, to take any top or bottom loads, will brace up the whole job and prevent a nasty crack-up. This is clearly seen in the drawing of the Kestrel Trainer, just above the right wing tip.

Some models seem to crack up after every flight, and others go calmly through a complete season with perhaps nothing worse than a crushed longeron. Apart from rough handling, the life of a model depends on the stressing and design of each small part.

This may all seem very complicated, but you will be surprised how easily it all comes to one when you start to build your own design.

Generally speaking, if a frame is rigid *before* it is covered it is too strong. We must not forget the tensioning effect of the covering material.

One other very important thing to remember when cementing or glueing two parts together is always to arrange for the glue to be in compression or in shear, never in tension—that is to say, never allow the glue itself to take any pulling load, and to overcome this difficulty you will probably have to " notch " one piece of wood to another. This may be tedious, but do it; it all helps to improve the model's " uncrackability."

Spruce or birch are seldom used when balsa is obtainable, except in the case of dowels and small fittings, such as cabin frames.

Mention of cabin frames brings us to another point which if clumsily done spoils the whole appearance.

Make the framework carefully, steaming each part where curved, and keep those parts to scale. Make the framework thin enough, even if it means making it of $\frac{1}{32}$ in. square birch or cane. Make it that size, because the celluloid (not cellophane, except on the very smallest of models) will hold all together tightly as in a rigid box formation.

Do not use a cellulose cement on celluloid, as it will spoil the appearance, as one is bound to get a little squeeze-out between the framework and the celluloid. Instead, use an ordinary fish glue. Any surplus can be wiped off, and a thin coat of varnish applied over the joint will waterproof the whole job.

Use as little metal on the model as you

possibly can. Wire, of course, does enter the construction in the form of propeller shafts, landing gear, bracing, and so on; but use the straightest and best plated piano wire; it will pay in the long run.

Knitting needles—steel, of course—make excellent propeller shafts, provided they are softened somewhat by heating to a very dull red over a gas flame and allowed to cool off very slowly. The hook will have to be bent red hot.

By using another knitting needle of the same gauge — probably 16 gauge — and after slightly softening a flat can be filed along three sides to give a triangular section, thus forming a reamer. This tool is then used for reamering out the hole in the bush to the exact size of the propeller shaft. A very true-running shaft is the result. Little things like this all go to make up a perfected whole.

So far we have only dealt with the normal type of model aircraft, consisting of a single airscrew placed in the front of the aircraft, and the rubber motor strung through the fuselage.

There are, of course, more advanced types that the builder may care to tackle when he has mastered the art of the single-engine job as referred to above.

In twin-engined jobs the motors can be attached to a point just behind the trailing edge of the wing in the centre of the fuselage, and then taken outwards to the propeller hooks in the nacelles by suitably designing the wing ribs to accommodate the rubber, as in the author's "Airspeed Envoy." In this case both airscrews turn in the same direction, and not in opposite directions to cancel out the torque, as it was found that as the motors were both offset from the centre line, torque was not very troublesome. What little there was, however, was overcome by using one more loop of rubber on the left-hand motor.

Quite small motors were used, as these two motors were each equivalent to each motor on a two-gear gearbox without the friction of the gears.

The final flexible drive consisted of a tightly wound steel spring, 24 s.w.g., wound on a $\frac{3}{32}$ in. dia. former, and about $\frac{3}{4}$ in. long, and this gave all the flexibility required. We must in passing, give Mr. C. A. Rippon his due share in putting us on to this type of drive, as the whole design depends upon it.

By using this flexible drive all sorts of different types of aircraft become available for scaling down by the model maker. See Fig. 20.

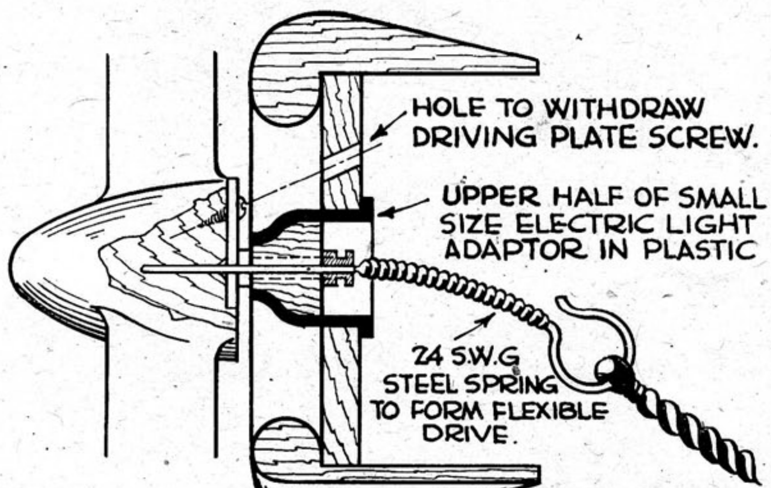


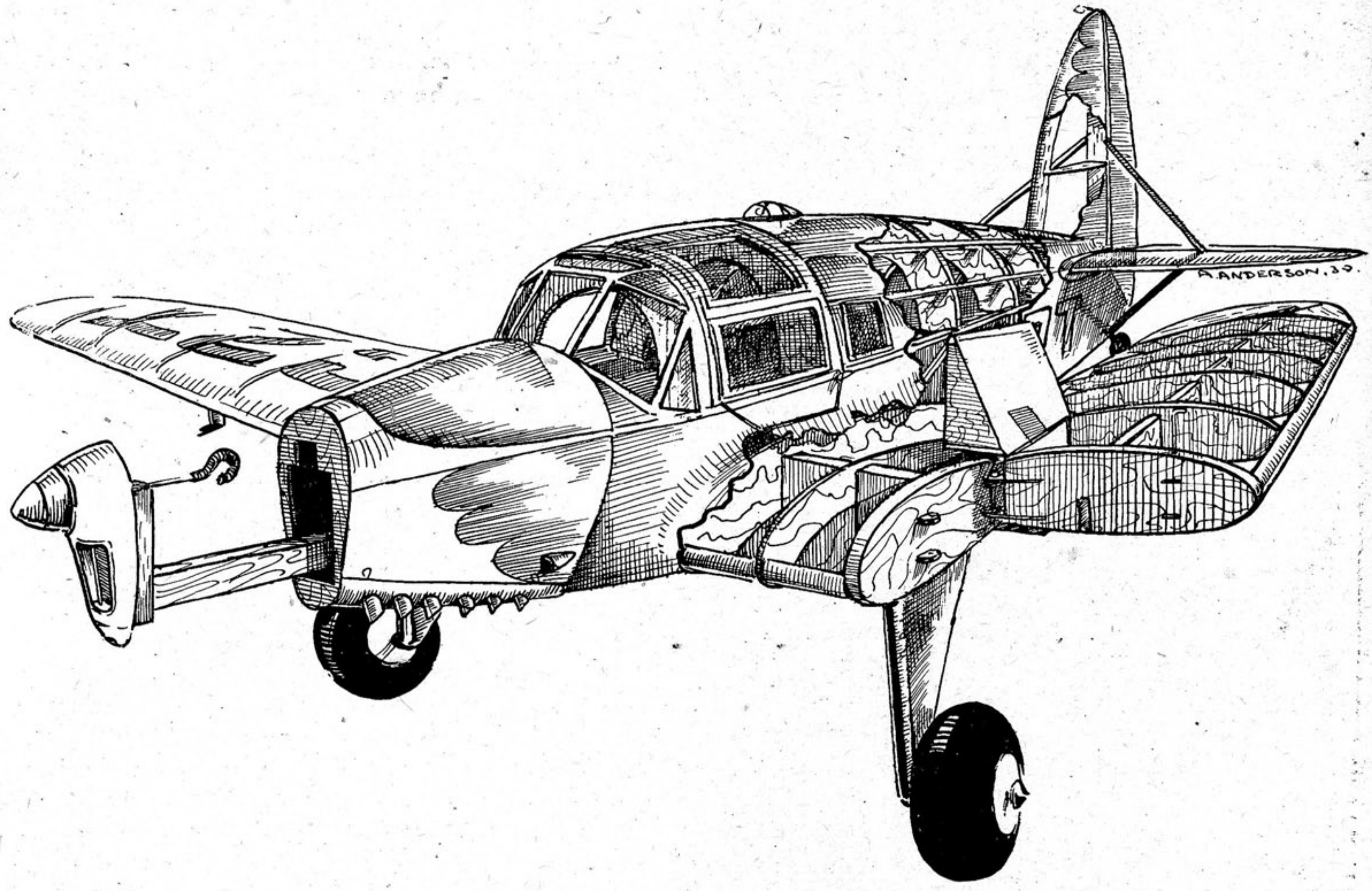
Fig. 20.

Flying-boats with the motor and propeller well up above the fuselage, such as the supermarine "Walrus" and American "Consolidated," all become possible, but with a thrust line in such a position that the builder will require to experiment a lot to get satisfactory flight.

Then there are the "pusher" types, with the propeller behind the main-plane, as in some light 'planes, and the large American Aircuda, with the propellers at the rear of the nacelles.

In fact the field of scope for scale model aircraft engineers is very attractive indeed, and as time goes by so more and more outstanding examples of their ingenuity and resourcefulness will stimulate us all to do better.

THE B.A. "EAGLE"



CHAPTER XII

STARTING THE BUILDING

GLUEING. SOLDERING, ETC.

WHEN we start building model aeroplanes, one of the first things we require is a smooth, flat board to work on. The ideal is a fairly large drawing board, but a good pastry board makes an excellent substitute, and a piece of plywood about $\frac{1}{2}$ in. thick is also very good. We also want some greaseproof paper to put over our drawings to prevent the work sticking, and some pins to hold the parts in place. Pins known as French pins have large heads, and are the easiest to deal with.

Before going on with the construction, here are a few notes about glues, or cements, as they are sometimes called.

Glues such as Seccotine and Croid are useful for hardwoods like spruce and birch, and are perhaps the most useful for these. Durofix is suitable for hardwoods, and very good for balsa. It has the added advantage of being waterproof. There are also a number of quick-drying glues for balsa that are also waterproof. Seccotine and Croid may be used for balsa, and there is a range of LePage's glues for various purposes. For sticking the paper or silk covering on the model, a photo-mounting paste like Grip-fix or Bond-fix is best. Quick-drying glues are indispensable for carrying out repairs on the flying-field, as it is often possible to stick two pieces together by holding them in place for about half a minute.

Soldering is a job that is practically indispensable where really good models are concerned, and lots of people seem to find difficulty with it, so perhaps a few notes will not be out of place.

Cleanliness is probably the most important thing, and there is an old saying that is very true, that a job well prepared is half done. The parts to be soldered must be perfectly clean, first using a file or emery cloth and then using a flux to chemically clean it. There are two well-known makes of flux—Fluxite and Baker's. Fluxite is a paste that is useful and convenient for brass, but when it comes to steel Baker's seems more successful, especially with a novice. Baker's make the well-known soldering fluid, which is specially recommended for steel, and also soldering paste, which is very good for either steel or brass. This does not mean that the soldering fluid will not do for brass; it is in fact excellent, but needs more complete washing away afterwards. The soldering " iron " is really made of copper, and must be " tinned " at the tip. To do this, file the tip bright and smooth, and heat the " iron," preferably in a gas flame or a clean fire (the red part) until it is just hot enough to melt a piece of solder on the clean tip. What is known by ironmongers as " blowpipe " solder is the easiest to use, as it is in sticks about $\frac{1}{8}$ in. wide. Dip the end of the solder in the flux and hold it in a clean tin lid, or on a piece of tin, and melt off a spot or two with the tip of the " iron." Then rub the tip in the solder until it is coated with solder or " tinned." If the tip has been cleaned well, and the solder does not run freely and stick on nicely, although it is running, dip the stick of solder in the flux, and put a spot on the tip of the " iron." If this does not do the trick, the iron is most likely too hot. Avoid getting the iron too hot, as it takes the tinning off; have it just hot enough to run the solder freely. It takes a little practice to get used to this. If the iron does get too hot, the only thing to do is to plunge it immediately into cold water, and start tinning all over again. The iron must always be kept well tinned, and if the tip seems hard when you file it, get it hot and plunge it into cold water. Never dip the iron into the flux, or in a short time you will find the flux eating into the iron, just behind the tinning. Tinning the parts to be soldered is also a good idea, but is not always necessary. To tin them, clean with a file or emery cloth and smear with flux. Rub with a hot tinned iron, and add a little more solder if necessary, till there is a thin coating all over. Wipe away the surplus with a piece of rag while it is still running. The tinned parts are smeared with flux, held together and touched with a spot of solder on the tip of the iron. Hold the iron there just long enough to run the solder where required. If the parts are large you may have to add a little more solder. When finished, clean away all flux with a damp rag, preferably while the job is still warm. Sometimes, when the parts to be soldered are large, they are " sweated." This is done by putting on a thin coat of solder (tinning) where the joint is to be made, smearing with flux, and holding them together in a flame till the solder melts. The flame of a methylated spirit lamp or bunsen burner is the sort to use. Now a warning. Be very careful not to drop hot spots of solder on the carpet or table-cloth, or you will have the head of the household running you round with the rolling pin!

Something else useful to know is how to make drills that we can use for making holes in brass for gearboxes, parts of undercarriages, etc. It is, like a good many other things, easy when you know how. Very often when we want to drill a hole for a 14 or 18 s.w.g. propeller shaft we have no drill, but a piece of wire of that gauge can be used to make a drill. All we have to do is to file or grind the end to the shape shown in Fig. 21. We grind the two flats on the sides first to make it something

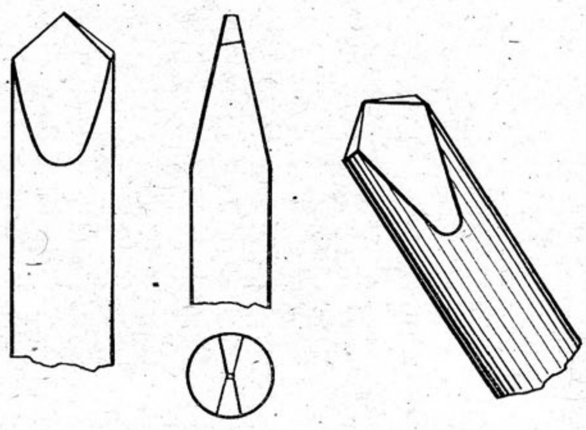


Fig. 21.

like a screwdriver, and then point it. Note carefully how this pointing is done. It forms two V-shaped flats that can be seen in the end and side views. In the side view, that is, the top right in the figure, the outside edge of the flat slopes upward. This is important, as it gives clearance to the metal behind the cutting edge of the drill. Having pointed the end like this, we get it red hot in the fire or gas flame and quickly plunge it into water.

CHAPTER XIII

FUSELAGES

TYPES OF STRUCTURES. METHODS OF BUILDING. JIGGING. WINDSCREENS.

WE must bear in mind all the time we are building our model that little things here and there will help to make the finished article more like the real thing. For instance, if we are modelling a fuselage with flat sides, fabric-covered, we can make our model with flat sides to be covered with paper. Similarly, if we are modelling a monocoque fuselage we can make our model with curved frames and cover them with thin sheet balsa. The nose of the machine is almost bound to be made like this, though some noses are best carved from solid balsa and hollowed out. As an example, aeroplanes with " Gipsy " and similar engines could have the nose modelled with sheet balsa, and those with " Rolls-Royce " engines would have the carved nose. This is due to the cowling on the " Rolls-Royce " engines being so much more curved. We can see this difference quite easily by comparing, say, a " Hurricane " and a " Moth." There is another method of reproducing these curved noses, and that is by building a structure of formers and stringers and filling in with small blocks of balsa. We can use $\frac{1}{8}$ in. square stringers and blocks $\frac{1}{8}$ in. thick. The blocks should be a good fit in the

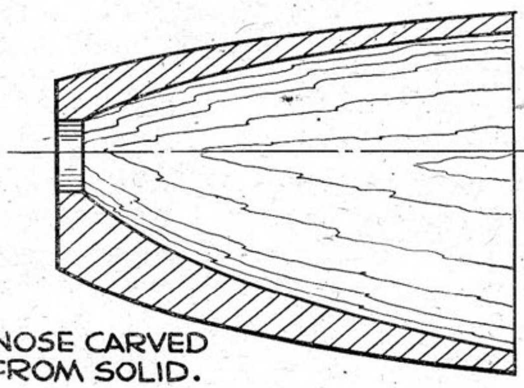


Fig. 22.

spaces, and should protrude a bit, so that when the edges are sandpapered down to the level of the stringers the middle does not show any sign of flatness. Figs. **22** and **23** show the carved and built-up noses. The nose for radial type engines can be made by using circular formers covered with sheet or strips. The strips should be about $\frac{1}{4}$ in. to $\frac{1}{2}$ in. wide, and afterwards sanded smooth. If we are making a nose, say, **4** in. diameter, we can wrap $\frac{1}{16}$ in. sheet round. The grain will have to run fore and aft, and we can cut pieces of balsa to length and stick them together side by side before wrapping them round.

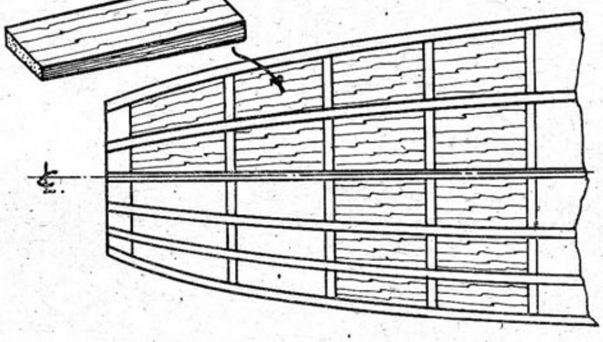


Fig. 23.

There are a variety of ways of building fuselages, each having certain advantages. Sometimes different methods can be combined, as in the rounded top and flat sides of the Miles and Percival machines. We can make the main structure of the fuselage rectangular, and add a superstructure of formers and stringers, as can be seen in Fig. **15a**. If we can arrange one face of this main structure to be flat when finished it will be a little easier to construct. Well now, let's see how we build such a structure. First of all, lay the drawing on a flat board and pin a piece of greaseproof paper over it. Next lay two longerons in place, and hold them with pins. We can then put in spacers at intervals of about two inches. (See Fig. **24a**).

Start with the middle spacers and work towards each end. An easy way to cut the spacers to length is to hold a piece of balsa with the end against a longeron and with a razor blade or knife to mark the position and angle of the inside of the other longeron.

Remove the balsa and lay it on a flat piece of wood, and make a clean cut vertically through. To make a clean cut, press lightly and slide the blade in the manner of sawing. For each spacer we must cut another one for the other side of the fuselage the same length, and with the same angles on the ends. Stick the spacers in position by putting a blob of glue on each end and pushing each end against the inside of the longerons. Use a small blob, so that it does not spread too much on the paper. Before removing the side it is a good idea to steam it, as this helps to keep its shape. For steaming we can use a kettle as long as the water does not come above the spout, but be careful not to let it boil dry, or you may find yourself getting into hot water! A very useful gadget can be fixed up by soldering a short piece of tube into an empty milk tin. The sort you make two holes in to empty it is required, with the tube in one, and the other enlarged to take a cork for filling. You can make a good steamer with different jets to fit the outlet; a round hole about $\frac{3}{16}$ in. diameter for steaming structures and a broad flat jet for steaming the paper when the model is covered. A simple affair could be made by putting a large screwed propeller bush into an old dope tin. The hole should not be less than 18 s.w.g., and would be better larger. A washer of some sort—thin ply if you have nothing better—will help to make a steam-tight joint. Do not boil the water too fast or you may blow the lid off. When steaming, hold the balsa right up close to the jet, in the invisible part if possible, but keep your fingers clear, 'cos it's 'ot!

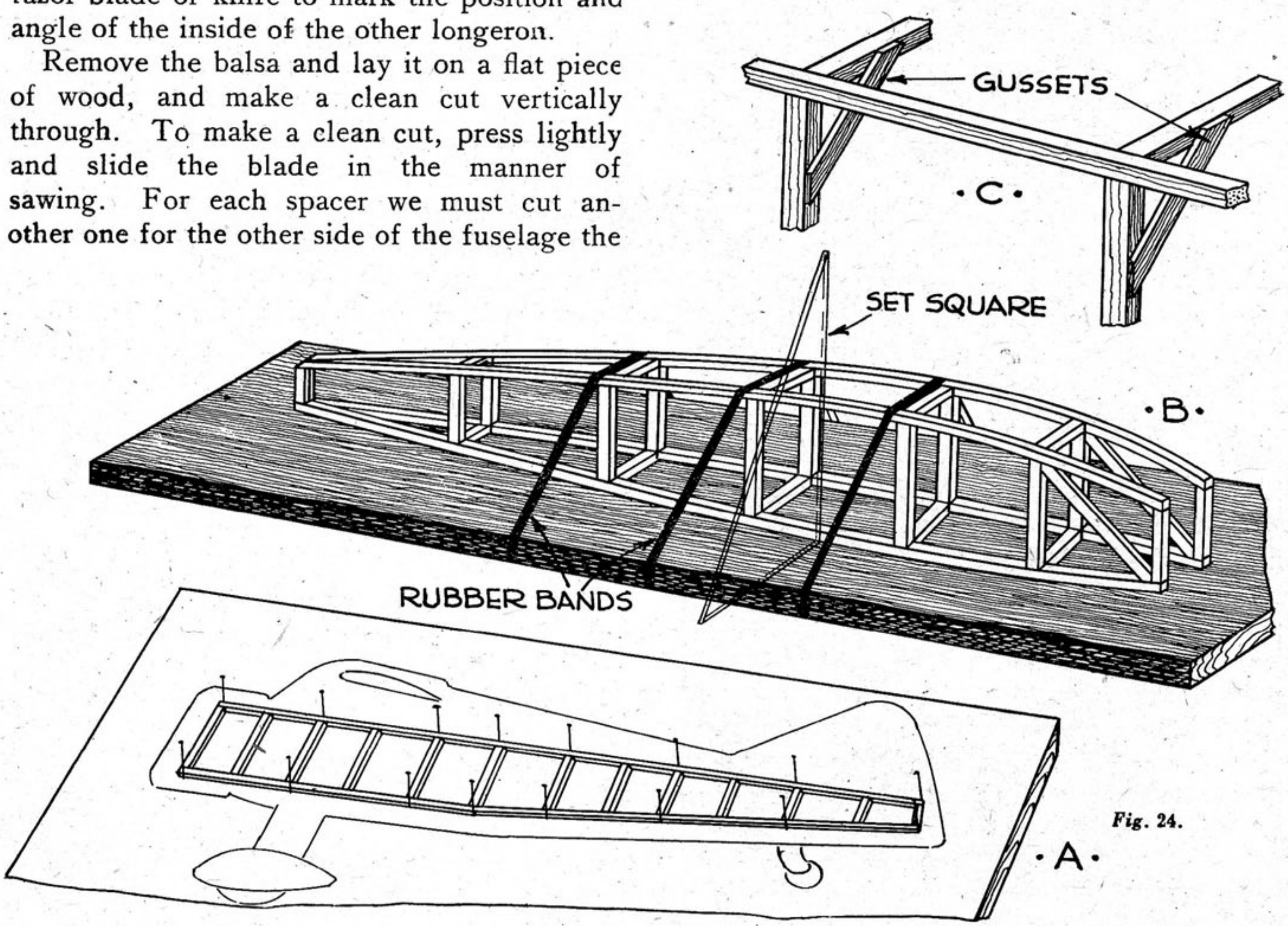
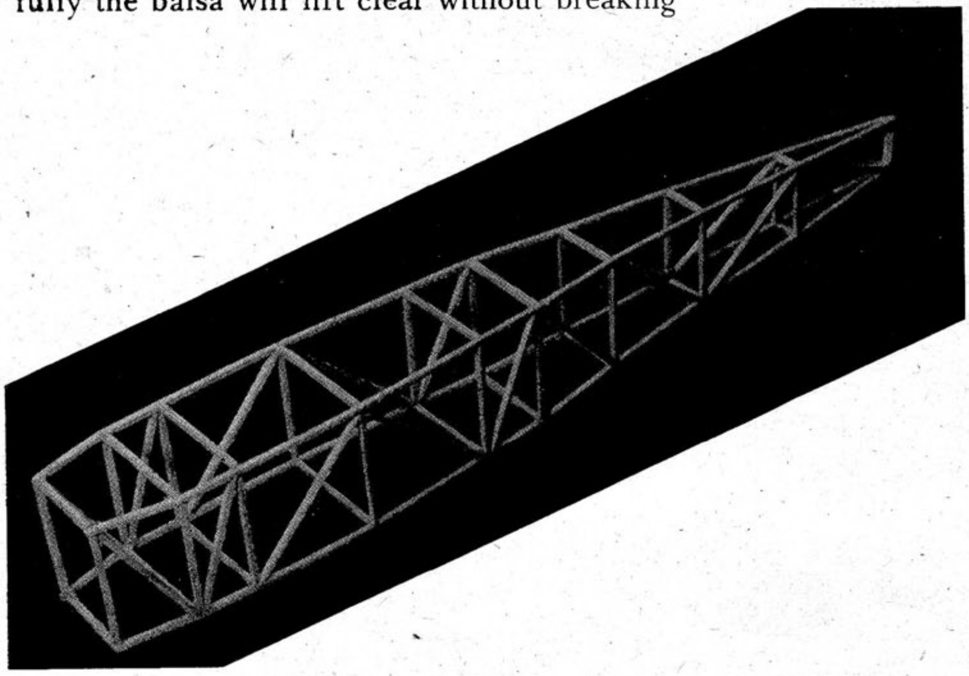


Fig. 24.

Well now, to get on with the fuselage. When the balsa is dry after the steaming we can remove that side and build another one just like it. Some of the pins will have to be removed, but leave as many in as possible, as it helps to get the second side exactly like the first. If there is any tendency for the balsa to stick to the paper, slide a razor blade between the balsa and the paper between the joints and work it gently along to the joint. By working carefully the balsa will lift clear without breaking or tearing the paper. Do not try to cut with the blade, but use it as a wedge. The next part of the job is to stick these two sides together with spacers in between. We pin a plan view to our board, not forgetting the grease-proof paper, and for this part a narrow board about four or six inches wide is handiest. We stand the two sides on the plan on their flat surfaces and put pins in to hold them in the right place at the middle or widest part. Cut spacers to hold the two sides apart, and stick them in place. If you are using a narrow board you can slip rubber bands over the fuselage and board to hold everything in place while the glue dries. If, however, our board is wide we can still use the rubber bands, only fixed each side with drawing pins. Long thin bands are best, stretched across the fuselage and down each side at an angle of about 45 degrees. See Fig. 24b. Keep the structure square by pulling the bands tighter on one side than on the other. If we put gussets of $\frac{1}{8}$ in. by $\frac{1}{16}$ in. balsa in the corners, as shown in Fig. 24c, the fuselage will be stronger and all the better for it. Before removing the rubber bands, give the structure another steaming, but watch it for squareness if you have not put in the gussets.



Another method of building this primary structure is to use formers as shown in Fig. 25a instead of spacers. One of these is made from sheet and the other from strips of balsa glued together. The notches in the corners are for the longerons. In this case we do not build the structure on a flat board, but glue the longerons to the formers. This method was used before the

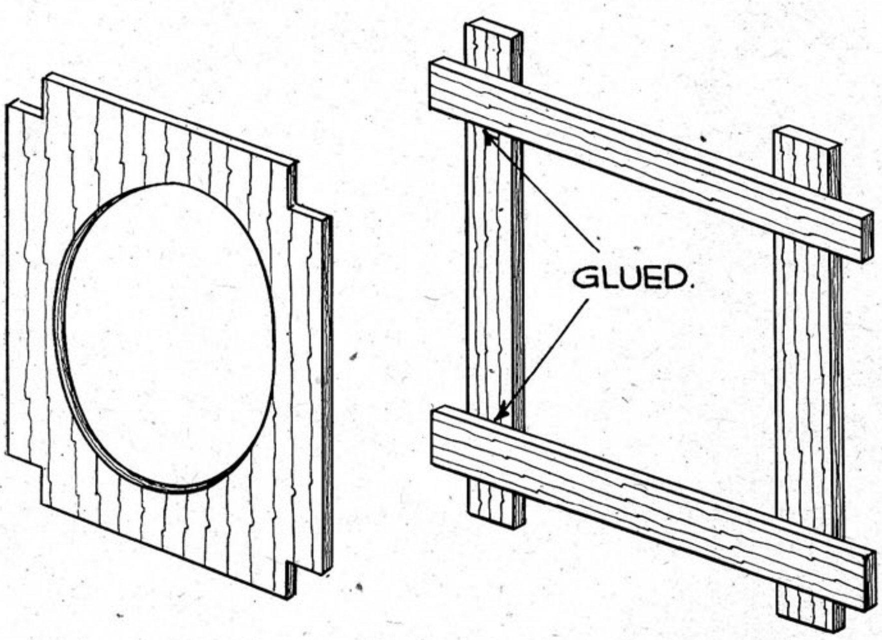


Fig. 25a.

introduction of balsa, when models were made of spruce longerons and plywood formers.

Having built this rectangular structure, we shall now have to add formers and stringers as previously illustrated in Fig. 15a.

Formers for a model up to about 30 in. span could be made from $\frac{1}{32}$ in. hard sheet balsa, or, better still, two thicknesses of soft balsa glued together with the grain crossing. In this case it is better to stick the balsa together before cutting it. When cutting single thicknesses, always cut into the grain, and only a bit of a curve at a time. Fig. 26 explains pretty well how to do it, and it depends on how sharp the curve is as to how many cuts you need to make.

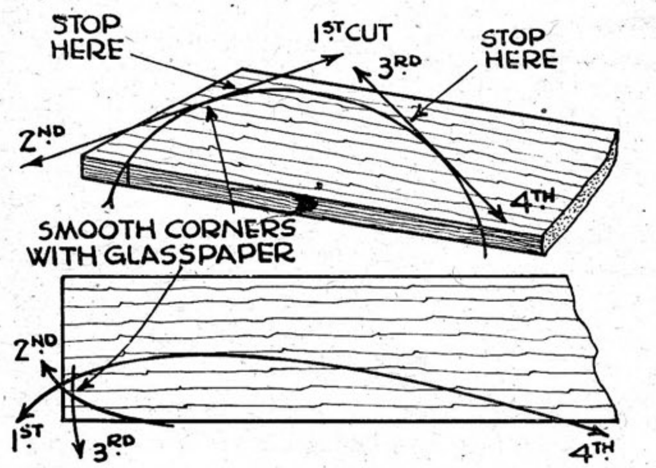


Fig. 26.

In this way you will tend to split the waste wood rather than the former or wing rib, or whatever we are cutting out. For cutting out the balsa you can use a razor blade broken off across the corners, a pen-knife with the point kept razor sharp on an oilstone, or a special balsa cutting tool. With this special tool we can get a variety of blade shapes for various work, such as hollowing out nose-blocks and cutting holes in wing ribs to lighten them.

Now for rounded fuselages that are not made with a rectangular primary structure. One method is to cut out the formers and hold them in place with pieces of packing on a straight, square rod that passes right down the fuselage, while you glue on the stringers or planking. This is shown in Fig. 27, while a variation of it is shown in Fig. 28. In this latter the formers are slotted to take a strip of thick ply that must be quite straight. It should be as thick as possible, and as wide as can be got into the fuselage.

Another method, shown in Fig. 28, is to use four " master " stringers, keels, or backbones, or whatever they are. We can make these stringers (or whatever they are) from $\frac{1}{16}$ in. hard balsa sheet, and they should be about $\frac{1}{8}$ in. to $\frac{1}{4}$ in. wide, and must be cut to the required curve. The formers should be slotted for the stringers, but not to the full depth. We want them to stand up above the formers a little, the

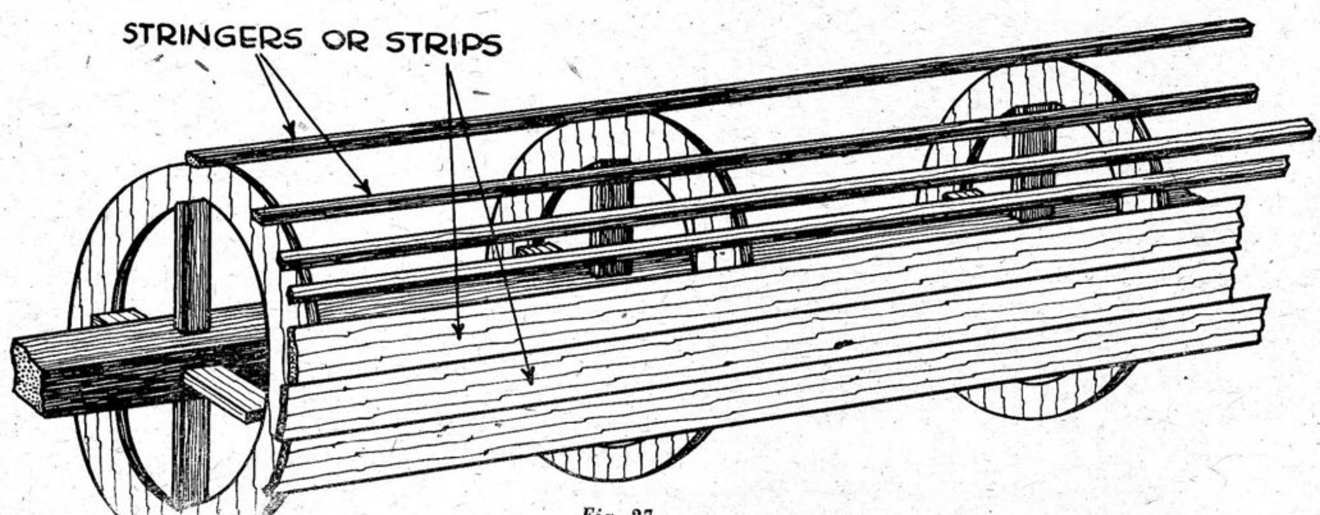


Fig. 27.