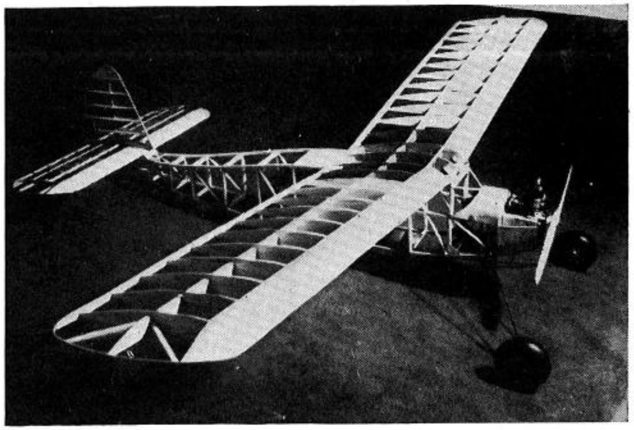


This 'plane was built by Mr. Stevens to a well-known design. Span is 7 ft. 6 in., and the engine is a 9 cc. " Dennymite."

CHAPTER XIII

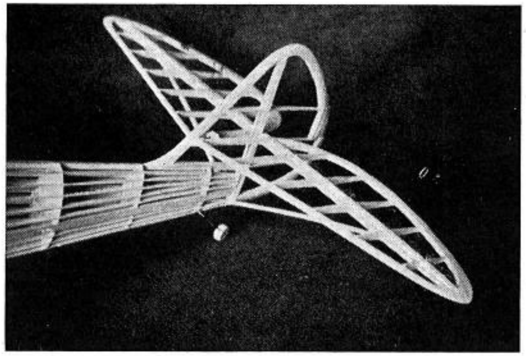
TAIL UNITS

IN power-driven model aircraft construction the control surfaces may be built up in three different ways. On small light models the fin and elevator may be built straight in to the fuselage, with the tail 'plane being set at no angle of incidence, and functioning purely as a stabiliser, as explained in Chapter IV. For larger models, for the sake of portability, the tail-plane and fin are built separately from the fuselage.

Fig. 65 shows a tail-plane and fin built integral with the fuselage. This is the tail unit of the fuselage shown in Fig. 60.

FIG. 65.

This photograph is of the tail unit shown in the photograph of a complete fuselage in Fig. 60, on page 129.



In Fig. 66 is shown the fin and elevator built as one unit, which also incorporates what is in effect the tail end of the fuselage. Beneath the leading edge of the fin will be seen a raised block, which registers into the tail end of the fuselage. Whilst this method of combining the fin with the stabiliser is a little cumbersome, it has the merits of rigidity, and the unit

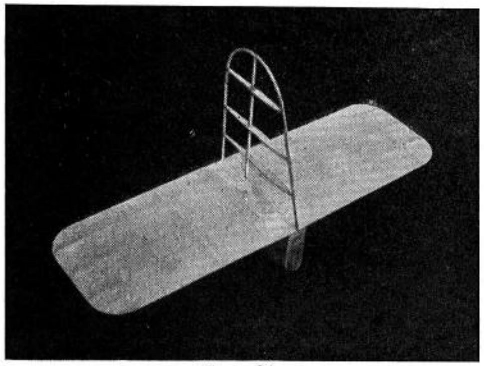


FIG. 66.

as a whole may easily be adjusted. It is held up to the tail end of the fuselage by a short length of rubber twisted round opposite pairs of hooks at its junction to the fuselage. By the insertion of thin packing pieces at the top or bottom, or at either side, of the fuselage, variation in incidence and in direction of the fin may be made.

Fig. 67 shows the rear end of another model built by the author, in which the tail unit may be seen, held up by rubber bands, to the rear end of the fuselage.

Cantilever spring mounting for the tail wheel and the connections for the booster battery, may be noticed in this photograph.

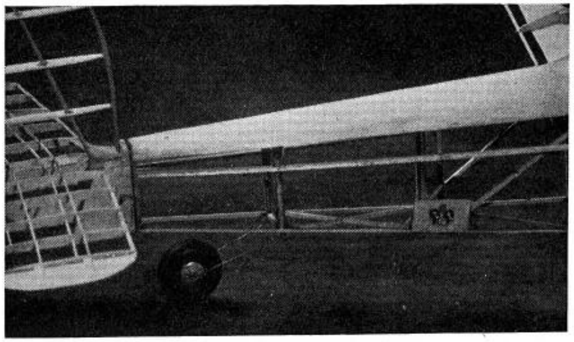


Fig. 67.

The construction of tail units should be as light as possible to avoid unnecessary weight. In Fig. 68 are shown the control units for the high-wing cabin monoplane described by the author. The stabiliser is built as a separate unit, and is located on a platform formed at the rear end of the fuselage. The span of this unit is 30 inches, with a chord of 10 inches, and completed and covered with silk and doped the weight is 3 ounces. The fin has balsa ribs with strips overlaid on their edges to support the silk, as is described in the chapter on Wing Construction. The outline is made from a piece of $\frac{3}{16}$-inch diameter cane steamed to shape. It will be noticed that there is a vertical post and a raking post, both of which rise to the highest point of the fin. The purpose of this is that in the event of the machine making a " nose-over " landing, and the top of the tail hitting the ground, the blow is distributed

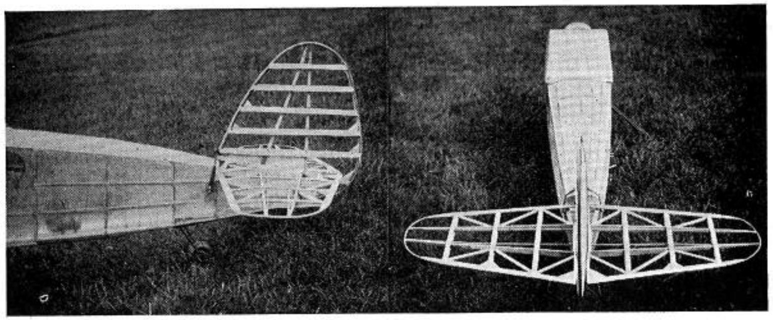


Fig. 68.

In this photo is shown the tail unit of the Author's 'plane, illustrated on page 108.

throughout the whole framework of the unit, and no damage is sustained. The vertical post carries through to the bottom of the fin and is located in a middle plate fixed to the bottom of the fuselage. At the front end of the fin there is a small peg over which a short rubber band passes down to either side of the fuselage, as may be seen in the photograph. The construction is such that the fin may be deflected to either side of the centre line by a few degrees, and the stabiliser may also be adjusted for variation of angle of incidence. The method of fixing the fin holds the stabiliser in position, yet on release of the rubber band both units may immediately be detached.

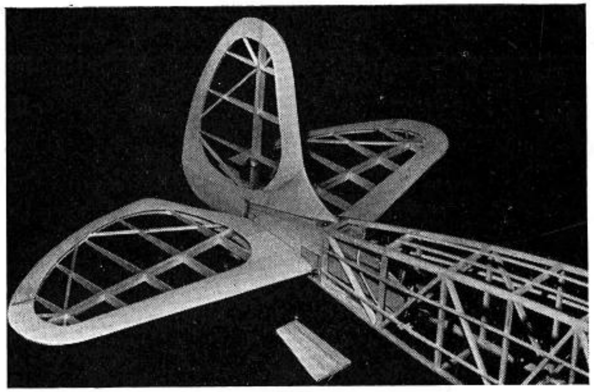
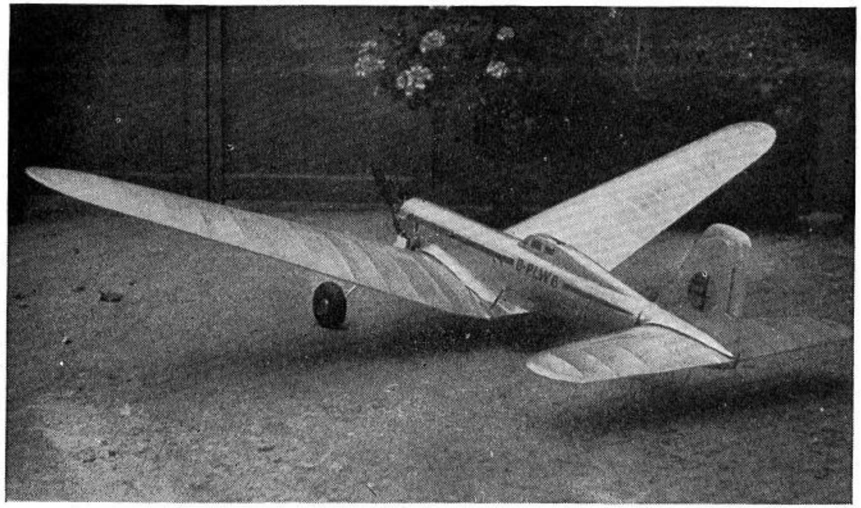


Fig. 69.

In this photo is shown the construction of the tail unit of the 'plane illustrated in Fig. 51.



This well streamlined 'plane is a very successful one of several built by Lt.-Col. C. E. Bowden in 1938. The badge of membership of the National Guild of Aero-Modellists—of which Lt.-Col. Bowden is Hon. Chairman—can be seen on the tail unit.

CHAPTER XIV.

LANDING CHASSIS, TYRES, AND WHEELS

Types of landing chassis—Details of various constructions —Factors affecting the design of landing chassis—Pneumatic tyres—Airwheels—Semi-solid tyres—Solid and built-up wheels —Axle tubes and methods of fixing to wheels.

NO matter what size or type of model aircraft is under consideration, the first point to be settled in regard to the take-off and landing apparatus—i.e. the chassis and wheels—is whether the chassis shall be constructed from a purely practical point of view—as light and as strong as possible without much attention to appearance—or whether it shall be a copy of some type in actual use—which will be obviously more elaborate, and weighty.

Similarly it must be decided whether the wheels shall be " solids "—either of metal or wood—or whether penumatics shall be used.

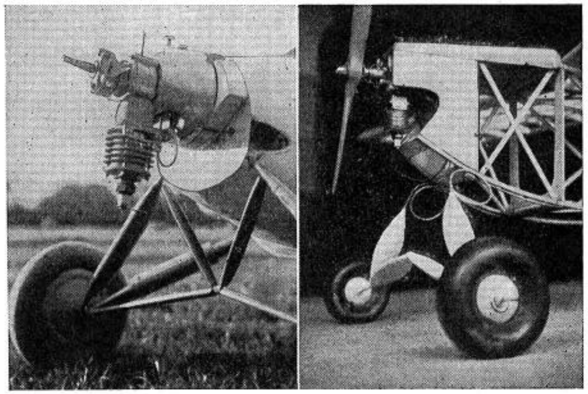


FIG. 70.

Now unless a model aircraft has a fairly light wing-loading resulting in a reasonably flat glide, it will not make a 3-point landing, but will " come in " at an angle of anything between 10 and 20 degrees to the ground.

For this reason it is essential that any type of landing chassis should be capable of a " backwards " movement instead of an " up-and-down " movement. A good test of any landing chassis is to drop the whole aircraft vertically from a short distance above the ground, when no appreciable movement of the wheels should take place. If, however, the aircraft is thrown " into the ground " at an angle, the wheels should move backwards, and so reduce the landing shocks to the rest of the aircraft.

In this respect, the simple " strut and wire " type of chassis is ideal, since the " safety-pin " type of coil spring which it incorporates allows of a backwards movement of several inches. This type of undercarriage is illustrated on the right of Fig. 70.

However, the great drawback of this type of chassis is that it is not " real " looking, and cannot be used on any scale type of model. If the machine is being built to a " performance " specification, the need for lightness will compel the designer to adopt a simple " strut and wire " type similar to that shown in Fig. 71, which is easy to construct, will stand a

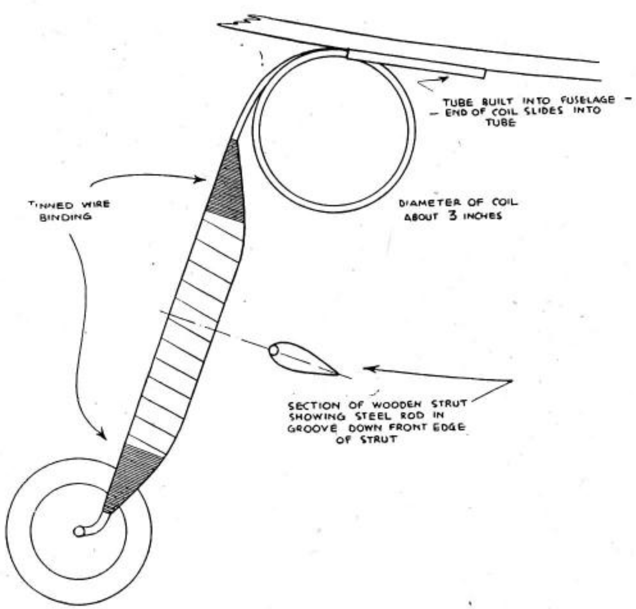


FIG. 71.

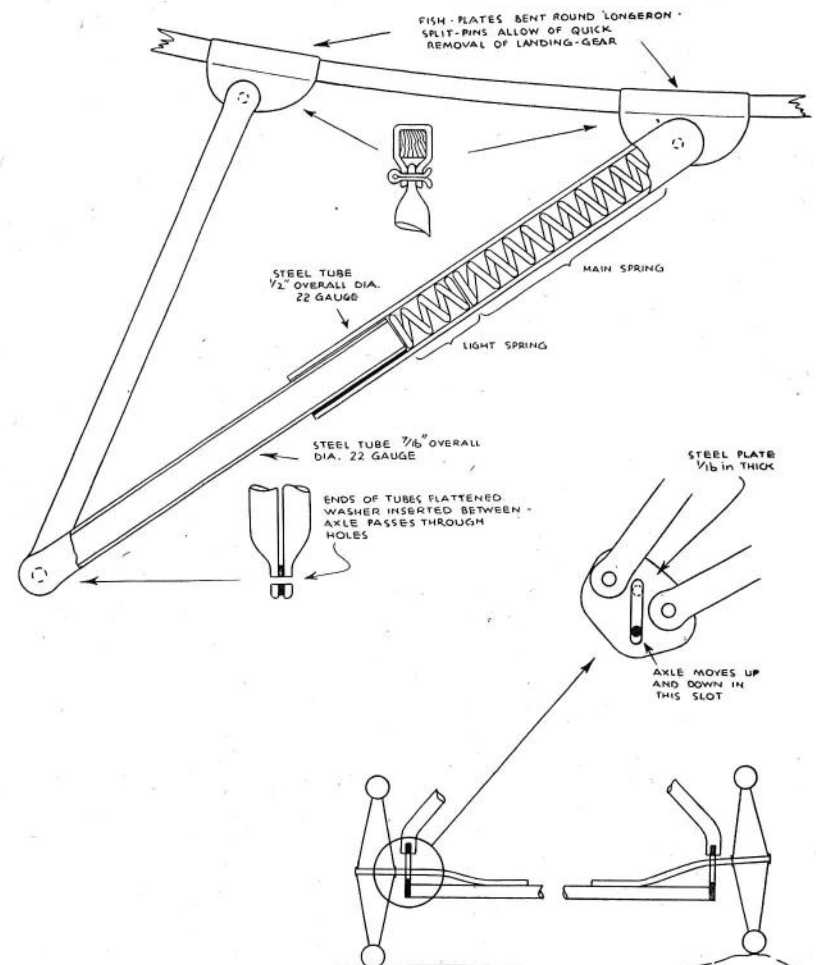


FIG. 72.

lot of hard wear, and may be built in any size. For aircraft up to 3 pounds weight, the spring-steel wire should be of $\frac{1}{8}$-inch diameter; from 3 to 6 pounds weight it should be $\frac{3}{16}$-inch diameter, and above 6 pounds it should be not less than $\frac{7}{32}$-inch diameter.

The wooden " fairings " may be either of birch or balsa and should be tightly bound with strips of silk after affixing, in halves, to the steel rod.

In Fig. 72 is shown a somewhat more elaborate landing chassis in which use is made of compression springs contained in tubes which slide one within the other; suitable "fairings" of balsa being afterwards affixed to the tubes if it is desired to " improve their looks." Built with the sizes or tubes as shown such a chassis would be suitable for a machine of about 5-7 pounds in weight.

Fig. 73 shows a chassis built on this principle for a large high-wing machine weighing some 9 pounds. The tubes were of steel, and of $\frac{1}{2}$-inch and $\frac{9}{16}$-inch diameter respectively, a movement of 2 inches being obtainable. The rods were of $\frac{3}{16}$-inch diameter *mild* steel, this being used since the fairings were of birch, and quite large sections—some 2 inches deep by $\frac{3}{4}$-inch wide—to match the size of the machine, the span of which was 11 feet.

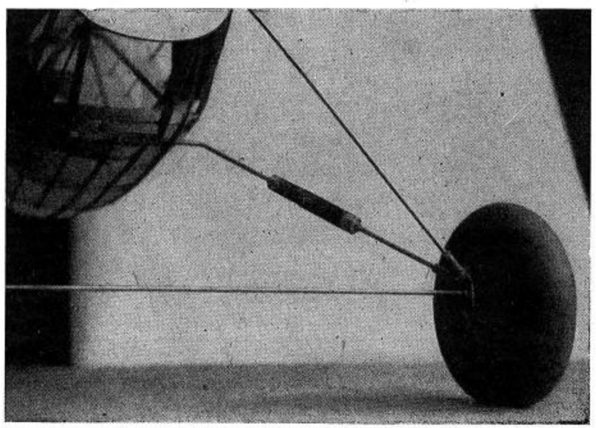


Fig. 73.

Fig. 74 shows the general details of the construction of a fairly elaborate landing chassis suitable for large machines, which will stand up to a great deal of hard wear, and which is very realistic looking. Built to the dimensions shown in Fig. 72, the chassis is suitable for a machine weighing about 6-8 pounds.

Fig. 75 shows the general construction of the shock-absorber units, from which it will be noted that the steel rods

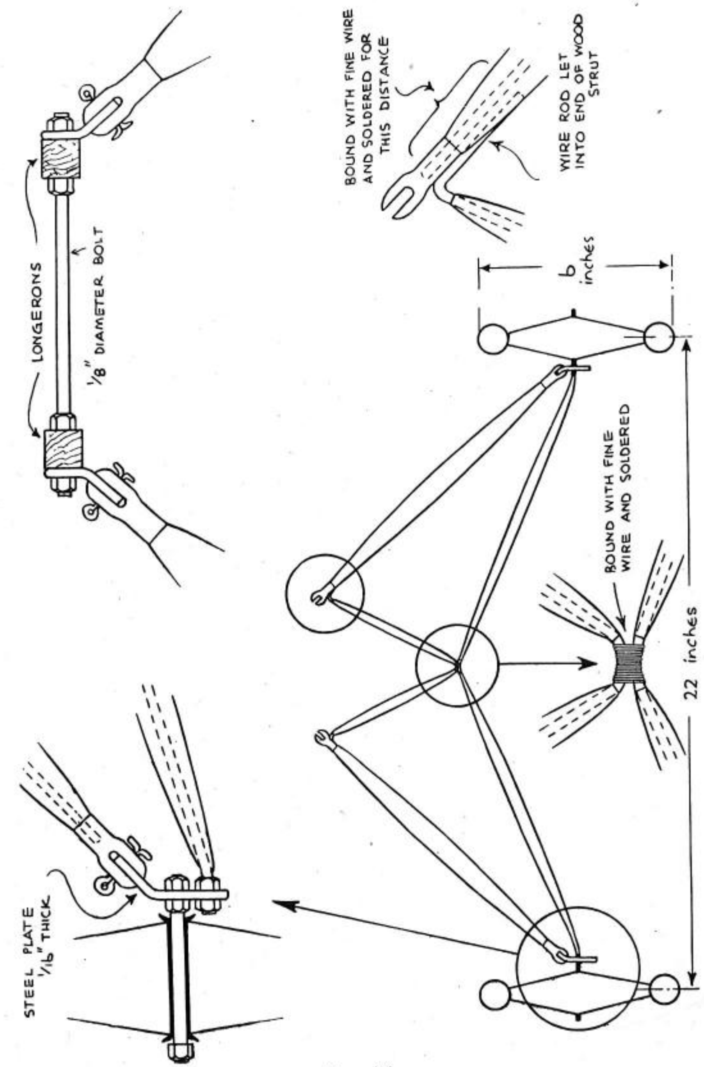


Fig. 74.

are of $\frac{1}{8}$-inch diameter. It is essential that at the points where the rods enter the lugs they are welded—otherwise there is a risk of their snapping off. If welding facilities are unobtainable, as, say, at a small village garage, the rods should be increased in diameter to $\frac{3}{16}$-inch and soldered after screwing into the lugs.

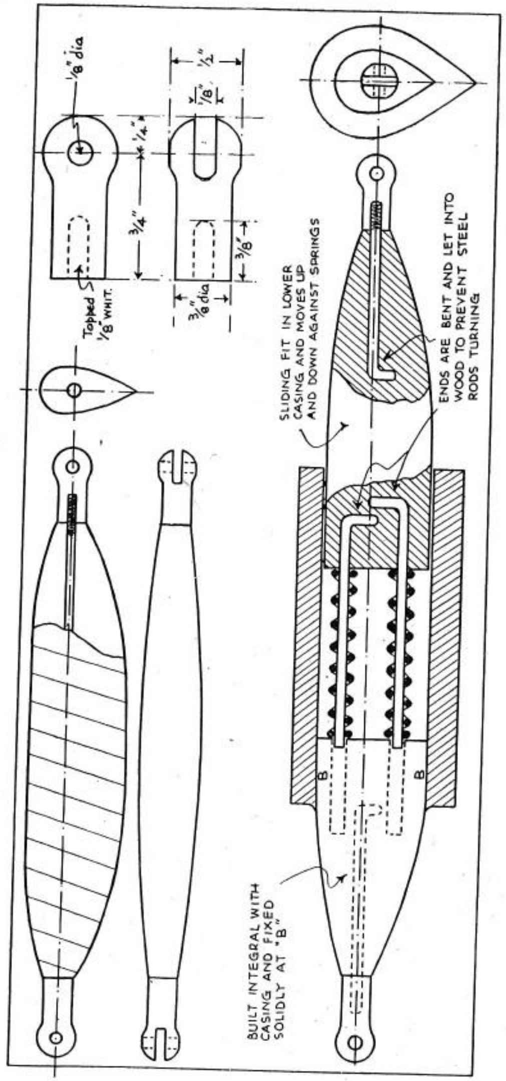


FIG. 75.

This method of construction was adopted for the 10 ft. span low-wing petrol 'plane, a photograph of which appears on page 59, and with the diameter of the steel rods increased to $\frac{3}{16}$-inch, and the size of the lugs also increased, the whole unit functioned well with an all-up weight of 14 pounds. The

track was 2 feet 2 inches, and the weight of the whole unit 1 pound 6 ounces.

The struts are all made by laying up two half sections of birch (*not* balsa), each with a semicircular groove down the centre to accommodate the steel rod. The halves are pinned and glued together, finally shaped, and taped with two layers of silk.

This type of classis can be made to work equally as well as the simpler types, *provided* attention is given to 2 points. Firstly, the front struts *must* hang vertically; and secondly, the rear struts, incorporating the shock-absorbing springs, *must* be anchored to the fuselage at a point well behind the front strut anchorages, both these features being shown in Fig. 76. A good rule is to make the distance between the anchorage points at least equal to the vertical distance from the front strut anchorages to the ground. By this arrangement the front struts act solely as radius arms, and during landing take not much more than the actual weight of the aircraft; whilst the rear struts, being inclined, are not so very far out of line with the direction of the glide into the ground, and are thus directly able to move "backwards" under the force of impact.

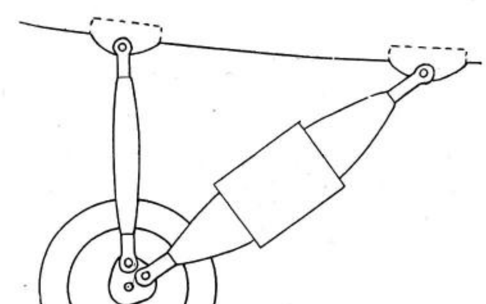


FIG. 76.

The type of landing gear which the author has originated, and which has given extremely good results, is that shown fitted to the high wing cabin monoplane illustrated in this book. Essentially it consists of two cantilever legs, which are mounted on a rigid support in the centre of the fuselage. The legs of the model described were made of solid drawn steel tubing of light gauge and 1-inch × $\frac{3}{8}$-inch section. At their bottom ends were bolted two $\frac{3}{16}$-inch diameter spindles, on which the pneumatic-tyred wheels revolved. At their upper ends the two tubes were flattened, and through them passed a single bolt, which acted as a pivot. The support for the bolt was

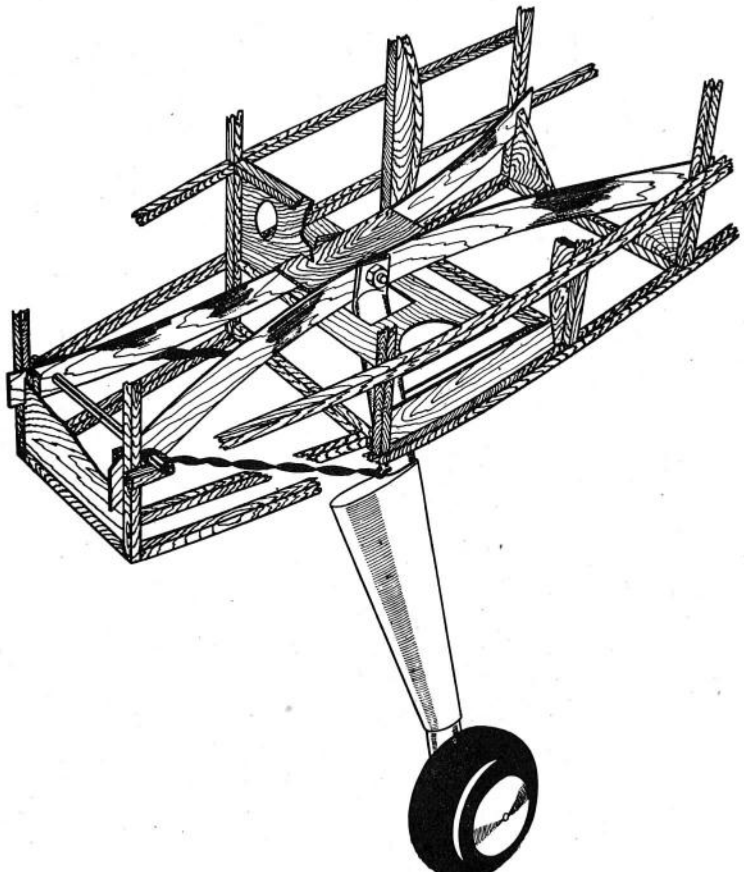


FIG. 77.

built up from a box frame of $\frac{1}{16}$-inch three-ply, so designed that the stresses were distributed from the nose to halfway down the length of the fuselage. Fig. 78 is a plan view looking down into the fuselage, and Fig. 79 shows the near

side leg projecting through the slot in the bottom of the fuselage. The pivot bolt may also be seen. Rubber bands are looped round each leg, and led up into the nose of the fuselage, where they are anchored to a $\frac{3}{16}$-inch diameter wood dowel, which passes through from side to side. This dowel may be seen in Fig. 77.

In Fig. 78 may be seen the platform on which the battery is placed, and located in position by rubber bands. In Fig. 79, below, may be seen the guide in which the leg moves backwards and forwards. Note also the battery leads provided with "crocodile" clips, as referred to in Chapter 15.

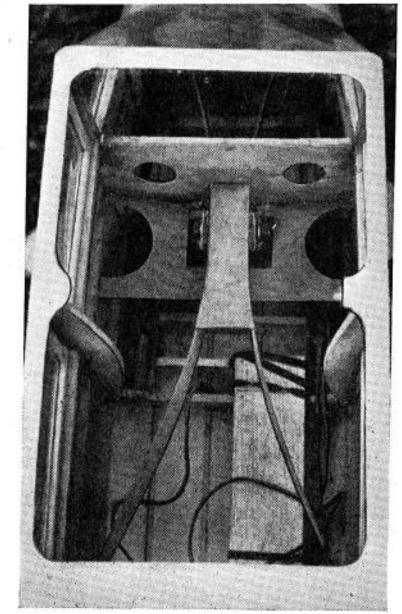
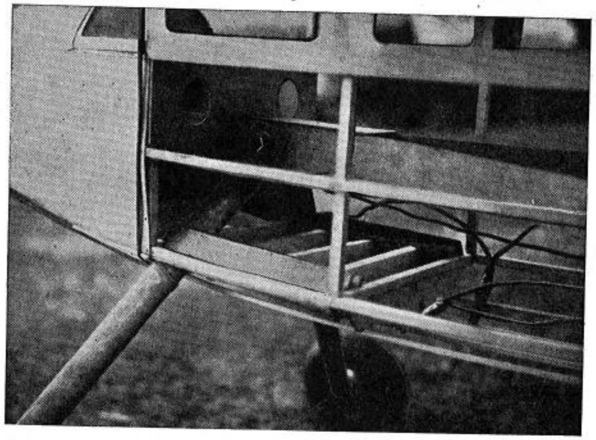


FIG. 78.

FIG. 79.



The advantages claimed for this type of landing gear are:

(1) The completely independent springing of each wheel.

(2) The length of movement of the legs may be varied at will.

(3) The tension in the rubber may also be varied. Several strands of $\frac{1}{4}$-inch × $\frac{1}{16}$-inch rubber are used, and are arranged in tension so that the legs are always held in the forward position. In the model here described the movement along the slot shown in Fig. 79 was about 3 inches, so that the wheels were able to move back about 6 inches when the machine touched down. The efficacy of this arrangement has been thoroughly well tried out, and the author is content that it cannot be bettered. It is essentially simple, extremely robust, and gives that backward and forward movement that is so desirable in the undercarriage of a petrol 'plane. To see the machine glide in to land, touch down, and watch the legs move back, or perhaps only *one*, if one wheel touches before the other, is a very pleasing sight.

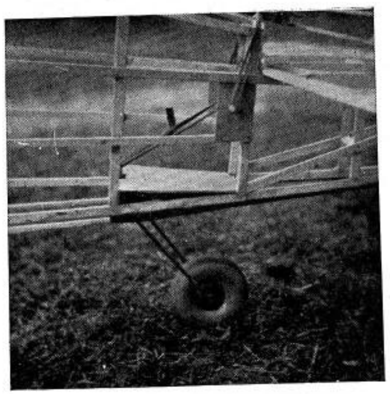


FIG. 80.

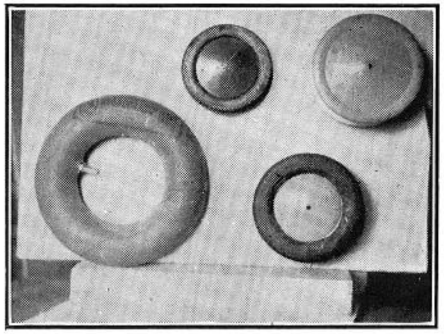
The author has adopted the same principle of suspension for the mounting of tail wheels, as shown in Fig. 80. A single length of wire is bent to pass through a tubular support, after which the ends are turned down and inwards to carry the tail wheel. Thus the lugs have only to be pulled apart for the wheel to drop out. The length of rubber forming the tensioning device can be seen in the photograph anchored at its top end to a horizontally located dowel rod. To the two outer ends of this is affixed the rubber band which holds the fin in position, as illustrated in Fig. 67 in the chapter on tail units.

The type of landing chassis illustrated in Figs. 77—79 offers no " up and down " movement, which is not required for landing, but is required for taking-off. It should, therefore,

only be used in conjunction with pneumatic-tyred wheels, which will be found to provide the necessary degree of resiliency. For use on large aircraft, where a wheel diameter between 6 and 8 inches is required, use may be made of small inner tubes, size 8 inches × 2 inches, as used inside normal type covers and fitted to light trolley and barrow wheels. These inner tubes weigh $4\frac{1}{2}$ ounces, complete with the usual type of cycle valve, and may be purchased from Messrs. Dunlop Rubber Co. Ltd., for 2s. 6d. each. In Fig. 81 is shown an

FIG. 81.

At top right is shown the hollow balsa wheel on which is fitted the Dunlop tyre shown at bottom left. The two other wheels are built up from discs of 3-ply to take Meccano motor tyres.



inner tube, and at top right the hollow balsa wheel on which it is mounted. Fig. 82 shows the tyre and wheel on a machine,

FIG. 82.

and Fig. 83 is a scale drawing showing the construction of a wheel. It will be noted that the wheel is made in halves,

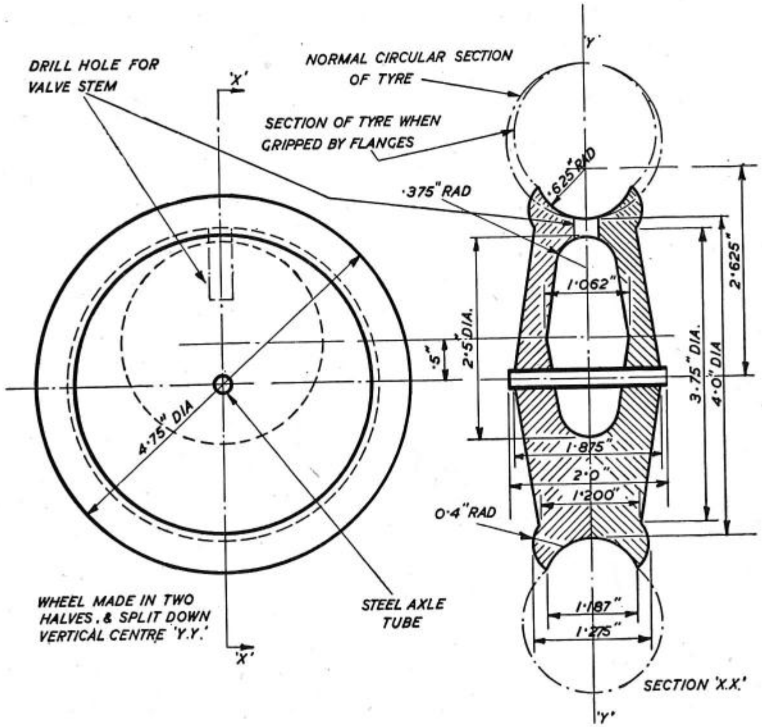


Fig. 83.

each of which has been hollewed out *eccentrically* to balance the weight of the valve.

The diameter of the wheel is made about $\frac{1}{8}$-inch greater than the inner diameter of the tyre (measured when inflated to the desired pressure). So that when it has been sprung over the wheel flange it grips the wheels snugly. The flanges are brought well up the sides of the tyre to prevent it being pulled off in the event of a side landing.

For sizes below 8-inch diameter a range of pneumatic-tyred wheels, complete with miniature valves, may be obtained from various model aircraft firms.

The *width* of the tyre mainly determines the area of the tyre in contact with the ground, and whilst narrow tyres are satisfactory for a take-off from a road or other hard and level surface, they are quite unsuitable for heavy aircraft when taking off from the average grass field, as the concentration of weight

on the narrow wings will cut a path *through* the blades of grass. On the other hand, pneumatic tyres of the correct proportion offer a relatively much larger surface area in contact with the ground, and consequently the weight distribution is much less per unit of area, resulting in the tyre " riding over " the grass instead of cutting into it.

Solid balsa wheels, sometimes fitted with rubber rings let into grooves cut round the circumference, are very light and may be made to look quite realistic if the rubber ring is of the correct thick section to represent a tyre.

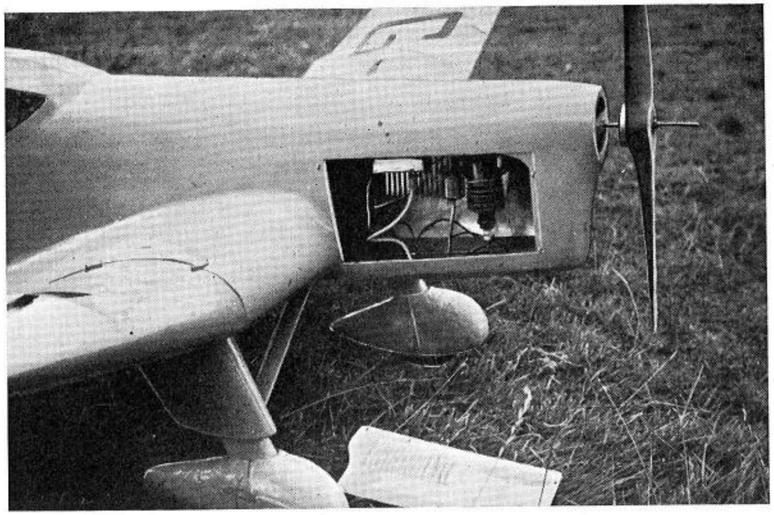
Satisfactory wheels, fitted with solid tyres as sold by Messrs. Meccano, may also be made by forming two convex discs from three-ply which are fixed on either side of a disc of hard wood, through which the axle tube passes—the tyre being gripped between the two flanges so formed. Such a wheel, fitted with a 4-inch diameter tyre, is also shown in Fig. 81.

Owing to the softness of balsa wood it is not advisable to insert the axle-tube direct; it should first be driven into a bushing of hard wood of a diameter equal to about three times that of the tube. This cylinder is then glued into the centre of the wheel.

All wooden wheels of any size may, with advantage, be made hollow (unless, of course, weight is actually required from the point of view of aiding stability) by forming two flanges, scooped out in their centres, which are then glued and pinned together. The wheel shown in Fig. 83 was made of balsa wood and, complete with steel axle-tube, weighed $3\frac{1}{2}$ ounces.

Weight low down is always an advantage from the point of view of lateral stability; and weight at the nose keeps the main wings well forward, and thus well separated from the stabiliser, which helps longitudinal stability.

Thus it is seen that several valuable advantages accrue from the use of pneumatic-tyred wheels of reasonable weight, and in conjunction with a scale type of landing chassis, are recommended as well worth the cost or time involved in their construction, as well as adding very considerably to the appearance of the aircraft.



This " close-up " photo of Mr. Newman's " Mew Gull " shows how the engine is mounted in the front of the fuselage. The engine is a 15 cc. " Grayspec " two-stroke. A photo of the complete machine is on page 66.

CHAPTER XV.

THE MOUNTING OF ENGINES AND ACCESSORIES

Typical engine mountings—The " Comet " cone—The electrical circuit — Batteries — Coils — Condensers — Time switches—Contact breakers—Advantage of complete assembly on one panel.

THE engine of a power-driven model aircraft can be mounted in one of several ways—either by itself, with the petrol tank and electrical equipment located in the fuselage, or it may be mounted on a sub-frame on which is also fixed the petrol tank, or it may be mounted as a " self-contained " unit, with petrol tank, coil, condenser, ignition switch, and throttle control all on one framework. If the engine is to be mounted by itself by far the best way is to use a light electron casting, as shown in Fig. 84. This was designed by Lt.-Col. C. E. Bowden, and is to be highly recommended.

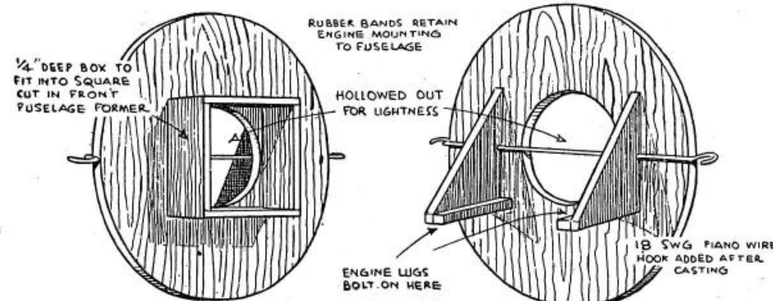


FIG. 84.

On the left of the illustration is shown the rear side of the mounting. The box section fits into a similar shape recess built into the nose of the fuselage, against which the circular disc lies. As will be seen from the right-hand illustration, two triangular shaped lugs project forward, to which the engine flanges are bolted. It will be seen that the engine may be mounted upright or inverted. The length of wire which passes horizontally through, and which has hooks formed on its two ends, is for fixing lengths of rubber which are laced back to suitable anchorages at either side of the fuselage. This form of mounting has two advantages, firstly packing strips of metal or 3-ply wood may be inserted between the circular disc and the nose of the fuselage, to vary the angle of thrust both up or down or sideways; and secondly in a " nose-over " landing the mounting may be knocked off from the nose of the model due to the stretching of the rubber. Through the hole in

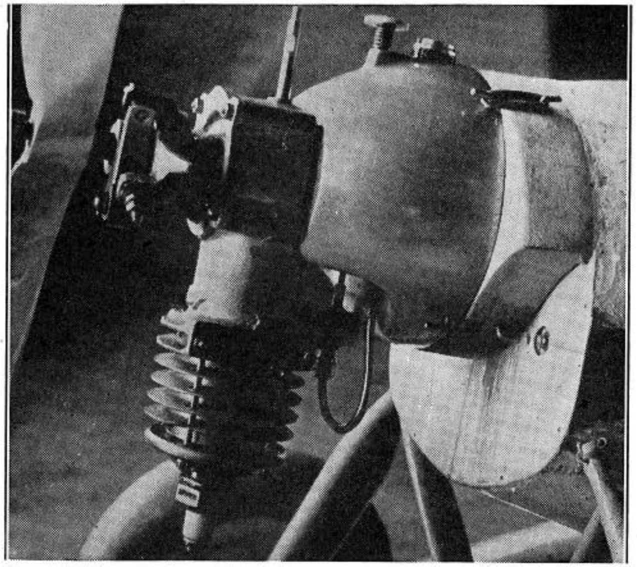
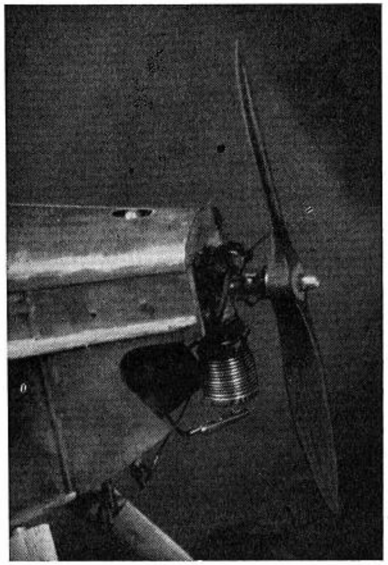


FIG. 85.

the centre of the disc pass the petrol pipe and electrical connections.

Another way in which an engine with its petrol tank may be mounted in a semi-flexible manner, is by the use of an aluminium or electron " cone." In Fig. 85 is shown the electron mounting developed by the manufacturers of the 18 cc. " Comet " engine. There are 4 pegs equally disposed round the circumference of the " cone," to which lengths of rubber are twisted to and from 4 oppositely located pegs at the front of the fuselage. At the top right hand corner of the photograph may be seen a pair of pegs with the rubber band tightly laced between them. To the left, and at the top of the " cone," is the filler cap of the petrol tank, which is a separate unit bolted inside the hollow " cone." To the left of the

tank filler is the throttle control, which passes down through the " cone " to the carburetter, which is bolted to the cylinder crankcase. At the back of the cone is a raised projection, rectangular in shape, which fits into a small recess formed in the front of the fuselage. This locates it accurately in position, at the same time allowing the whole unit to be knocked out of place in the event of a " nose-over " landing. Most engines are supplied by the manufacturers mounted on a wooden test frame. Two examples of these frames are shown in Fig. 103 of the 2·5 cc. " Spitfire," on page 170, and the photograph of the 6 cc. " Baby Cyclone " engine, Fig. 100, page 166. Quite a good way of mounting any engine is to mount the test frame direct into the front of the fuselage. In Fig. 86 is shown a " Baby Cyclone " mounted in the inverted position direct into the fuselage of one of the author's planes. The front of the fuselage consists of two $\frac{3}{16}$-inch thick panels of 3-ply, through



The " engine room " of the " Cyclonic." One of the screws on which the engine mounting pivots may be seen.

FIG. 86.

which two wood screws pass into the wooden engine test frame. A great advantage of this method is that the engine pivots about the two screws, and in the event of the machine landing on its nose, as soon as one blade of the propeller strikes the ground the whole engine unit is tipped up. It can soon be set back to its normal position, and if the two screws which form the pivot are retightened the friction is quite sufficient to hold the engine in position. This method of engine mounting is also shown in the right hand photograph of Fig. 70, page 137.

A very neat and practical design for an all-in-one engine mounting is that shown in Fig. 87, designed by the manu-

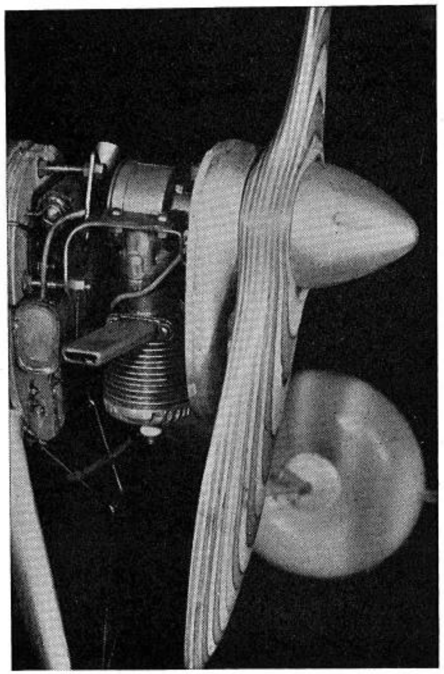


FIG. 87.

In this photo is shown the special flexible and adjustable engine mounting, designed for the 'plane illustrated on page 193, in the chapter on high-speed petrol 'planes.

facturers of the 'plane shown on page 193. The mounting for the engine consists of an inverted U-shaped frame of spring steel, which is mounted to a bulkhead at the front of the fuselage by three bolts, arranged in triangular fashion. The top one may be seen in the photograph, and the near side lower one can be seen just above the petrol tank, which is behind the exhaust pipe. The mounting being of spring steel, allows of a certain amount of flexibility, and by adjusting the nuts on the three steel rods, side and up-and-down

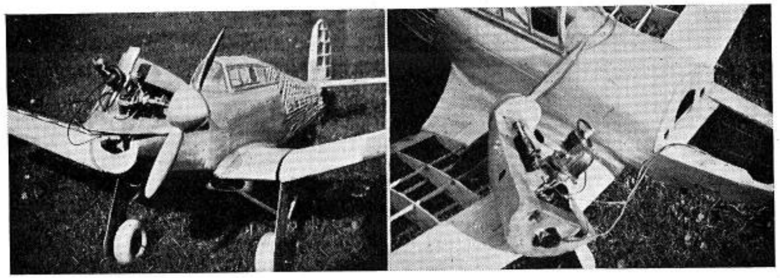


FIG. 88.

adjustment to the engine position may be made. There is a cowling which fits closely over this " engine room," totally enclosing it.

In Fig. 88 are shown two photographs of the engine mounting on Mr. Miller's Hawker " Hurricane." The 9 cc. " Ohlsson " engine is mounted in the inverted position, and drives the propeller shaft through an extension mounted on ball bearings. For large aircraft the author is in favour of mounting the engine separately, and the electrical equipment all on one panel. In Fig. 89 is shown the unit as used on the 10-foot span low-wing model described in the last chapter of

Instead of using dry batteries, the aero-modeller may use a very small accumulator. An example of the type suitable for use on model aircraft is shown in Fig. 94, page 159.

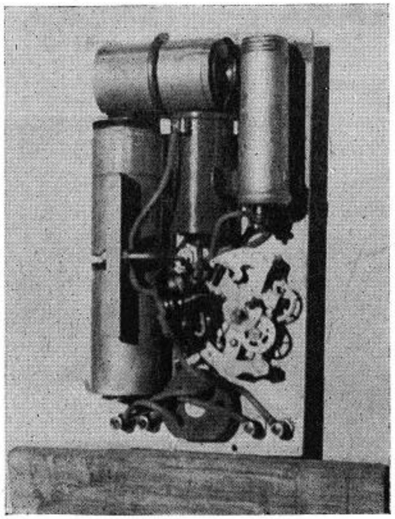


FIG. 89.

this book. At the top right-hand corner is the condenser, and to its left, in the centre, is the coil. Along the left of the panel and across the top are three $1\frac{1}{2}$-volt cells, making up the $4\frac{1}{2}$-volt battery. At the lower right is the time switch, built

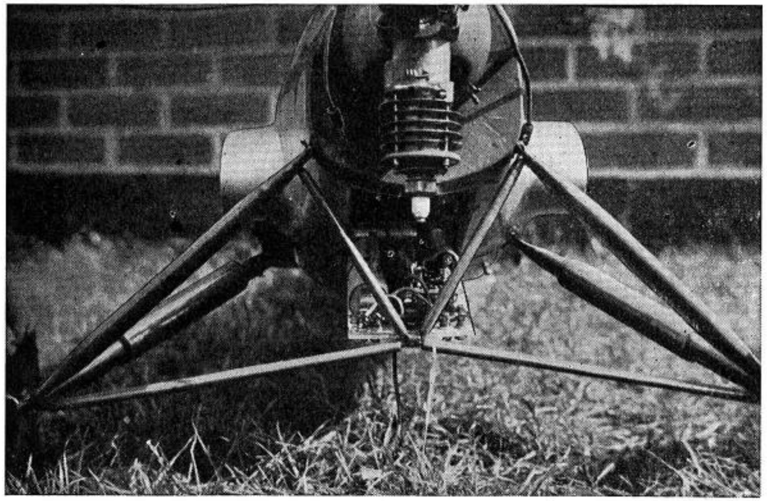


FIG. 90.

from a small clock, and at the centre bottom is the change over switch from booster battery to the cells on the panel. On the left of the switch are sockets into which are plugged the booster battery connections, and on the right are two more sockets into which are plugged the wires leading to the contact breaker on the engine shaft. The advantage of mounting all the electrical equipment on one panel is that all assembly and testing may be done on the workshop bench. The unit slips into position on the underside of the fuselage, as shown in Fig. 90.

In Fig. 91 is shown the mounting of the 9 cc. " Dennymite " engine of the author's high-wing cabin monoplane illustrated in this book. In this case the engine is mounted on aluminium brackets bolted to a 3-ply bulkhead which slides into grooves formed on either side of the fuselage. The petrol tank is behind the crankcase, and the coil and condenser are slung between the aluminium brackets. The battery is mounted in the centre of the fuselage, and the time switch and

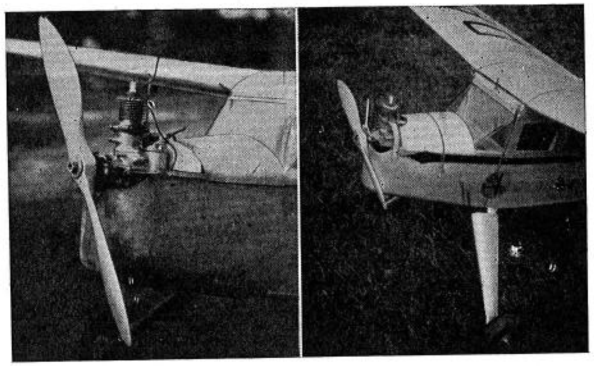


FIG. 91.

connections for the booster battery are towards the tail. The wiring is so arranged that by disconnecting two wires behind the engine bulkhead the complete unit may be slid out of the fuselage. This particular aircraft was designed for "heavy" flying, and the front of the fuselage is panelled with $\frac{1}{32}$-inch 3-ply, and reinforced with a block of balsa at the bottom front centre part. As will be seen from the right-hand photograph in Fig. 91 a shaped wooden cowling is fixed over the fuselage from the windscreen close up to behind the cylinder, pretty well closing in the lower part of the engine. Some idea of the strength of this type of construction may be gained from an examination of the three photographs in Fig. 92. None of these have been in any way retouched. They show the engine and front of the fuselage exactly as the machine was lifted off Fairey's Aerodrome in the summer of 1939, when the machine made a power nose-dive from over 100 feet! (The

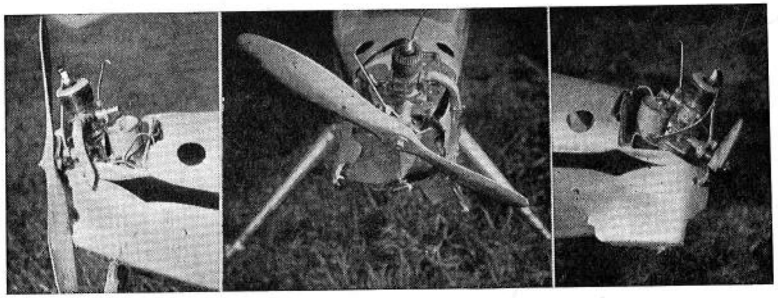


FIG. 92.

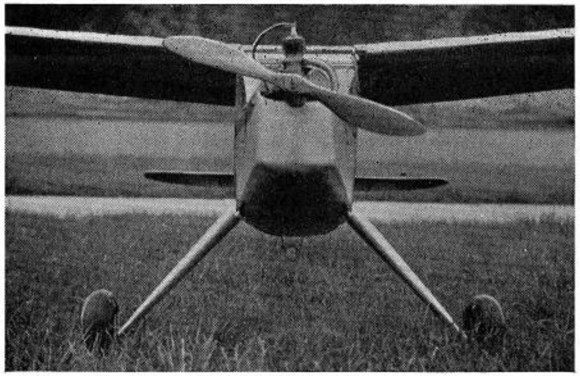


FIG. 93.

cause of this was that the machine had been sent up on a very windy day, and in a previous flight one of the rods supporting the wings had been cracked but not noticed. Consequently, when the machine was well up, the wings gradually "folded up," and the machine went into a vertical dive!) In the middle photograph it will be observed that the lower part of the fuselage has been knocked in and the lower blade of the airscrew has been cracked, but not broken off. The engine was completely undamaged, and repair work consisted of dismantling the engine assembly, straightening out the aluminium brackets, and mounting the unit on a new 3-ply bulkhead. As for the front of the fuselage, the portions were gently eased back into position. A sheet of $\frac{1}{32}$-inch 3-ply was curved and placed round the inside of the nose, and after a liberal application of glue a piece of silk was applied to the outside. The repair took just over two hours to complete, and the nose was rebuilt as new, as shown in the photograph, Fig. 93. Incidentally, the circular holes which may be seen on the photographs, behind the engine, are those through which a wire hook is inserted to attach the rubber bands used as shock absorbers for the cantilever legs, as illustrated in Fig. 77, page 144. This portion of the fuselage is covered normally by the cowling shown in the right-hand photograph in Fig. 91, being held in position by a rubber band stretched over the top and looped round the $\frac{3}{16}$-inch diameter dowel rod which passes from one side of the fuselage to the other, from which the shock absorber rudder bands are looped.

The electrical system in model aircraft, and in particular

methods of wiring same, often leave much to be desired. Many aero-modellers, whilst possessed of excellent skill in the design and construction of their models, seem to think that "any old piece of wire," twisted to "any old clip or bolt," will do! On many occasions has the author seen a good performance marred by an engine misfiring, due to faulty connections in the electrical circuit. All connections in the wiring of model aircraft should be made as strongly and as carefully as possible. Soldering alone is not always sufficient, and where possible the ends of wires should be formed into loops and threaded to a bolt and locked into position with a nut, the end being soldered in position. The high tension lead in particular should be of irreproachable quality; it should be as short as possible, which is an argument in fovour of mounting the coil as near to the engine as possible. The lead should on no account come in contact with any metal part, and if it is necessary to pass through a hole in the metal engine mounting this hole should be bushed with a short length of rubber tube. Many are the devices adopted for making connections to the

FIG. 94.

popular $4\frac{1}{2}$-volt pocket flash-lamp type of batteries, which are used in model aircraft. The type of connection which consists of contacts against which the tongues projecting from the battery are pressed, is definitely condemned by the author. The contacts have an awkward way of loosing their "springyness" or tension at the wrong moment! The practice adopted by the author for the past two or three years is to twist the ends of the contacts into circular shape, as if being wound up like a clock spring. The two wires that are to be connected

Fig. 95.

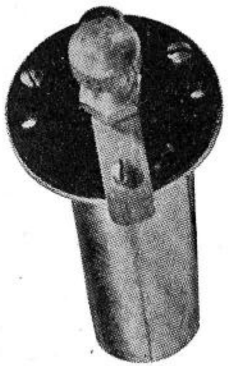


Fig. 96.

are joined to "crocodile" clips, which may be purchased for about 3d. or 4d. per pair from wireless accessory shops. These clips are so named because the operative portions are shaped like the jaws of a crocodile, and are held in the closed position by quite a powerful little spring. In connecting to the torch battery one jaw is passed through the circular hole formed by looping the tongue, and the other jaw passes outside the loop. A sure and positive contact is thereby made, and will never part from the battery, however rough the landing. A crocodile clip is also used by the author at the end of the high tension lead where it is connected to the sparking plug.

Coils should be of the best obtainable, and weigh anything from 2—4 ounces. Any engine up to 6 or 9 cc., if in good trim, should be capable of being started up from a $4\frac{1}{2}$-volt pocket flash-lamp battery. Heavier coils weighing from 10—14 ounces may be operated also from this type of battery, but will require replacement after some 15—20 minutes use!

However, a really "hot" spark may be obtained from these heavier coils, and if the additional weight can be carried on the 'plane, it is better practice to use a large heavy coil with one battery rather than a light coil with two or more

batteries in parallel. Most proprietary engines are supplied complete with a suitable coil and condenser, and it is most important that the combination of condenser and coil, as supplied, should be maintained. Condensers are "matched" to the coils with which they are sold, and if at any time a replacement condenser is required, care should be taken to see that it is of similar capacity, if not of similar make, as that originally supplied with the engine, as an unsuitable condenser can completely spoil the proper functioning of a good coil.

Up till a short while ago, time-switches were usually made from adapted clocks, or clockwork motors, as used in small toys. Recently time switches specially designed for use in model aircraft have been put on the market, and it is strongly recommended that these should always be used in preference to the "home-made" variety. All sensible aero-modellers will realize that if there is one part of their 'planes which must be 100 per cent efficient and foolproof in operation, it is the *time switch*. Many a time anxiety has been caused by a 'plane flying away until the petrol in the tank was used up, due to the time switch not having operated at the correct moment;

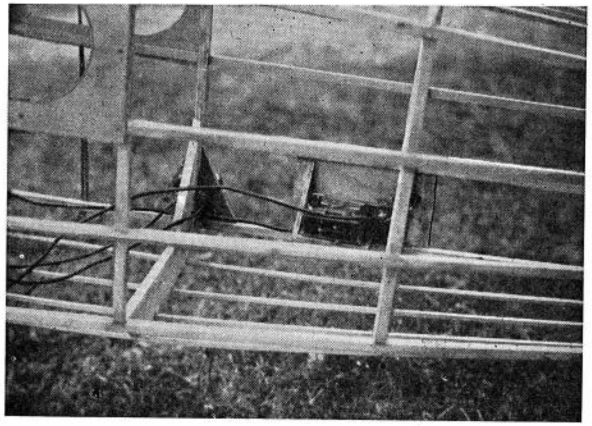


Fig. 97.

and apart from the loss which may result if the 'plane cannot be found, of far greater importance is the damage to person or property which may be occasioned by the 'plane flying beyond the confines of a safe flying ground.

One type of clockwork-driven time-switch which has given excellent results may be seen on one of the author's 'planes in

Fig. 97. Another type, which consists of a small cylinder from which air is expelled by a powerful spring—the rate of expulsion being controlled by a sensitive valve—is shown in Fig. 96.

Miniature sparking plugs have been produced by well-known plug manufacturers, and if reasonable care is taken 100 per cent good results should be obtained from them.

In Fig. 99 are shown photographs of two sizes of plugs, the photographs being actual size. There is also a type of plug manufactured which is detachable for cleaning. It is, of course, essential that the points of miniature sparking plugs

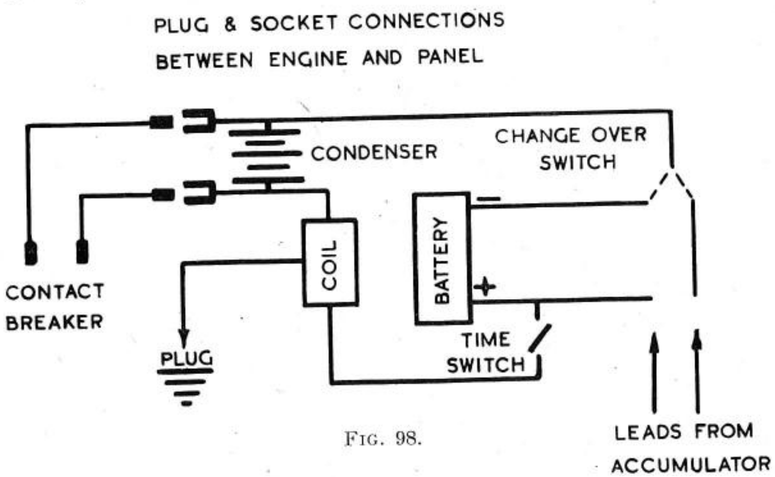


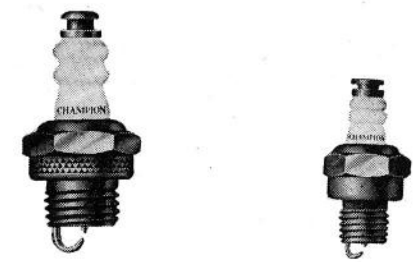
FIG. 98.

should be kept clean, and the porcelain surround of the central electrode should always be kept free of carbon. Difficulty is sometimes experienced in cleaning the narrow annular space between the central electrode and the bore of the screwed portion of the plug, and this is best achieved by careful scraping with a long, thin knife blade. Good cleaning can also be carried out by using a small portion of a stiff wire brush, as used for the cleaning of files or the teaselling of wool.

Contact breakers, as supplied on proprietary engines, are of good quality, and should give no trouble.

Contact breakers, as supplied by well-known manufacturers, may be relied upon to stand up to their work, but if the aero-modellist has built his own engine, or perhaps obtained one of a non-proprietary brand, he is advised to

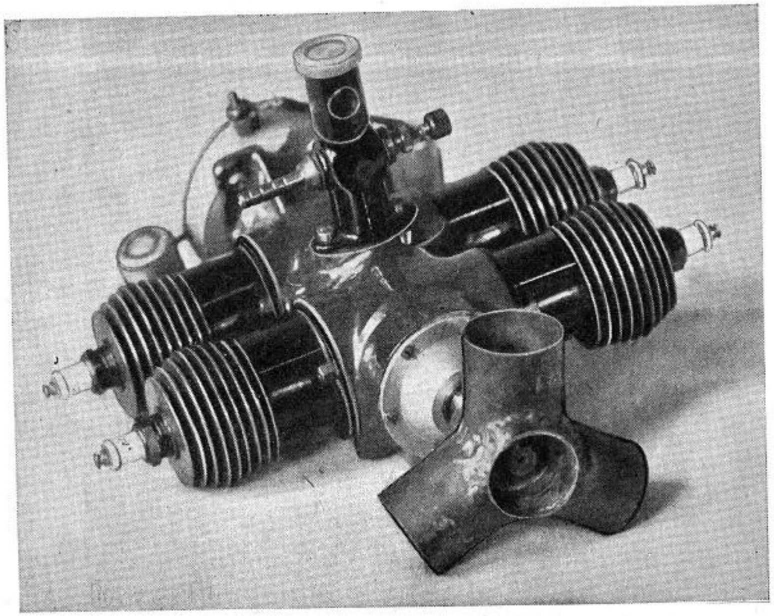
consider using a proper motor-cycle type of contact breaker, in preference to building one himself from " bits and pieces." It must not be overlooked that when a two-stroke engine is running at 4,000 r.p.m., the contact breaker (*and* plug, of course) have to operate 66 times per second—thus it is essential that the " make and break " shall function correctly. As this is best achieved by a properly designed spring which has been tested by the manufacturers to operate up to speeds as high as 10,000 r.p.m., it is preferable to equip the engine with a contact breaker of this type rather than experiment with pieces of clock spring, etc.



These two photographs are actual size.
FIG. 99.

It is most important to see that the surfaces of the contact points truly meet over their full area. If this is not the case, and the two discs are only touching at one point, sparking and pitting will soon occur. Particularly for high-revving engines the spring pressure should be quite strong. The author has on a number of occasions speeded up engines shown to him, about which the complaint was made that they were not giving their usual high revolutions, by placing his finger on the spring make-and-break and applying a small amount of pressure. A remedy which can easily be carried out on the field if the spring should become distorted is to put a couple of turns of rubber round the unit.

In Fig. 98 is shown the correct electrical circuit which should be used on petrol 'planes. A simplification is to cut out the change-over switch shown at the right-hand top corner, and plug the accumulator leads directly in parallel with the leads coming from the battery. Prior to releasing the aircraft



The above photograph shows the "Condor" four-cylinder engine to be used in the author's 1-5th full-size scale model of the Westland "Lysander." The bore is 1-inch, and the stroke ¾-inch, which gives a cubic capacity of the four cylinders of just under 40 cc. The rating is 1·6 h.p. at 7,500 r.p.m., but preliminary calculations have shown that a speed of 4,500—5,000 r.p.m. should give sufficient power to fly the model. The crankcase is of cast iron, and carries three large ball races supporting the crankshaft. As the engine is a two-stroke, opposite pairs of cylinders fire together. At the rear of the engine is a case in which is contained the contact-breakers, there being two units, each with its own coil and condenser.

they have to be detached, but great care must be taken that they are so connected that it is impossible to plug the positive of the accumulaator to the negative of the battery, otherwise the coil will soon melt!

CHAPTER XVI

ENGINE TESTING AND TUNING

Engine testing and tuning—Test benches and revolution counters—Running in of engines—Tuning—Power-weight ratios.

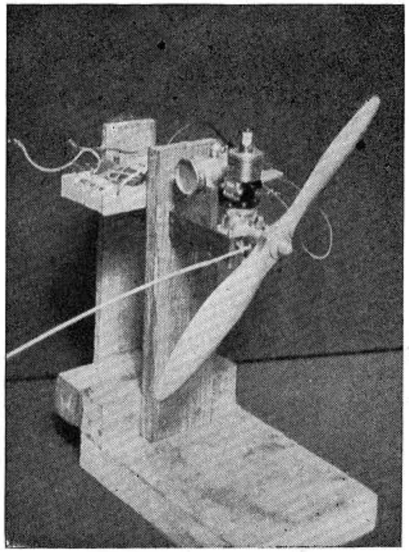
ENGINE testing and tuning is one of the most interesting features of model aircraft work—one to which a great deal of time may be devoted, and one from which some very useful results may be obtained.

A "test-bench" on which the engine may be mounted can quite easily and quickly be constructed from material to be found in any workshop; and with the aid of a revolution counter the aero-modeller may tune up his engine to its best efficiency.

Fig. 99 shows a typical test bench, of the type which can

FIG. 99.

The engine shown in this photograph is a 6 cc. "Baby Cyclone," and the test bench on which it is erected was designed and built by Mr. Ross.



be constructed quite easily from a few pieces of hardwood, and screwed down in any convenient position. Alternatively, the engine may be mounted on bearer brackets, or a test-frame can be gripped in a stout vice, as shown in Fig. 100.

For serious bench testing on miniature petrol engines it is essential that a revolution counter should be available.

The most useful type of revolution-counter is that which incorporates a clock mechanism, and gives direct readings of the exact number of revolutions made in the period during which the clock is working—a period under the control of the operator. Such a speed indicator, however, costs about £3.

Quite accurate results may be obtained by two operators, one controlling a stop-watch, and the other operating a "counter" of the type which counts up to 10,000. These counters may be purchased for as little as 10s., and whilst not *supposed* to be operated at speeds above 1,000 r.p.m., will

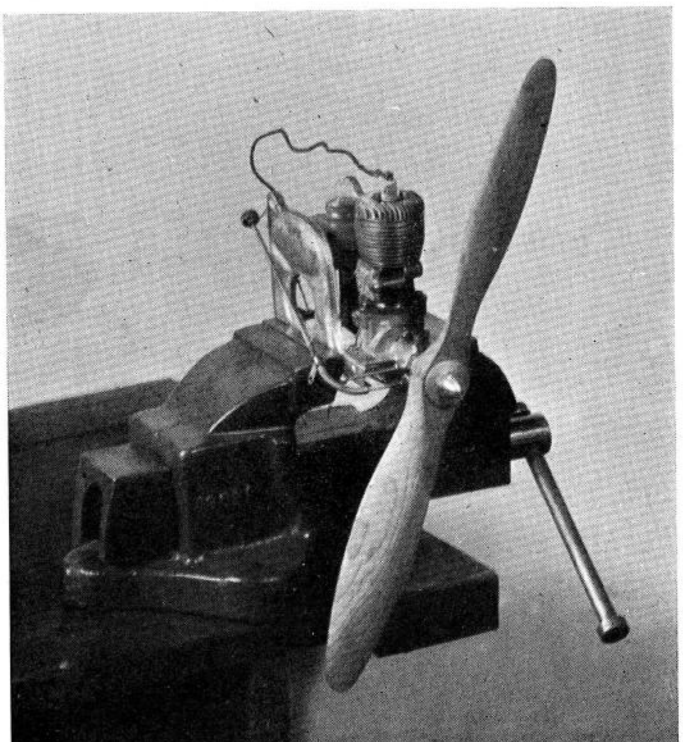


FIG. 100.

Here is shown one of the latest "Baby Cyclone" engines, on the pressed steel mount-cum-petrol-tank, designed and supplied by the makers of the engine.

stand up to speeds as high as 4,000 r.p.m., provided they are not held to these high speeds for more than 15—20 seconds at a time.

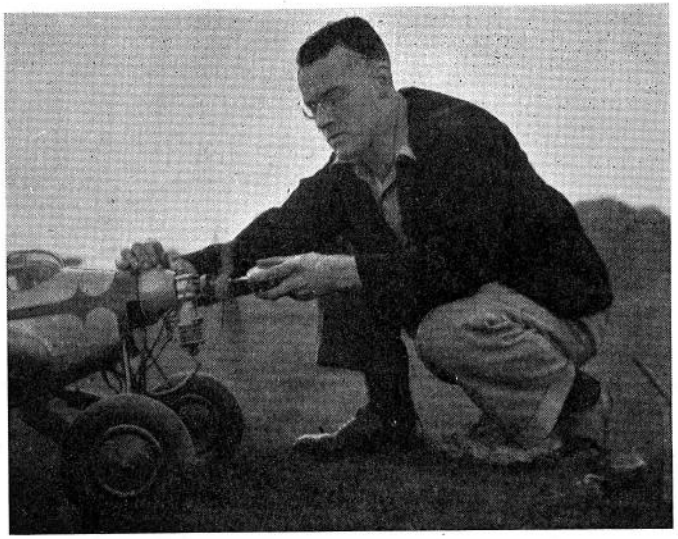


FIG. 101.

The Author practising what he preaches!—checking the r.p.m. of the engine on the flying field, preparatory to sending the the 'plane off on a test flight.

It is surprising the amount of internal friction which may be developed in a new engine—not "run in"—and as a suitable "running-in" bench may be easily made, it is recommended that this process should always be carried out before running an engine under load.

If a suitable electric motor is not available in the workshop, the domestic vacuum cleaner, or sewing-machine motor may perhaps be borrowed and quickly coupled up with a short length of rubber hose slipped over the ends of the engine and motor shafts.

Fig. 102 shows one of the author's "Comet" engines being run in—the simple mounting and flexible drive may be noted.

The process of "running in" may be described as of two kinds, the lapping together of newly-paired surfaces, and the polishing of surfaces which have already been lapped.

If the engine is absolutely brand new, the piston ring (or rings) must be lapped to the cylinder bore. This is carried out by driving the engine at some hundreds of r.p.m., lubricated with a mixture of the correct engine oil and metal polish, mixed in equal portions. If an old piston is available to which the rings may be fitted, so much the better, and the lapping should be continued until they are seen to be " bedding " over their *full width and circumference.*

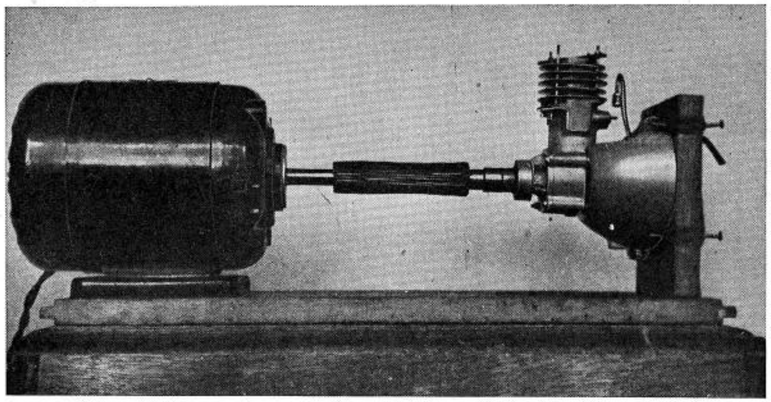


FIG. 102.

The engine shown in this photo is an 18 cc. " Comet." It is mounted on the special streamlined " cone " supplied by the makers of the engine. The flexible coupling between the motor and engine shafts is a short length of garden hose pipe.

After lapping in of the rings the engine should be thoroughly cleaned and again run with lubricating oil only. After some two or three hours' running, it should be completely dismantled and the piston and other bearing surfaces examined for "high spots," these being very carefully removed by scraping.

Scrupulous cleanliness and attention to detail work are, of course, of primary importance with the small petrol engines used in model aircraft, and after any parts have been dismantled and attended to in any way, they should always be thoroughly washed in petrol before being reassembled.

Particularly with two-strokes, complete " gas-tightness " *must* be obtained; and all " mating " surfaces, such as crankcases and covers, cylinder-heads and barrels, should have

metal-to-metal joints, made by lightly grinding the surfaces together with the finest grinding paste obtainable.

Leakage of air past the crankshaft bearing is a " fault " which may develop in an engine with plain journal bearings, as these become worn, or even in a new engine if ball bearings are fitted; and special attention should be paid to see that as effective a seal is made at these parts as possible.

Ball-bearings may be packed with a "high melting-point" *grease* which will effectively prevent the passage of air, and plain journal bearings may be quite well sealed by placing a fibre washer which is a fairly tight fit on the crankshaft—between the end of the crankcase cover and the back of the cam. This washer *must* be made an exact fit in the gap between these two surfaces, and, being a tight fit on the crankshaft, will revolve with it, lightly rubbing against the face of the crankcase.

If this fibre washer is kept " wet " with engine oil it will be found that a very nearly 100 per cent airtight seal is effected.

The desirability of smoothing and polishing all gas passages is, of course, well known, and provided this is done, the engine made really gas tight and internal friction reduced to a minimum by careful " running-in," a powerful and reliable performance will result.

The starting up of miniature petrol engines is one which often gives the newcomer to them considerable trouble. Certainly, any previous experience with motor-cycles or other types of combustion engines is of little use, and the aero-modeller is wise who will forget all he has learned about full-size petrol engines, and approach the subject with an open mind. It is well that there should be a consideration of the following points, which arise from the fact that the best combustion is obtained when there is a ratio of approximately 14 parts of air to one of petrol when measured by *weight.*

(*a*). 1 cubic foot of petrol weighs about 47 pounds.

(*b*). 1 cubic foot of air weighs ·076 pounds.

This means that 1 cubic foot of petrol weighs approximately 640 times 1 cubic foot of air. Since the best air to petrol ratio is that of 14—1, it follows that there should be approximately 8,700 times the *volume* of air to the *volume* of liquid petrol to give the best combustion.

Now, assuming that the inspiration efficiency of a 10 cc. 2-stroke petrol engine, running at 5,000 r.p.m., is 100 per cent, the engine would inspire approximately $1\frac{3}{4}$ cubic feet of air per minute. A 1-8,700 part of this volume equals 6·1 cc., and this is the volume of liquid petrol which the engine will use per minute. A 1-5,000 part of this 6·1 cc. of liquid petrol equals $\frac{1}{4}$ of 1-1,000 of a cubic inch per stroke—about the size of a pin's point!

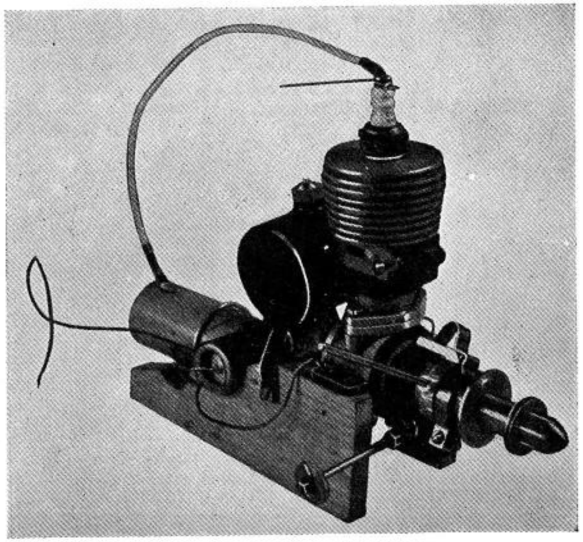
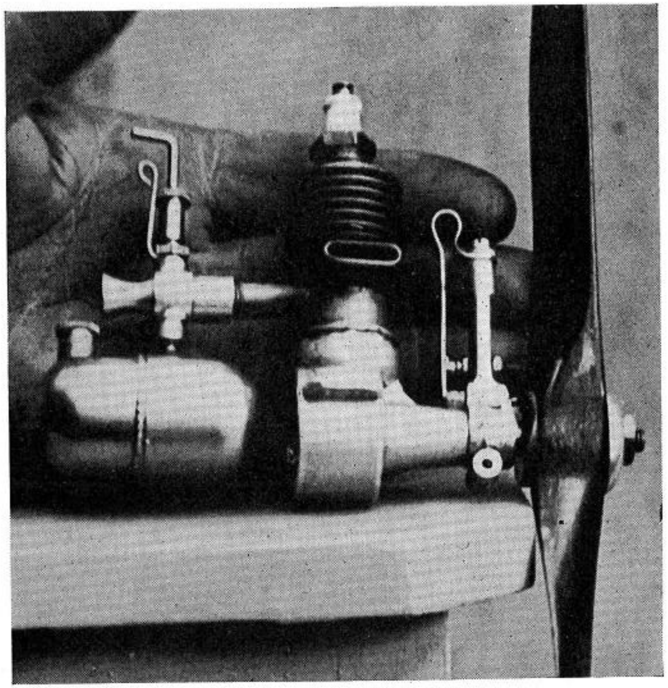


FIG. 103.

In this photo is shown the 2·5 cc. "Spitfire." Of British manufacture, this engine is of robust yet light construction. The ignition control is variable, and induction is via a rotary valve and hollow crankshaft.

If the reader can bring himself to understand what this minute quantity of liquid represents, he will get a better understanding of the difficulties which are involved in tuning the carburetters of small petrol engines. On a number of occasions the author has seen an aero-modeller flood the carburetter of his engine, and then attempt to start up with petrol dripping from it! Now this is quite useless. Petrol is a liquid, and everybody knows that it is inflammable. But petrol to be ignited in a cylinder of a petrol engine must be in *gaseous* form, and, as pointed out above, the most efficient ignition is obtained when the ratio of air to petrol is about 14 to 1 by weight, or nearly 9,000 to 1 by volume. If petrol is drippping from a carburetter

intake of perhaps only a quarter of an inch bore, it will be realised that it is quite impossible for 9,000 times this volume of air to be drawn through the intake, or for the petrol to become vapourised. The result of this is that the mixture is far too rich, and the engine will not start. Another way of appreciating this important point is to consider what is happening at the place where the needle valve seats. As the throttle valve is unscrewed, and the tapered part of the needle is moved away from its seating, there is provided a steadily increasing annular space around the needle, up which the petrol passes. A simple calculation in the above case would



Several engines of Italian manufacture have recently become available. Here is a 3 cc. "Giglio."

show that the 6·1 cc. of liquid petrol, when considered as a thin column passing into the engine during one minute's running, would be like a very fine wire, so small in diameter that a tube of only a few thousandths of an inch bore would (in theory) pass the required amount of liquid. However, due to what is known as capillary attraction, the liquid would have to be forced up a tube of such a small bore as this. Consequently, a tube of at least $\frac{1}{16}$-inch bore is necessary, but this will pass far more petrol than is required.

From the foregoing it will be seen that the annular space round the throttle valve will actually be larger than is really required, even when the throttle needle is unscrewed perhaps only two turns. It is for this reason that needle points are given such a fine taper, so as to make their control as sensitive as possible. It is for this reason, also, that the author is in favour of running an engine with as strong a mixture of oil to petrol as the engine will take without the sparking plug oiling

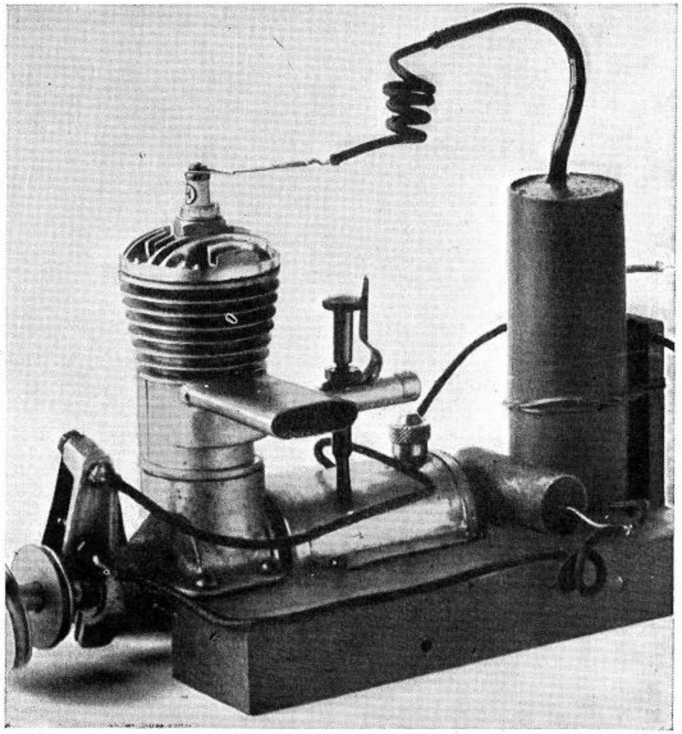


FIG. 104.

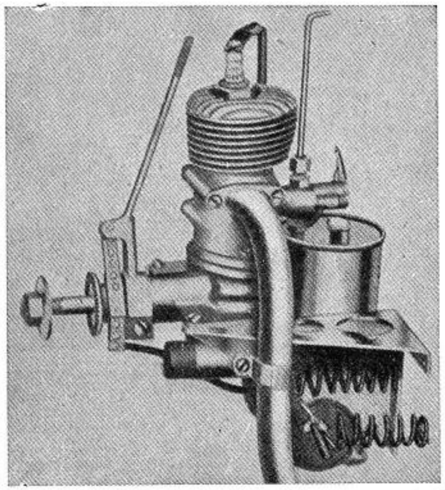
Here is the 7·5 cc. "Gwyn Aero," a powerful engine which may be run either upright or inverted. Induction is via crankcase and transfer port, and the ignition control is variable.

up. After all, the cost of oil used in a miniature engine is negligible! Oil, of course, is considerably more viscous than petrol, and by using a mixture of about 1 part oil to 3 of petrol there is a larger and bulkier mixture passing through the throttle valve than if the mixture was reduced to a ratio of only 1 part of oil to 5 of petrol. Proof of this argument may easily be obtained by tuning an engine on a 3 to 1 mixture and then changing over to the 5 to 1 mixture. It will at once be found that in the latter case the engine is a good deal more "sensitive," and a slight variation in the position of the throttle control will have a considerably greater effect on engine speed than in the case where a 3 to 1 mixture is used.

Now obviously different makes of engines will have their own particular characteristics, but the following general instructions for starting up a miniature petrol engine may be taken

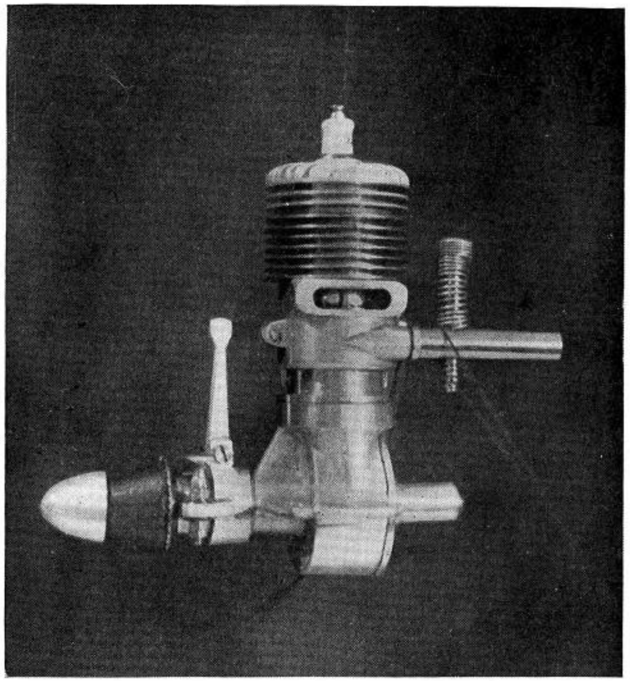
FIG. 105.

This photograph is of the 9 cc. "Dennymite" de-luxe unit. A long lever is fitted to the variable ignition control, and a long pipe leads the exhaust clear of the fuselage. The coil and condenser are mounted between the aluminium engine bearer brackets.



as applying throughout the general range of petrol engines at present in use in model aircraft.

Usually, the throttle position for full speed is somewhere between one-and-a-half and three turns of the throttle needle for engine sizes ranging from 2·5 cc. to 18 cc., and it is best to set the throttle between these positions, according to engine size. To start, one finger should be placed over the air intake (or, of course, if there is a slide fitted, as is on the "Dennymite," it should be closed), and the propeller given three or four sharp " flips " with the other hand. Not more than four should be given. The reason for the first operation should be clearly understood. No matter if the petrol feed is by gravity, the fuel may still not flow naturally through a small bore pipe. If it is by suction, it must be sucked up into the carburetter, for a start. Therefore, the air intake is completely closed, so that the



Quite a number of aero-modellists design and build up their own engines. Here is a quite " professional-looking " 9 cc. two-stroke built by Mr. J. Forster, of Bromley.

full power of the suction caused by the engine being revolved is devoted to inducing petrol into the carburetter intake. Next, and immediately the first operation has taken place, the finger is removed from the air intake and the throttle valve completely closed. Following this, the third operation takes place, and consists of starting the engine. During the second operation the hand not used in starting should be gripping the throttle control ready to open it the moment the engine starts.

From the foregoing it will be seen that the engine is started

up with the throttle valve *completely closed;* that is the secret of successful starting, and where so many newcomers to miniature petrol engines make their mistake. If any attempt is made to start the engine with the throttle valve open, once the intake has been flooded with petrol the liquid will continue to flow at a faster rate than is used at the nominal few revolutions at which the engine is being turned when flicked over by hand. So the inevitable too-rich mixture is produced. With the throttle valve closed, and the air intake unobstructed, only air can enter the engine, and so in the course of two or three revolutions by hand-flicking, the correct ratio of petrol vapour to air is arrived at, and the engine starts. Immediately on this taking place, the throttle is opened about one turn, and a few seconds afterwards it may be opened as far as is necessary to allow of the engine to give its full r.p.m.

Recapitulating, the process of starting a miniature petrol engine can be divided into three separate phases. Assuming the reader is right-handed the operations are as follow:—

(1) The left hand having opened the throttle one to two turns, and the air intake having been closed by a finger or the slide valve, the propeller is given three or four sharp flicks with the right hand.

(2) The air intake is uncovered and the throttle closed by the left hand. This remains holding the throttle control, whilst the engine is flicked with the right hand until it starts.

(3) Immediately on starting the throttle is opened by the left hand, and the engine run up to speed.

The three operations are carried out consecutively, and (for the purpose of this set of instructions, it being assumed that the electrical gear is all in order, and a good spark is arriving at the point of the plug), should not take more than half-a-minute.

The Author about to launch his large low-wing 'plane from a moving car. Photo (taken from another car travelling alongside) was obtained by Mr. A. King, at Digby Aerodrome, 1939.

CHAPTER XVII

FLYING PETROL MODELS

A NUMBER of people seem to think that following the design and construction of a petrol 'plane comes the *flying* of it, but this is not so—there is an intermediary stage—testing and trimming the model for glide. Theoretically, it should be possible for a machine to be flown " off the board " after it has been trimmed so that the centre of gravity coincides with the centre of lift of the main wings. In full size practice of course, the weight of every part is " taken out," and the centre of gravity of the completed machine will invariably come quite close to where it was meant to be. In model practice this should follow also, but there may be differences according to the class and grade of wood and glue used. One modeller might use more nails, binding wire, or glue, in the construction of the tail unit than another modeller; and naturally at a point so far distant from the centre of gravity a little difference in weight would make quite a difference in the balance of the 'plane. It is, therefore, good practice to leave the location of the battery to the very last; it is a handy unit of weight, and it can be lashed to a little platform by rubber bands, so that it can be moved backwards and forwards to give trim to the model when it is completed. In Fig. 78, page 145, which shows a view looking down into the cabin of the author's high-wing 1939 model, may be seen on the right a platform across which are stretched two or three rubber bands; these hold the battery in position. When the machine is ready for balancing, it should be suspended from a point exactly over the centre of lift, on a line passing through the airscrew centre to the centre-line of the fin. The model must then be trimmed by movement of the battery, so that the thrust line is exactly horizontal. (No down thrust used).

(Whilst the author does not wish to appear to be dogmatising, he submits that *down thrust* on a petrol 'plane is definitely bad practice. It is used on rubber-driven model aircraft to counteract the excessive thrust developed during the first few seconds run of a powerful rubber motor. Nevertheless, down-thrust means wasted power, and it should not be resorted to in petrol 'planes. The thrust line is therefore defined as being parallel to the datum line of the fuselage.)

When the correct trim has been found, suitable blocks of wood should be arranged to hold the battery so that it can always be located in the same position. Next comes the question of trimming for lateral balance. The model should be supported at the airscrew boss, and at a point located at the fin in line with the trailing edge of the stabiliser. It should hang in that position, due to the centre of gravity of the whole model being below these two points of support. Normally, for machines up to about 4 or 5 ft. span trimming should be so effected that the 'plane hangs level. It may be that one wing is slightly heavier than the other, in which case the battery must be shifted sideways across the fuselage to obtain the correct balance.

With this effected, and the fin set in dead straight ahead position, the main wing at the correct angle of incidence, and the stabiliser arranged according as to whether it is to be "lifting" or "non-lifting," the 'plane is ready for its first gliding trials.

According to the size and wing loading of the model so must this procedure vary. Apart from its overall size, the

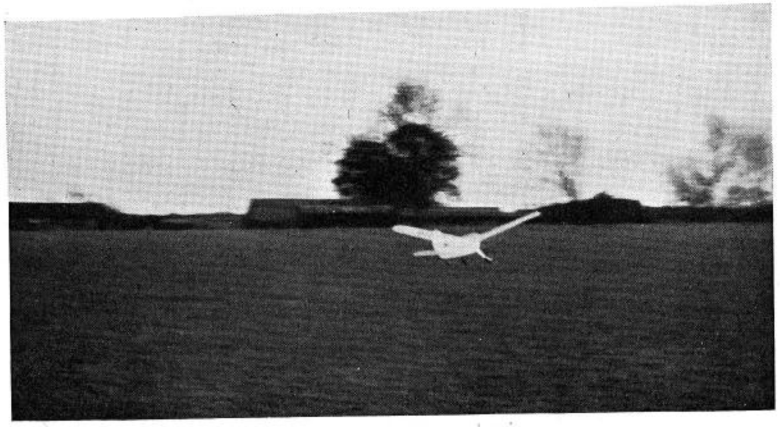


Fig. 106

The shoulder-wing 'plane illustrated on pages 40 and 41 just after taking off.

Fig. 107.

The correct way to carry a petrol 'plane. (May also be used as a protection from rain or sunshine!)

lighter the wing loading the slower the 'plane will fly, and the minimum flying speed will therefore determine the gliding procedure. If the wing loading is only about 8 to 10 ounces per square foot, the 'plane may be launched forward with the launcher stationary, and he can then run forward and often catch the 'plane before it has reached the ground. If the wing loading is over 12—14 ounces the aero-modeller will have to run before launching the machine forward. If the wing loading exceeds 1 pound per square foot the minimum flying speed will exceed that at which a man can run (for any distance!), and therefore the only thing that can be done is to "ground-hop" the model under control. Taking the case of the lighter machines first, they may be hand-launched into the wind with the nose slightly downwards. If there are no warps in the wings and the various units have been correctly mounted, very little adjustment should be required to ensure that the model will glide forward in a straight line. Care should be taken to see that the machine lands level, i.e. that both wheels touch the ground at the same moment, and that their tracking is correct, so that the machine continues to run straight forward.

If it is found that there is any tendency to turn in a circle

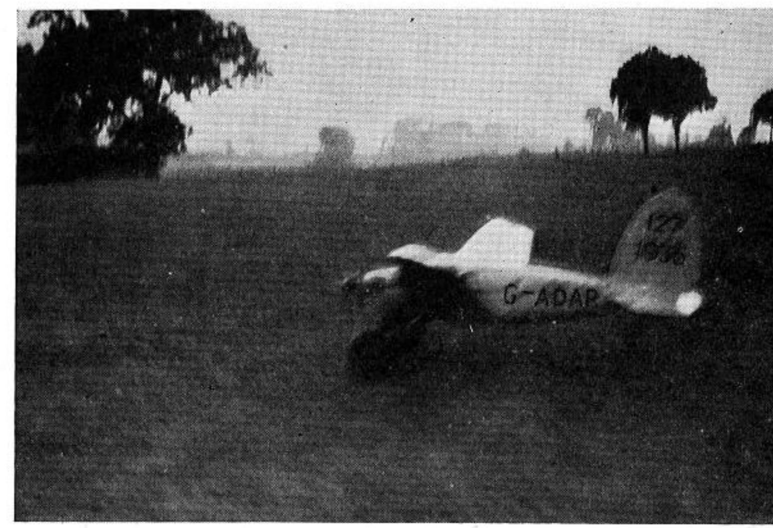
Mr. J. C. Smith, Hon. Competition Secretary of the S.M.A.E., test flying a small petrol 'plane at the end of a short length of string.

this will be found to be due to a warp in one or other of the wings, fin, or stabiliser planes. If there is a warp it can be easily and effectively removed by holding the affected portion close to a fire for about half-a-minute; the unit should then be twisted by the two hands in a direction opposite to the warp by about the same amount as the original twist. This movement should take several seconds, and should be gradually but deliberately done, still in front of the fire. Finally, whilst the reverse warp is held, the unit should be carried away from the fire, and the arms lifted up and down to cool the unit as quickly as possible by waving it through the cool air. With little practice it will be found that quite bad warps (these, of course, are not encouraged!) can be permanently removed.

Returning to the first trimming glides: In addition to checking that the machine travels on an even keel, care must be taken to see that it descends at a constant speed. If the glide is too steep it is possible that the wing has not sufficient incidence, or that it is a little too far back—so far as *balance* at the moment is concerned. In the latter case it would be

best to move the wing slightly forward, but if it is arranged in a fixed position, as on a scale model, then the battery must be moved farther to the rear of the fuselage. Packing up the leading edge of the stabiliser will naturally lift the tail and keep the nose down, whilst packing up the trailing edge will cause the nose to rise.

It follows from the foregoing that there are really two methods of trimming a petrol 'plane in regard to longitudinal stability. Firstly, the stabiliser can be set in the "non-lifting" position, i.e. with its fore and aft axis normal to the thrust line, and with the main wing in a fixed position, the whole of the trim being adjusted by the backward or forward movement of the battery, and up or down movement of the wing for variation in incidence. The second method is where



The 10 feet span low-wing monoplane illustrated on page 36 travelling at 20 m.p.h.—tail up, and just about to take-off. Photo taken from car travelling alongside the 'plane.

the stabiliser is expected to contribute to the lift of the machine, in which case it is set at a positive angle of incidence. In this latter case, every adjustment of the stabiliser will have to be made in conjunction with a readjustment of the angle of incidence, and also a variation in the location of the main wing. With the stabiliser "non-lifting" trimming is somewhat easier, but if this unit is arranged for lifting it helps to get the tail up quickly off longish grass, which is a great help with the larger type of models.

When the gliding and trimming tests have been satisfactorily carried out short test flights may then be made, but it is most essential to see that wing and tail unit fixings are so

The trend of American design in medium size petrol 'planes is shown in this photograph of Gordon Lawson with his parasol-type model.

arranged that there is no doubt that they go back to their same settings each time the machine is assembled. An aero-modeller who has his 'plane correctly trimmed and adjusted and " knows " his model, can take it to a field, assemble it, and fly it straight off the ground. (In entering competitions it is the practice of the author to proceed on these lines. There is always the odd chance of a crack-up on a trial flight, or even someone else's 'plane flying into one's own! So the author's advice is: Test out the machine at least a day before

the competition, so that there is time (if only the night before!) to carry out any necessary repairs. Obviously, if the 'plane is to stand a chance in any serious competition, it must be in tip-top condition, and there is little point in tempting the fates within a few minutes of zero hour on the actual day).

So much for trimming the 'plane for *gliding*. This ensures a clear start to the model, and also that, as soon as the engine is cut off, the model should glide to earth in a straight line and at a constant angle. But *during power flight*, a different set of conditions obtains. There is the torque developed by the engine to be controlled. Now this may be explained as follows: There is an elementary law of mechanics that teaches that to every action there is an equal and opposite *re*action. The revolving airscrew presses against the air, and due to the reaction offered by the air the airscrew travels forward, taking the machine with it. Now, whilst the main power developed by the airscrew is directed to moving the 'plane

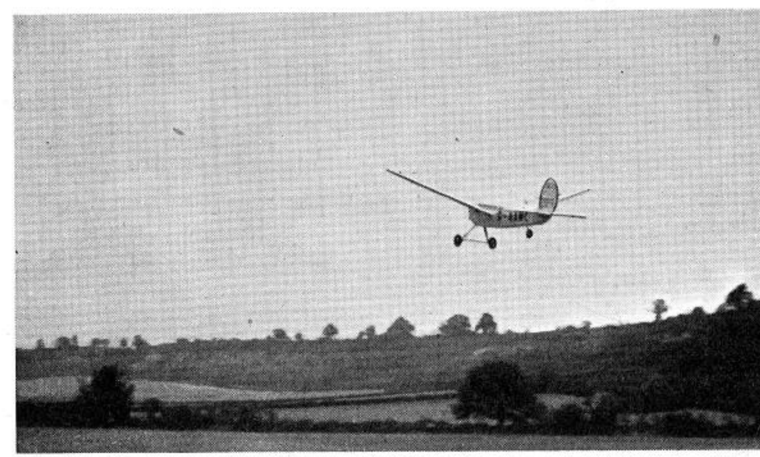


FIG. 109.

" Over the hills and far away " . . .

forward through the air, there is a small component whose reaction is exerted at right angles to the direction of travel, and this tends to rotate the 'plane about its longitudinal axis. All miniature petrol engines revolve in an anti-clockwise direction when viewed from the front. This reaction, therefore, causes the machine to tend to rotate in a clockwise direction, and this must be effectively counteracted, otherwise the machine will tend to travel with one wing lower down than the other—which can only lead to disaster! In further explaining this aspect of the trimming of petrol 'planes, the reader is asked to consider himself standing *behind* a 'plane and looking forward in the same direction in which it is flying. He is thus viewing the engine from behind, and it is revolving, therefore, in a clockwise direction—the airscrew torque reaction being equal and opposite tends to cause the machine to rotate in an *anti*-clockwise direction—thus, as the machine is viewed from behind the *left* wing tends to drop. If the machine were allowed to take off in this condition it would circle to the left and continue in steadily diminishing circles until it crashed in a tight spin!

To counteract the effect of this torque it is the usual practice to offset the engine a few degrees to one side of the centre line of the fuselage, i.e. in the case above described the engine would be twisted to the *right* so that the effect to the airscrew would be that it would be tending to cause the machine to travel "crab-wise," bearing to the right. When the correct adjustment is found, i.e. when this offset of the engine balances the torque, the machine travels forward in a straight line. In practice, this method is not 100 per cent correct, as 3 or 4 per cent of the effective power of the airscrew is lost. There is a further small disadvantage, that if the engine speed is varied, i.e. the plane is flown on different

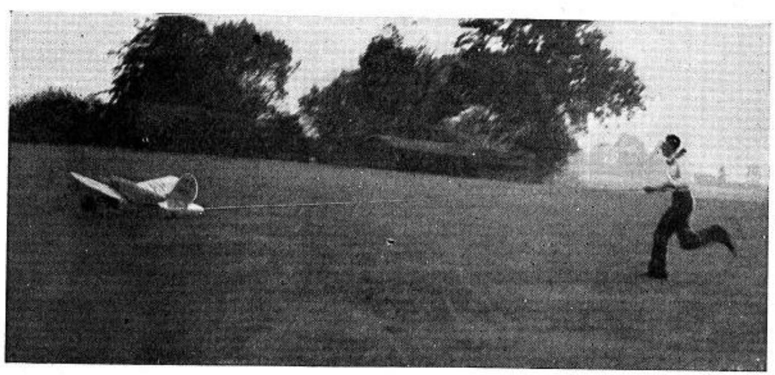


FIG. 110.

"Ground-hopping" a large 'plane by the method described in this chapter. (Photo by Author; violent exercise by friend!)

FIG. 111.

The Author's high-wing 'plane photographed after taking-off during a rainstorm at the 1939 Northern Rally.

throttle settings the amount of torque will vary. But in practice this latter disadvantage does not appear to be of any great consequence.

Another method of dealing with engine torque is to offset the fin. In the above example, the leading edge of the fin would be set over to the left of the centre line of the fuselage tending to make the machine circle to the right. This is not good practice because, as soon as the engine stops, and therefore the torque ceases, the offset of the fin will make the machine glide in a circle to the right.

An interesting model is that shown on page 16. This was built by Mr. Trevethick, and amongst several novel features is one by which the fin is hinged and connected by suitable link mechanism to the time switch. The engine is set facing straight forward with no side thrust, and its torque is counterbalanced by the fin being offset. However, when the time switch cuts out the engine it also trips a catch, which allows a spring to return the fin to its straight ahead position, thus maintaining the glide in a forward direction.

Generally speaking, about 3 or 4 degrees of engine offset is sufficient, but it is best to conduct experiments to find out the best position for each individual model. The correct setting can be found if the model can be tested on a perfectly level piece of ground. By setting the stabiliser at a considerable angle of positive incidence, and the main wings at *no*

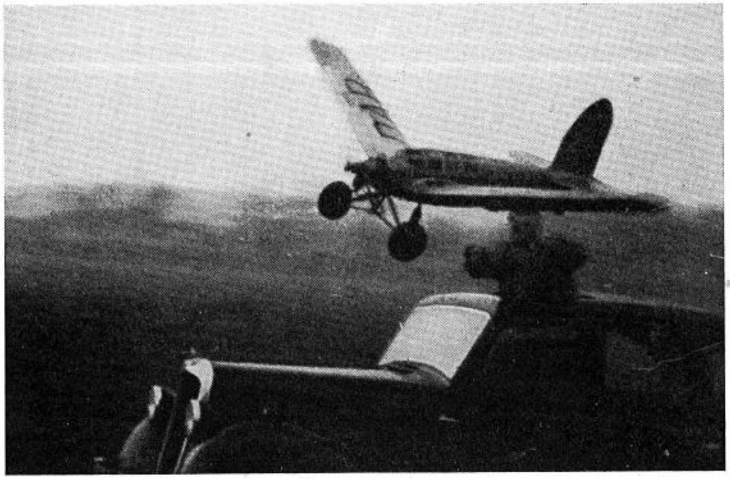


FIG. 112.

The Author launching his large low-wing monoplane from a moving car. Photo taken at a demonstration given at Lincoln in 1939.

angle of incidence, and allowing the 'plane to taxi, if the engine is started up, and the machine allowed to run along the ground, the tail will soon rise, but the machine will not, due to no lift being obtained from the main wings. Three or four such trips will soon enable the aero-modeller to find the correct position for the engine, so that the 'plane will taxi along the ground in a *straight line;* the time switch, of course, being set for a few seconds, so that there is no chance of the 'plane hitting the hedge on the far side of the field!

When circular flight is required a combination of adjustment of the engine position and of the fin may be used, but, of course, circular flight normally means circular gliding as well.

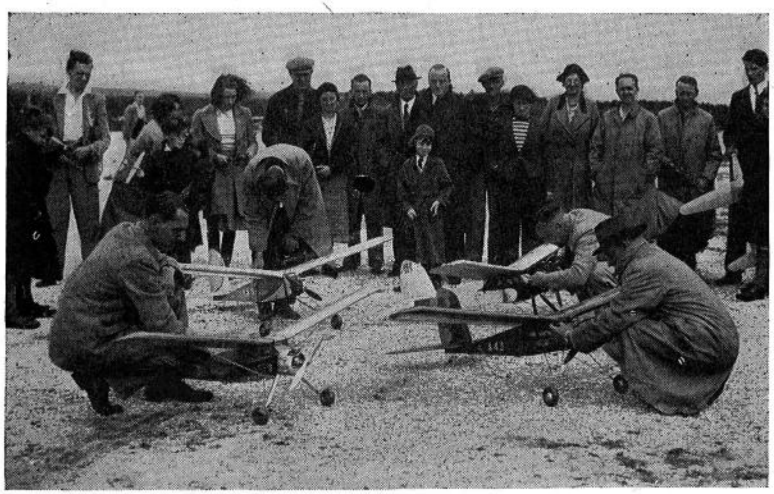
The test flying of large model aircraft is certainly a problem. Machines of 10 feet span and high-wing loading cannot be hand-launched—and anyway, most aero-modellers, certainly the author, are afraid to try it! The author's practice with large machines has been, therefore, to "ground-hop" them, the technique being as follows: A long length of string is tied to the tail end of the model, and is laid out on the ground behind it. The aero-modeller stands about 20 feet behind the 'plane, and holds the string lightly but firmly in one hand. The engine is started up and the machine released,

the aero-modeller running behind, and increases his speed with that of the model. When the speed of the model rises above that at which the aero-modeller can run, he allows the string to run through his fingers. By this means the machine can be kept under control until it leaves the ground. Perhaps its take-off speed will be 18 m.p.h.—if the aero-modeller can sprint at 14 m.p.h., then when that speed has been reached the string will run between his fingers at only a speed of 18 – 14 = 4 m.p.h. It will thus be seen that if a piece of string, about 200 feet long, is used, it is possible to keep some useful measure of control on the machine until it takes off, and in effect for time enough to see if the climb is going to be satisfactory. If things are not developing as they should, the aero-modeller increases his grip on the string, which in effect pulls the 'plane down. This, of course, is a tricky business, and it is not claimed that a machine may be pulled back to

A 10 ft. span petrol 'plane built by Mr. Hornsby.

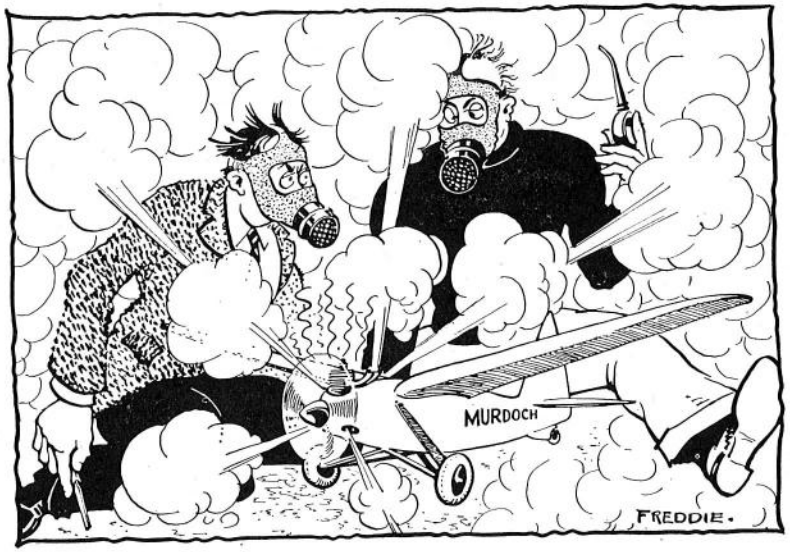
the ground entirely without damage; but that which *may* be sustained by pulling a 10 or 14 pound 'plane back to the ground from a few feet, will be much less than that which would *definitely* be sustained if a 'plane of that size gets away and then crashes!

Another method of testing out a large 'plane which the author has developed is that of the so-called " Mayo-launch." Here the aero-modeller stands up through the open roof of a car, whilst an assistant starts up the engine of the 'plane and then hands it up to him. The assistant then gets into the car and gradually accelerates it up to the take-off speed of the 'plane; this has been previously calculated, of course, and by the driver of the car carefully watching the car speedometer, it is possible to get to, and maintain, a speed when

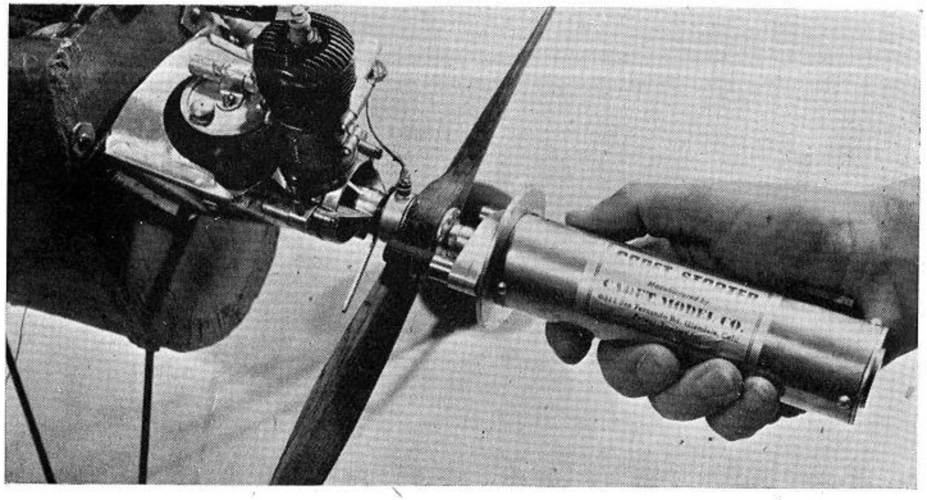


This photograph was taken at Haldon Aerodrome, and shows members of the Devonshire clubs tuning up the engines of their models.

the 'plane will just rise from the hands of the person supporting it. After several attempts it will be found that given a level road and a calm day, it is possible to travel along underneath the 'plane at just about its flying speed; by this means sufficient hold can be maintained on it to prevent it rising and flying away, and yet sufficient freedom be allowed to the aero-modeller to quite fairly judge whether the balance and trim is correct.



" You *are* right, it is a gas job."



Motor-car engines are not the only ones provided with self-starters! Here is a unit, containing a powerful spring, specially made for the starting up of miniature petrol engines, and introduced from America into Great Britain in 1939.

CHAPTER XVIII

HIGH SPEED PETROL 'PLANES

AT the present time, speed is often the "essence of the contract," and as, no doubt, there are aero-modellers who have contemplated the building of a high-speed petrol 'plane, the following investigation into the possibilities of obtaining a speed of 60 m.p.h. is offered. The author has *not* built a '*plane* that has attained this speed . . . he has not attempted to . . . but he *has* made some engine tests with a view to ascertaining if the necessary r.p.m. could be achieved.

The following calculations serve not only to show that a speed of 60 m.p.h. should be obtainable, but also as an example of how the various formulæ given in this book may be utilised.

No attempt has been made to "pre-select" the type of 'plane, or the initial conditions of performance, so as to obtain a "satisfactory" answer. The only data available being the fact that a 6 cc. engine is capable of developing a static thrust of approximately 3 pounds, which the author has ascertained from personally conducted tests; and the question to which an answer is sought, being: "Can a 6 cc. petrol engine fly a 'plane at 60 mp.h.?"

Steps in the investigation are as follows:—

(1) The horse-power required to maintain an aircraft in level flight may be calculated from the formula:—

$$H.P. = \frac{D.V.}{375}$$

when D = drag in pounds.
and V = speed in m.p.h.

Substituting in the above formula we get,

$$\tfrac{1}{5} = \frac{60\ D}{375}$$

$$\text{Therefore } D = \frac{375}{60 \times 5}$$

$$= 1{\cdot}25 \text{ pounds.}$$

$$= \text{maximum drag permissible.}$$

(2) We have a flying speed of 60 m.p.h. = approximately 90 feet per second; a maximum drag limit of 1·25 pounds, and a maximum thrust available of 3 pounds. Obviously, the machine cannot be too large; obviously, too, the airscrew must revolve at a fairly fast rate to give the necessary forward speed. Therefore, it cannot be too large, otherwise it will require more power to drive than is available.

Let us "work things out" for an airscrew of 10 inches dia. and a pitch of 9 inches, and see what result we obtain. To be on the safe side we will assume the efficiency of the airscrew will be $66\frac{2}{3}$ per cent, though actually it could be a trifle over 70 per cent under ideal conditions.

With a pitch of 9 inches and an efficiency of $66\frac{2}{3}$ per cent the actual forward travel per revolution would be 6 inches = ·5 foot. Therefore, to give a forward travel to the aircraft of 90 feet per second, the rate of revolutions must be 180 per second = 10,800 per minute—a pretty high figure.

However, we must keep to the rules, so let us proceed.

(3) The next calculation is to find the thrust that would be developed. Maybe it will be found that it will require more power than the engine can deliver!

Theoretically, the thrust which would be developed by an airscrew may be calculated from the formula:

$$T = 3{\cdot}142 \times r^2 \times p \times n \times {\cdot}076.$$

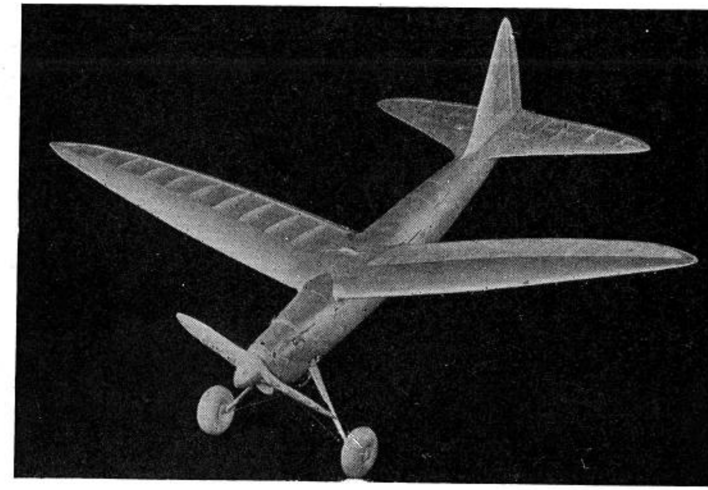
When r = radius of the airscrew in feet.
p = effective pitch in feet.
n = revolutions per second,
and ·076 = weight of one cubic foot of air, in pounds.

In other words, we calculate the volume, and thus the weight, of the column of air through which the airscrew will pass in one second.

Actually, due to "flexibility" of the air, the airscrew "slips," and does not travel forward, an amount equal to its pitch in one revolution, and as we have already allowed for an efficiency of only $66\frac{2}{3}$ per cent—by taking the *effective* pitch as 6 inches—we can calculate the thrust which will actually be developed, by taking p in the formula as 6 inches.

Thus we find the thrust:

$$= 3{\cdot}142 \times {\cdot}416^2 \times {\cdot}5 \text{ foot} \times 180 \times {\cdot}076$$



An ideal design for a high-speed petrol 'plane is shown in this photo of a well-known proprietary model. The span is 5 feet, and the engine is a 6 cc. "Baby Cyclone." The undercarriage legs are fully cantilever, and all wing fixings are internal, thus ensuring the lowest possible drag.

Thus thrust = 3·73 pounds.

Now this is too much, as the engine will only deliver 3 pounds thrust. However, we can rearrange the formula to give us the diameter our 9-inch pitch airscrew must be reduced to. Thus

$$r^2 = \frac{3}{3{\cdot}142 \times {\cdot}5 \times 180 \times {\cdot}076}$$
$$= {\cdot}14.$$

Therefore r = ·375 foot.
= 4·5 inches.
Therefore dia. = 9 inches.

Thus we find that we must reduce the diameter of the 9-inch pitch airscrew from 10 inches to 9 inches, to ensure that it will not overtax the engine.

What would happen, of course, with a 10-inch dia. airscrew would be that the engine would not reach its designed speed of 10,800 r.p.m.

The following data is now available:

(*a*) 60 m.p.h. = 90 feet per second.

(*b*) 3 pounds thrust.

(*c*) 9 inches dia. × 9 inches pitch.

(*d*) 10,800 r.p.m.

Before proceeding with the next step in the investigations we may pause to consider the dimensions we have now arrived at for the airscrew. In power model work—as distinct from rubber-driven aircraft—it is usual to limit the pitch of an airscrew to about three-quarters of the diameter, because, if the pitch is any greater, the efficiency will drop, owing to the blade angle being too great, unless the speed is very high.

In the case now under consideration, if the pitch were any less the engine r.p.m. would require to be greater, and as no doubt we shall be agreed that the r.p.m. are quite high enough already, perforce we must stick to the figure of 9 inches!

However, there is this point which is favourable: the efficiency of a model airscrew increases with its speed, and, as in the case of our example, the r.p.m. are about twice the normal figure, the airscrew efficiency will probably not suffer so very much.

And now, what sort of aircraft can be designed to have a drag not exceeding $1\frac{1}{4}$ pounds, and which will provide a suitable streamline housing for our $\frac{1}{5}$ h.p. engine?

Suppose we consider a fuselage, circular in shape, with a diameter of 6 inches and a length of 42 inches. Presuming that the fuselage has no excrescences and the skin is well smoothed, the drag coefficient would be approximately ·0004.

The drag of the fuselage may be calculated from the formula:—

$$D = KAV^2.$$

When K = drag coefficient.

A = projected cross sectional area in square feet at the largest section.

V = speed in m.p.h.

and D is given in pounds.

Thus
$$D = \cdot0004 \times \frac{3\cdot142 \times 3^2}{144} \times 60^2$$
$$D = \cdot0004 \times \cdot196 \times 60^2$$
$$= \cdot282 \text{ pound.}$$

Next let us consider the wing; its size, of course, is tied up with the weight of the whole machine, the type of airfoil to be used and its angle of attack. It is desirable that the wing loading should be fairly high, and as the drag must be kept as low as possible, the wing must be set at the angle at which the lift drag ratio is highest.

An airfoil section specially designed to have a very low minimum drag and to be suitable for a high-speed aeroplane wing is R.A.F. 25, full particulars of which are published in R. and M. No. 915 of the Aeronautical Research Committee.

The max. L/D ratio is 23·5 (in most airfoils it is between 15 and 18). At an angle of 0·7, K_1 is ·145—somewhat on the low side By increasing the angle to 2·6 degrees the L/D ratio is only reduced to 20·8, but the K_1 value rises to ·210 (i.e. by some 50 per cent).

We are "getting nearer," but still have two "unknowns"—the area of the wing and the total weight of the machine—one of which must be settled before we can use the well-known formula:—

$$L = C_1 \frac{p}{2} S \ V^2$$

to calculate the wing area.

Suppose we allow that the complete model will weigh 5 pounds "all up," we can now calculate the wing area required.

In the above formula,

C_1 = Lift coefficient of the airfoil under consideration.

p = ·002378.

S = Wing area in square feet.

V = Velocity in feet/second.

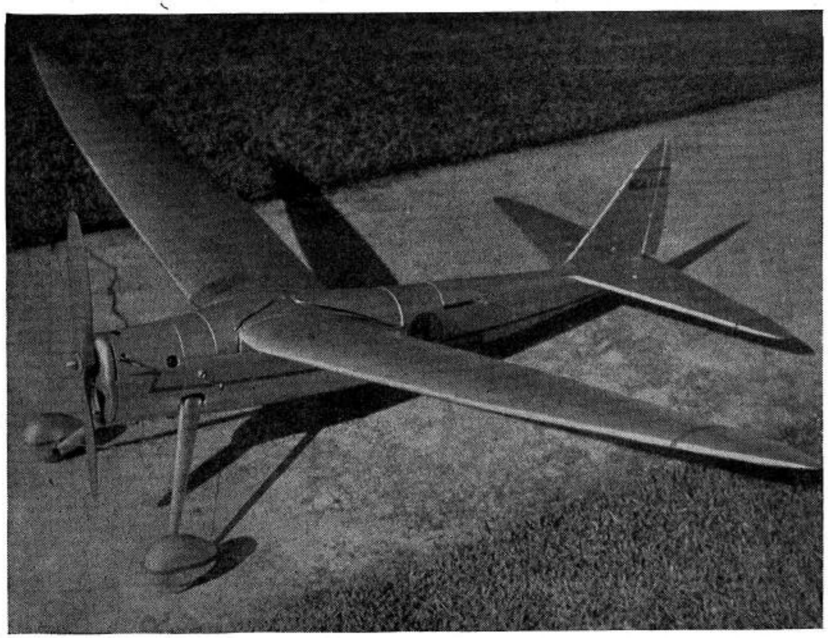
and L is given in pounds.

As S is the value we wish to calculate, we rewrite the formula in the form:—

$$S = \frac{L}{C_1 \times \frac{p}{2} \times V^2}$$

and substituting our particular figures in the formula we get:

$$S = \frac{5}{\cdot21 \times \cdot001189 \times 90^2}$$
$$= 2\cdot48 \text{ square feet.}$$



Here is another photograph of the proprietary petrol 'plane kit, which may be built up into such a fine-looking streamlined model. This model was built by Mr. S. Gardener, of Belfast.

Now before we can accept this figure, we must find the drag of the wing. This we calculate from the formula:—

$$D = C_d \times \frac{p}{2} \times S \times V^2$$

When C_d = The drag coefficient of the particular airfoil section.
p = ·002378. 2
S = Wing area in square feet.
V = Velocity in feet/second.
and D is given in pounds.

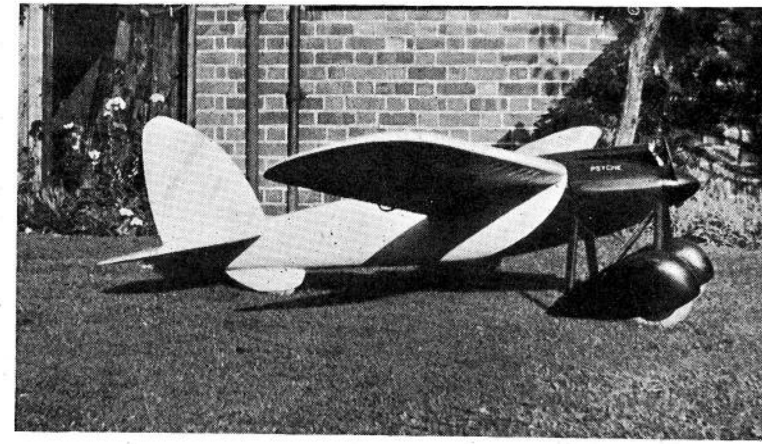
Referring to R. and M. 915 we find that the drag coefficient when the lift coefficient is ·21, is ·0101.

Substituting in the formula we get:

$$D = \cdot 0101 \times \cdot 001189 \times 2\cdot 48 \times 90^2$$

$$\text{Thus } D = \cdot 241 \text{ pounds.}$$

This added to the figure of ·282 pound calculated from the fuselage drag makes a total of ·522 pound.



One of the finest looking petrol 'planes built in this country; this model, built by Mr. Allman, has a totally enclosed 6 cc. engine, and monocoque fuselage extremely well finished.

Now obviously we must leave a margin out of our maximum of $1\frac{1}{4}$ pounds so we can reckon that the drag of the tail unit, engine cylinder and landing gear must not exceed a further $\frac{1}{2}$-pound. Rough calculations I have made indicate that this condition could be met, so at long last we may draw up a general specification for our speed model.

Designed speed	= 60 m.p.h.
Engine revolutions	= 10,800 per minute.
Airscrew diameter	= 9·1 inches.
Airscrew pitch	= 9·0 inches.
Fuselage (circular and fully streamlined)	= 6 inches dia. × 42 inches long.
Wing area	= 2·5 square feet.
Total weight of machine	= 5 pounds.

Many members of the R.A.F. are keen aero-modellers. This photo was taken at a meeting near London in the summer of 1939.

CHAPTER XIX

Description of the models built by the Author: the " Cyclonic "—The " Improved Cyclonic "—The 10 feet span low-wing 'plane—The 8 feet span high-wing cabin 'plane—The " Lysander."

As most of the photographs illustrating various parts of model aircraft in this book have been taken by the Author, and are of his own machines, it is thought that a general description of them would be of interest. The main constructional features of the aircraft are described, not so much as implying that these are necessarily the best, but because they will give a general idea of the type and kinds of material used in model aircraft of the size described.

The first model described is the " Cyclonic." A photograph of the machine uncovered is shown in Fig. 113, whilst Fig. 66 shows the tail unit.

The fuselage was of rectangular box-section shape, and consisted of four birch longerons, $\frac{3}{16}$-inch × $\frac{3}{16}$-inch, arranged at the four corners of a series of rectangular three-ply formers; the first two of these were of $\frac{1}{8}$-inch three-ply birch, and the remainder of $\frac{1}{16}$-inch, all of them, with the exception of the first one, being fretted out for lightness.

Cross-bracing struts were of $\frac{1}{8}$-inch × $\frac{1}{4}$-inch birch. All fixings being by means of very fine nails and glue.

From the front bulkhead forward the two bottom longerons were steamed and curved upwards, the space between them and the upper longeron being filled in with $\frac{3}{16}$-inch three-ply birch panels, which formed a very solid framework between which the engine unit was gripped. The wooden framework (called the " test " frame on which the engine is mounted) was inverted and held between the two sides of the fuselage by two wood screws which passed through holes (in the side frames), and direct into the " test " frame. Thus, in effect, the whole engine unit could pivot about these two screws, either upwards or downwards in the event of a crash.

(By this method it will be found that if two fairly thick steel screws are used, and washers are placed under their heads, quite sufficient grip will be obtained to keep the engine fixed in position. A small amount of glue may be smeared between the engine frame and the fuselage side-frames; this prevents the engine position from being altered by any sudden "jar"; but will "crack" in the event of a bad landing, or may be split by the insertion of a thin knife if it is desired to remove the whole unit from the fuselage.)

Adjustment for side thrust, of which only a small amount was required, was obtained by removing the engine bolts, and carefully "ovalling" the holes in the engine frame with the aid of a "rat's tail" file. The engine could then be "swivelled" into the desired position, and bolted up tight again in the wooden "test" frame.

The landing chassis consisted of a length of $\frac{5}{32}$-inch spring steel rod braced by a tie rod of $\frac{1}{8}$-inch diameter spring steel rod, which was welded to the two ends of the $\frac{5}{32}$-inch rod, and formed the axle for the two $2\frac{1}{2}$-inch diameter air-wheels which were fitted.

"Fairings" of balsa wood were laid up on either side of the rods and bound with strips of silk; these formed effective "streamline" struts, which were finally doped and painted.

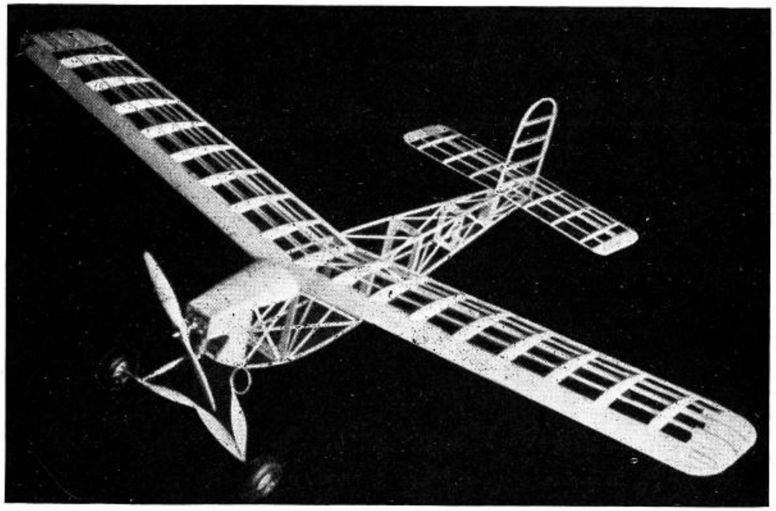


Fig. 113.
The "Cyclonic."

The main wing was made in halves, which were joined together by $\frac{3}{8}$-inch diameter wooden dowels about 3 feet long.

When assembling the wings, two rods were inserted into the tubes in one half-wing, and then the other half-wing was slipped on to the protruding lengths, the whole being held together by the usual rubber bands.

This method of wing fixing allows of the two 3 feet dowel rods acting as strengthening members through the centre of the wing, and yet, if in a crash the aircraft lands on one wing, the rods will break in the centre, when the halves may be quickly withdrawn and new rods inserted. Alterations in the angle of dihedral may be made by first steaming the rods to the correct angle before insertion into the half-wings.

The wings were built up from a series of longitudinal "stringers" of $\frac{3}{16}$-inch × $\frac{1}{16}$-inch birch let into former ribs of $\frac{1}{8}$-inch balsa, spaced at 4-inch intervals. The leading edge was of $\frac{1}{4}$-inch × $\frac{1}{4}$-inch, and the trailing edge of $\frac{3}{8}$-inch × $\frac{1}{8}$-inch birch. The tips of the wings were made from $\frac{3}{16}$-inch cane, the ends of which, for a distance of 4 inches, were bound to the leading and trailing edges.

The stabiliser and fin were built as one unit with the tail part of the machine, and connected by rubber bands looped round oppositely located pairs of hooks in the fuselage and tail unit.

The leading and trailing edges of the stabiliser, and also the edge of the fin, were all made from $\frac{3}{16}$-inch diameter cane steamed to shape. The formers were of $\frac{1}{8}$-inch balsa.

The main wing was held to the top of the fuselage by rubber bands which passed right round it, and were so arranged that there was a tendency to pull the wing forward hard up against the "step," which was built on the top of the fuselage.

* * * * * *

The model shown in Fig. 114 was an improved version of the "Cyclonic," where considerably more attention was paid to the profile appearance of the model. The wings were tapered and mounted more in a "mid-wing" position, whilst the undercarriage legs were mounted as cantilevers.

The fuselage was built up in exactly the same manner as before, that is, it consisted of four $\frac{3}{16}$-inch × $\frac{3}{16}$-inch birch longerons at the four corners of a series of rectangular bulkheads cut from three-ply.

The semi-circular shape to the top of the fuselage was obtained by forming sheet balsa (two thicknesses of $\frac{1}{32}$-inch) over a series of balsa stringers supported on shaped supports which rested on top of the bulkheads.

The wing roots were cut from $\frac{1}{16}$-inch three-ply birch, and were suitably mounted and braced to the sides of the fuselage. $\frac{3}{8}$-inch diameter birch dowel rods passed through these into the wings, for a distance of 12 inches. It should be noted that there were no external fixings for the wings . . . neither were there any inside. The rods were slightly stiff " sliding fit " in the three-ply, and the whole arrangement was such that, whilst the wings could quite easily be drawn on and off the rods, the friction grip was quite sufficient to prevent them working loose in flight.

The rods, of course, could be withdrawn from the fuselage, and broke in the event of a real crack-up.

The landing gear was of a new type, which I originated and developed, and which worked well. It was totally enclosed, and had a stroke which could be controlled from 0 inch to 5 inches in a backwards direction; "springing" was by means of loops of rubber so arranged that the tension could be varied, and the whole unit could be removed from the fuselage in under a minute.

Essentially it consisted of two aluminium tubes which projected up inside the fuselage, where they crossed, their upper ends being housed in suitable recesses constructed adjacent to one of the bulkheads.

That is to say—viewing from the front—the left leg passed through a slot in the underside of the left of the fuselage, and did so at such an angle that it passed diagonally up through the fuselage, so that its top end fitted up against the *right* longeron. Similarly, the right leg passed from the right bottom to the *left* top of the fuselage.

Thus the legs crossed at a point approximately in the centre of the (cross-section) of the fuselage.

From the top of the bulkhead in front of the one against which the ends of the legs abutted, a loop of rubber, $\frac{1}{4}$-inch × $\frac{1}{16}$-inch, of eight strands, was run, passing behind the two

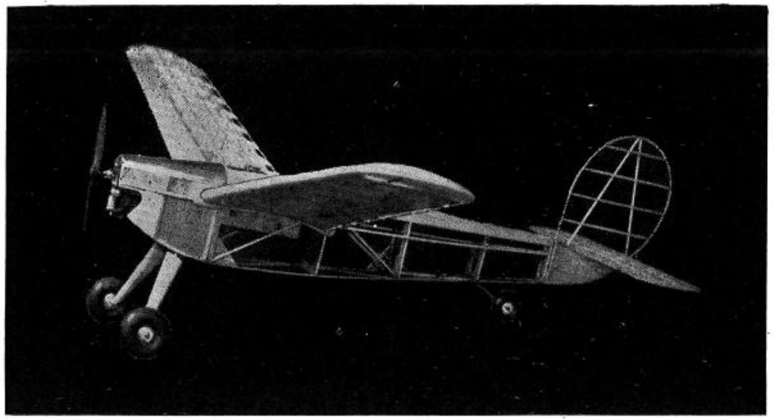


FIG. 114.

The shoulder wing 'plane illustrated on pages 40, 41, 187, and 183. A photo of the engine mount is on page 153, and part of the tail unit is illustrated in Fig. 67 on page 134.

tubes where they crossed, and back to the bulkhead again. By varying the length of rubber used, the tension could be varied, and by inserting suitable " buffers " of rubber in the two slots the length of the stroke could be varied.

The legs were of aluminium tube $\frac{3}{8}$-inch bore, and they were reinforced with $\frac{3}{8}$-inch diameter birch dowel rods, which were a tight fit throughout the length of the tubes. The streamlined fairings were of balsa covered with silk.

At the bottom ends the legs were slightly flattened and drilled to take $\frac{1}{8}$-inch diameter spring steel axles for the wheels. These were a pair of $4\frac{1}{2}$-inch diameter pneumatics.

The tyres were of ample section, and had, of course, totally enclosed valves. Ample resiliency was thus provided in the " up and down " directions.

The tail wheel was a $2\frac{1}{2}$-inch diameter pneumatic, and was mounted on a wire axle looped through the fuselage, and with both ends brought down and turned into the wheel axle to meet in the middle. Thus, by springing the two ends apart, the wheel could be removed.

Under the " M " of the lettering on the sides of the fuselage were the two plugs on to which the accumulator leads were fixed. No change-over switch was provided, the wiring being so arranged that the accumulator was connected in parallel with the usual 4-volt pocket flash-lamp battery used during flight.

The time-switch was mounted on the underside of the hatch, which was normally held in position by internal rubber bands. The opening was large enough to allow of inserting an arm inside the fuselage.

An aluminium cowl covered the engine-room, and the compartment containing the undercarriage legs, and was held in position by one light rubber band.

The fin and stabiliser were built as one unit, which was held to the end of the fuselage by a single rubber band; alterations in incidence, etc., being effected by introducing thin packing pieces between the unit and the end of the fuselage.

The wing was tapered from 12-inch chord at the roots to 9-inch at the tips, the section being R.A.F. 32.

The total weight of the model was 5 pounds which, with a wing area of $5\frac{3}{4}$ square feet, gave a loading of something under one pound per square foot.

* * * * * *

The 10 feet span low-wing monoplane has been illustrated in various parts of this book, but certain detailed descriptions of some of the parts may be of interest.

The fuselage was of monocoque construction, the covering being of $\frac{1}{32}$-inch three-ply birch, laid over a series of $\frac{3}{16}$-inch × $\frac{3}{16}$-inch birch longerons, spaced evenly round the circumferences of a number of bulkheads, the first two of these being of $\frac{1}{8}$-inch three-ply, whilst the remainder were of $\frac{1}{16}$-inch three-ply.

An interesting feature was the system of cross-bracing. Each of the struts was made from two lengths of $\frac{1}{8}$-inch × $\frac{1}{8}$-inch birch "sandwiched" between two pieces of $\frac{1}{32}$-inch three-ply, in which lightening holes were punched. These struts were approximately 11 inches long, and only weighed $\frac{1}{4}$-ounce each, yet were so strong that when held between the two hands and subjected to a "compression" stress they could not be broken.

To conform to the rounded curves of the fuselage the three-ply "skin" had to be built up of a considerable number of pieces. All joints were "butted" and backed by strips of the same material, being further strengthened by fine nails $\frac{3}{16}$-inch long.

These were pushed through the ply with the aid of a pair of light pliers, and then clinched over by a heavier pair. The fuselage, complete with windows, built-up wing-roots, engine "platform," and stabiliser roots, weighed $4\frac{1}{2}$ pounds; the largest diameter was 11 inches, and the overall length 4 feet 3 inches. When stood on end the fuselage has supported the author's full weight.

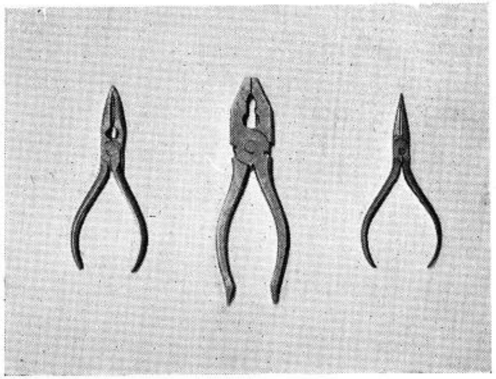


FIG. 115

The pliers on left and those on right have had their jaws slightly curved so that fine nails can be gripped right at the plier ends. The centre pair of pliers is used for clinching the nails—the gap between the jaws clearing the pieces of wood being joined together.

The two "half-wings" were each 4 feet 4 inches long, with root chords of 18 inches and tip chords of 10 inches.

The ribs were of $\frac{1}{32}$-inch three-ply, and were spaced 2 inches apart. The longitudinals, being of $\frac{3}{16}$-inch × $\frac{1}{16}$-inch birch. The leading edge was reinforced with a sheet of $\frac{1}{32}$-inch three-ply.

The weight of each half-wing was 11 ounces uncovered, and $1\frac{1}{4}$ pounds when covered with fairly thick silk, over which was spread several coats of aluminium paint.

The sole support for each wing consisted of an 18-inch length of $\frac{3}{8}$-inch diameter birch dowel rod, 12 inches of which passed through a series of holes punched in the first six wing-ribs, whilst the other 6 inches passed into a steel tube fixed in the fuselage. This tube, which was thus 12 inches long, was bent in the centre to the correct dihedral, and was permanently located in the fuselage. As the dowel rods passed into the wings at a point one-third of the chord distant from the leading edge, and it was thus possible to rotate the wings about the rods, and so vary the angle of incidence.

Steel pegs, suitably positioned in the fuselage and wing roots, were connected by loops of rubber, and so held the

FIG. 116.

A good idea of the size of the 10 feet span low-wing 'plane, a number of photographs of which appear throughout this book, may be obtained by comparison with the enthusiasts at work on it.

wings hard up to the fuselage. In the event of a " crash " the dowel rods broke, the ends being easily withdrawn and new rods inserted, the wings in consequence suffering little damage.

The stabiliser was mounted in an exactly similar manner to the wings, whilst the fin was fixed to a point down the centre line of the fuselage; a very small adjustment was, however, provided.

The landing chassis consisted essentially of a framework of $\frac{3}{16}$-inch diameter mild steel rods, suitably encased in birch streamlined fairings.

The rear legs contained strong coil springs, which moved over steel guide rods inside wooden fairings.

At the four points of anchorage to the fuselage the rods were screwed and welded to forked shackles, which engaged with steel plates bolted to rods, which passed across the fuselage, the actual connections being effected by four $\frac{1}{8}$-inch diameter split pins. By withdrawing these four pins the whole chassis could be removed from the fuselage.

At the bottom ends of the struts, the internal rods were also screwed and welded, this time to steel plates, to which

were screwed the wheel axles. Should these later become bent, they could be removed by the sliding off of one nut and new ones substituted.

The wheels were of $4\frac{1}{4}$ inches diameter, and were made of hardwood with $\frac{3}{16}$-inch bore brass axle tubes.

They carried 8-inch diameter by 2-inch section rubber tyres. These were standard products of the Dunlop Rubber Company, cost 2s. 6d. each, and were sold as inner tubes to fit inside covers in the usual way, the tyres being used on light trolleys, barrows, etc. The inner tubes, complete with valves, weighed $4\frac{1}{4}$ ounces each.

* * * * * *

The model flown by the author in 1939 was a high-wing 'plane of 8 feet span, as shown in photographs on pages 51, 208, and 209. An attempt was here made to produce a semi-scale model capable of a good performance, yet of robust enough construction to stand up to the average conditions encountered in this country. The fuselage was built from $\frac{3}{16}$-inch square birch longerons on three-ply bulkheads.

A photographs of the complete machine uncovered is on page 36, and individual parts of the aircraft are shown in photographs on pages 135, 145, 146, 157 and 158. Thus, in effect, the most interesting parts of this machine have already been described in different chapters of the book. The machine was powered with a 9 cc. Dennymite engine, as shown in Fig. 105, page 174, which gave sufficient power for a good performance, even when the machine was loaded up to an " all-up " weight of $8\frac{1}{4}$ pounds. With the omission of certain additional weight, and the introduction of slightly lighter sectioned members in certain places, this machine could easily be built down to a weight of as little as $6\frac{1}{2}$ pounds. A diagrammatic sketch of the arrangement of the springing of the undercarriage legs is on page 144.

As the model appeared to be popular, Mr. Pollitt, *Aero-Modeller* staff draughtsman, has drawn out a set of full-size plans for building the model. These can be obtained from the offices of *The Aero-Modeller*, price 10s. 6d. per set, post free.

* * * * * *

The author's latest model is a very ambitious project—a one-fifth full-size scale model of the Westland Army Co-operation Aircraft, " The Lysander."

The fuselage bulkheads are all of $\frac{1}{16}$-inch three-ply birch, into which fit the longerons. These are of $\frac{1}{2}$-inch × $\frac{1}{8}$-inch hard balsa, there being 40 of them.

The cutting of the slots in the bulkheads for these longerons presented a nice little problem. About 200 slots were required to be cut, each exactly $\frac{3}{8}$-inch deep by $\frac{1}{8}$-inch wide. As the longerons were $\frac{1}{2}$-inch wide, this meant that they would stand " proud " of the edges of the bulkheads by $\frac{1}{8}$-inch, and thus prevent the fabric touching the bulkheads. It was essential that the slots should be exactly to size, to afford a snug fit on the longerons.

To do this a special tool, consisting of a striking die of steel $\frac{3}{8}$-inch × $\frac{1}{8}$-inch, was made. This was actuated by a hand lever in such a way as to punch the slot out of the bulkheads.

(This ' gadget " took about four hours to construct out of scrap, but enabled all the slots to be accurately cut to shape in under half-an-hour.)

No jig was used in assembling the longerons in the slots. They were pushed into position, and rubber bands tied round to hold them during the drying of the glue, with which they were fixed.

FIG. 117.

This $\frac{3}{4}$-front view shows the clean lines of the fuselage, and, on the near side, the slot in which the undercarriage leg moves. Note the N.G.A. transfer on side of fuselage.

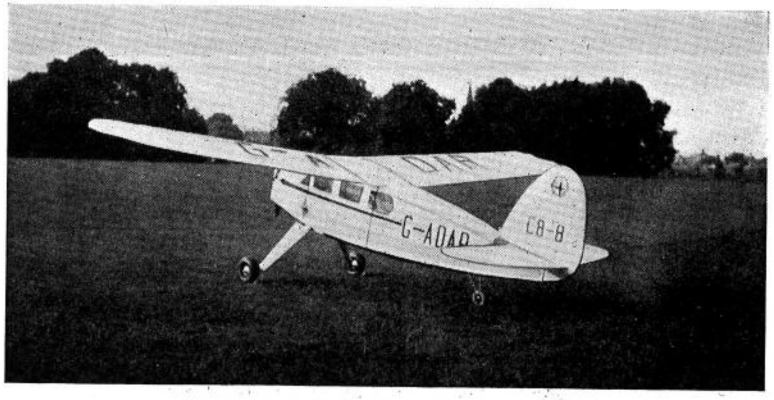


FIG. 118.

This photo shows the graceful curves of the fin, on which may be noted the N.G.A. transfer and S.M.A.E. petrol 'plane registration numbers. Full-size scale plans of this model, in which all parts are fully detailed, may be obtained from the offices of *The Aero-Modeller*, Allen House, Newarke Street, Leicester, price 10s. 6d. post free.

In the full-sized aircraft, the end of the fuselage, as far forward as the front anchorage of the fin, and the forward portion, are built of metal, and on the model this is represented by sheets of $\frac{1}{32}$-inch three-ply birch, silk covered.

The fuselage, as shown in Fig. 120, and with the forward covering of three-ply, not shown in the photo, weighs about 2 pounds.

The spats are carved from solid blocks of balsa, are some 13 inches long, and weigh about $2\frac{1}{2}$ pounds the pair. They are, of course, hollowed out to accommodate the wheels.

The question of springing the whole undercarriage was considered. After designing a somewhat elaborate arrangement, whereby the legs were hinged and able to move backwards and forwards, the author discarded this, and made the spats and legs solid with the fuselage, partly because they are so in the full-size aircraft, and partly because it was possible to construct a much stronger anchorage by this means. Suspension is thus entirely by the pneumatic tyres, Dunlop 8-inch × 2-inch, as on the 10 feet span low-wing 'plane.

It is considered that it will be well worth while to fit ball races to the wheels, as the author has found that quite an amount of friction can be developed when these wheels, of

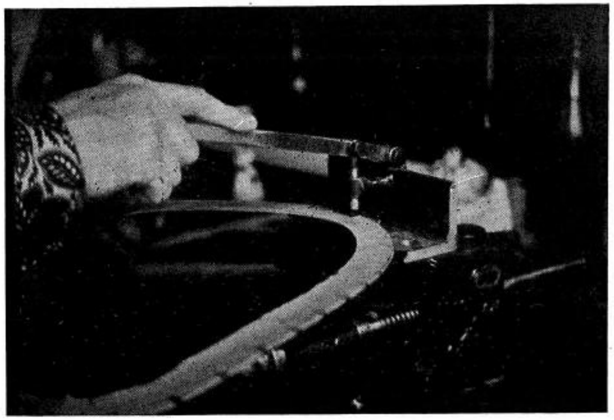


FIG. 119.

Cutting slots for the longerons in a 3-ply bulkhead, as described at foot of the previous page.

such small diameter, are revolving at a speed of close on 1,000 r.p.m. This is a point not realised by all petrol 'plane enthusiasts, but the figures are right! (The diameter of these wheels is 8 inches. Say the circumference is 2 feet. 20 m.p.h. is approximately 30 feet per second, so a wheel must revolve 15 times per second, or 900 times per minute.)

The undercarriage legs are carved from $4\frac{1}{2}$-inch × $1\frac{1}{2}$-inch hard balsa, and are reinforced by $\frac{1}{2}$-inch diameter birch dowels, where they join the spats. The legs are carried through the fuselage, and where they meet they are interlaced in the same way that one can interlace the fingers of one's hands. A very strong joint is thus formed, to which is anchored a " tension plate " of $\frac{1}{8}$-inch three-ply birch, several inches wide, which is carried right back along the floor of the fuselage to the tail of the model.

In addition, the interlaced joint is braced by compression struts, which run up to the front bulkhead; and finally there are two tubes, in compression when landing, and in tension when flying, which run up to a cross tube at the top of the fuselage, and which form the anchorage to which the wings are attached.

Altogether, the construction is very robust, and a complete " crack-up " will be necessary to disturb the landing gear.

The weight of the fuselage, covered, doped and painted, with fin, spats, wheels, and all instruments, is some 15 pounds.

The engine weighs $3\frac{1}{2}$ pounds; twin coils, 1 pound; and with battery, leads, switch, etc., will bring the total up to

about 20 pounds. The elevators weigh 1 pound. The wings at the time of writing are not yet built, but should weigh about 2 pounds each, thus bringing the all-up weight to about 25 pounds. As the wing area is about 10 square feet the wing loading will be $2\frac{1}{2}$ pounds per square foot.

As the Westland " Lysander " is still one of this country's latest types of military aircraft, it is not possible to obtain full particulars of the airfoil characteristics, but by various means the author considers he has got pretty near to the correct section. With slots and flaps it is possible to increase the lift fourfold, and this means that the flying speed (with flaps and slots operating), can be reduced to half that of the flying speed when they are in the normal position. According to calculations the speed with flaps and slots operating should be approximately 20 miles per hour, and thus about 40 m.p.h. with them in the normal or closed positions.

The centre-of-pressure travel is quite small, even with the slots and flaps fully extended. It is intended to use the two coils as a pendulum, suspend them inside the dummy petrol

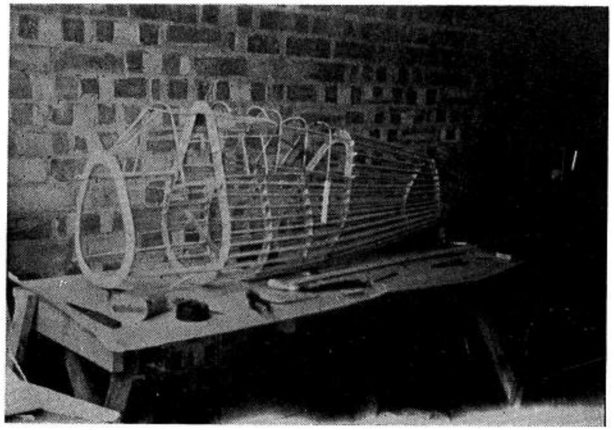


FIG. 120.
Fuselage of the " Lysander " under construction.

tank (which is located over the centre of gravity of the whole machine), and connect them by a simple link control to the elevators, which will be arranged to pivot.

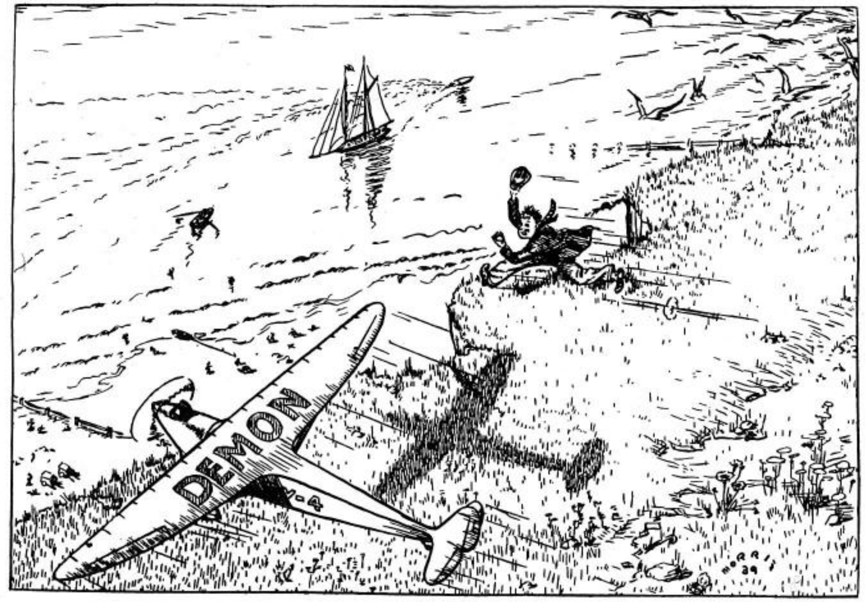
The slots and flaps will be held in the " open " position by springs or rubber bands, so tensioned that as the machine gathers speed the air pressure will tend to close them. This means, of course, that as they close the lift coefficient of the airfoil (considered as a whole) decreases; but at the same time the *drag* decreases much more rapidly, this enabling the machine to more quickly gather speed, until, at the take-off, the flaps and slots are fully closed. This is actually what happens on the full-size aircraft; the operation is entirely *automatic*, and not controlled by the pilot.

When in flight, and power is cut off, the immediate failure of the propulsive thrust of the airscrew causes the 'plane to slow down; and so, due to the decreased air pressure, the slots and flaps commence to open.

The airscrew diameter is 2 feet 2 inches, the 3 blades being of Clark Y section. They are mounted in a steel hub, provision being made to allow of adjustment of pitch.

According to preliminary calculations, an engine speed of 4,000 r.p.m. will be sufficient to fly the model, giving a thrust of 7 or 8 pounds, depending on the pitch of the blades; and there is little doubt that the engine will provide this power.

This machine has been built essentially as an experiment, and as such it must be regarded; as to what will happen when an attempt is made to fly it . . . Well! " 'Tis better to have tried and failed, than not have tried at all."



" Gosh! Bet there'll be something in *The Aero-Modeller* about this! "

APPENDIX 1.—FORMULÆ.

APPENDIX 2.

APPENDIX 3.

APPENDIX 4.

APPENDIX 5.

APPENDIX 6.

APPENDIX 7.

Formula 1.—Pressure on a Flat-plate Type of Airfoil.

The pressure acting on a flat-flate type of airfoil may be ascertained, approximately, from the formula:

$$P_v = P \frac{2 \text{ Sin } a \text{ Cos } a}{1 + \text{Sin}^2 a}$$

$$\text{i.e. } P = P_v \frac{(1 + \text{Sin}^2 a)}{2 \text{ Sin } a \text{ Cos } a}$$

Formula 2.—Velocity of Wind Necessary to Support a Flat-plate Type of Airfoil.

The Velocity of the wind necessary to support the plate at this angle may be ascertained from the formula:

$$V = \sqrt{\frac{P}{\cdot 0032}} \text{ miles per hour.}$$

Where P is in pounds per square foot.

Formula 3.—Lift of an Airfoil.

The formula is $L = C_l \frac{p}{2} SV^2$.

where L = Weight in pounds.
p = Mass density of air.
= ·002378 slug per cubic foot.
S = Wing area in square feet.
V = Velocity in feet per second.
C_l = Lift coefficient.

Formula 4.—Speed of a 'Plane.

$$V^2 = \frac{L}{C_l \frac{p}{2} S}$$

where L = Weight in pounds.
p = Mass density of air.
= ·002378 slug per cubic foot.
S = Wing area in square feet.
V = Velocity in feet per second.
C_l = Lift coefficient.

Formula 5.—Drag of an Airfoil.

$$D = C_d \frac{p}{2} SV^2.$$

where D = Drag in pounds.
p = Mass density of air.
= ·002378 slug per cubic foot.
S = Wing area in square feet.
V = Velocity in feet per second.
C_d = Drag coefficient.

Formula 6.—Thickness of the Boundary Layer.

The thickness of the boundary layer can be found from the formula developed by Van der Hegge Zijnen:—

$$T = 4{\cdot}5 \sqrt{\frac{KL}{V}}$$

where T = Thickness of layer, in feet.
K = ·00016.
= Kinematic viscosity of air.
L = Distance from the leading edge of the airfoil in feet.
V = Airspeed, in feet per second.

Formula 7.—Reynold's Number of Thickness of Boundary Layer.

The Reynold's number of the thickness of the boundary layer may be calculated by multiplying the thickness of the layer by the speed and dividing by the kinematic viscosity.

$$\text{i.e. R.N.} = \frac{TV}{K}$$

where T = Thickness of layer, in feet.
V = Airspeed, in feet per second.
K = ·00016.

Formula 8.—Parasite Drag.

Parasite drag may be calculated from the formula

$$D = KAV^2.$$

where K = the drag coefficient of the fuselage, and depends on its particular characteristics.

A = the projected cross-sectional area, in square feet, at the largest section.

V = the speed—in miles per hour.

and D is given in pounds.

K varies from about ·0002 to about ·0009, and averages about ·0004 for totally-enclosed fuselages of approximately circular cross-section.

(4) An average value for K for tail-planes which have a flat under-surface and a thickness-to-chord ratio of about 1:18 may be taken as ·000075.

For fins and rudders the value of K may be taken as approximately ·00006 per square foot for area.

An average value for K for struts is ·00025—the drag being in pounds per square foot of projected area: but this must be increased by from 50 to 100 per cent, according to the amount of " interference " which may be thought to exist.

The drag of wheels varies with the ratio of diameter to tyre width, and is also dependent on the degree of "fairing" between the tyre and the hub; also the value of K is relatively greater for small diameter wheels—say 2 to 4 inches—than it is for those of from 6 to 9 inches diameter.

For wheels of from 2 to 4 inches diameter—with a diameter/width ratio of about 2·5 to 1, the value for K is about ·0029, whilst for wheels of from 6 to 9 inches diameter, with a diameter/tyre ratio of about 4 to 1, the value of K drops to about ·0015.

For average conditions the drag of a single-cylinder engine may be taken as being equal to ·0006 V^2 pounds, where V is in m.p.h.

Formula 9.—Area of Stabiliser.

An empirical formula, developed by the Author, for calculating the area of a stabiliser, is:—

$$Sa = \cdot 257W \times \frac{15}{AR + 6\cdot 4} \times \frac{3\cdot 9}{ar + \cdot 05} \times \frac{\cdot 65}{M} \times \sqrt{\frac{S}{L}}$$

Where W = Main wing area in square inches.
AR = Main wing aspect ratio.
ar = Stabiliser aspect ratio.
M = Moment arm divided by overall length.
S = Main wing span in inches.
L = Overall length of aircraft, in inches.
and Sa = Required area of stabiliser in square inches.

Formula 10.—Chord of Rectangular Wing.

Assuming that the main wing is of rectangular plan form, its chord may be calculated from the formula

$$C = \sqrt{\frac{W}{AR}}$$

Where AR = Aspect ratio.
and W = Wing area in square inches.

Formula 11.—Area of Fin (Petrol 'Plane).

The area of a fin for power-driven aircraft may be calculated from the following empirical formula, developed by the Author:—

$$A = K \times \sqrt{\frac{WS}{M}}$$

Where W = Weight of aircraft in pounds.
S = Span of aircraft in feet.
M = Moment arm in feet.
and A = is given in square feet.
and K = ·25 for high-wing monoplanes.
= ·30 for mid-wing monoplanes.
and = ·35 for low-wing monoplanes and biplanes.

Formula 12.—Area of Fin (Rubber Model).

The area of a fin for a rubber-driven model may be calculated by C. H. Grant's formula:—

$$AF = 0{\cdot}1\ \frac{A}{(M)}(3 + N + 0{\cdot}58\sqrt{ST})$$

Where A = Main wing area.
M = Moment arm.
N = The distance from the centre of gravity to the airscrew bearing face.
S = The wing span.
T = The tip rise of the main wing—i.e. the distance the tip is above the centre section of the wing.
and AF = The required fin area.
(All the values being either in inches or square inches).

Formula 13.—Minimum Flying or Stalling Speed.

The minimum flying or "stalling speed" of an aircraft may be calculated from the formula:—

$$V = 19{\cdot}77\sqrt{\frac{W}{C_l\ \text{Max.} \times S}}$$

Where W = Weight of aircraft, in pounds.
S = Main wing area, in square feet.
V = is given in miles per hour.

Formula 14.—Power Required to Maintain Steady Horizontal Flight.

The power required to maintain an aircraft in steady horizontal flight may be calculated from the formula:—

$$H.P. = \frac{DV}{375}$$

Where D = Total drag, in pounds.
and V = The speed, in miles per hour.

Formula 15.—To Find the Lift Coefficient of a Given Airfoil at a Given Speed.

To find the C_l of the wing, the formula

$$L = C_l\ \frac{P}{2}\ SV^2$$ may be re-written

$$C_l = \frac{L}{\frac{P}{2}SV^2}$$

Where L = Weight in pounds.
p = Mass density of air.
= ·002378 slug per cubic foot.
S = Wing area in square feet.
V = Velocity in feet per second.

Formula 16.—Rate of Climb.

The rate of climb of an aircraft may be calculated from the formula:—

$$R/C = E.H.P. \times \frac{33{,}000}{W}$$

Where EHP = Excess H.P. available.
W = Total weight of the aircraft.
and R/C = is given in feet per minute.

Formula 17.—Tractive Resistance Offered to Aircraft by Surface over which It may be Taxiing.

The tractive resistance may be calculated from the formula:—

$$R = \frac{W \times F}{2{,}240}$$

Where W = the weight of the aircraft, in pounds.
F = Coefficient of friction, which is expressed in pounds per ton weight—it is equal to about 60 pounds/ton for rubber tyres on a good macadam surface. On the closely-mown grass of a tennis court F = about 220 pounds/ton; and on the average aerodrome field F = about 350 pounds/ton. For average conditions F may be taken as 300 pounds/ton.
And R is given in pounds.

Formula 18.—H.P. Required to Overcome Tractive Resistance Offered to Aircraft by Surface over which It may be Taxiing.

The H.P. required to overcome tractive resistance may be calculated from the formula:—

$$\frac{R \times S \times 5{,}280}{60 \times 33{,}000}$$

Where R = Tractive resistance in pounds.
and S = Speed in miles per hour.

Formula 19.—Tractive Effort Available for Acceleration.

The tractive effort available for acceleration may be obtained from the formula:—

$$F = \frac{H.P. \times 33{,}000 \times 60}{D \times 5{,}280}$$

Where D = Speed, in miles per hour.
and F = Tractive effort available for acceleration in pounds.

Formula 20.—Distances Travelled during Take-off.

The distance travelled during the take-off may be calculated from the formula $S = \frac{V^2}{2a}$

Where V = Take-off speed in feet per second.
a = Rate of acceleration, in feet per second, per second.

Formula 21.—Diameter of Airscrew.

A model aircraft airscrew, for power work, will be working at its highest efficiency when the value of " J " is approximately ·5; and by use of the formula:—

$$D = \frac{88 \times MPH}{RPM \times \left(\frac{V}{ND}\right)}$$

An approximate figure for the airscrew diameter may be calculated, *provided that*, under " in flight " conditions, the value of " J " is ·5.

Formula 22.—Static Thrust from an Airscrew.

Theoretically—that is assuming 100 per cent efficiency—the static thrust developed by an airscrew may be calculated by use of the formula (usually an efficiency as about 60—66 per cent):—

$$T = 3{\cdot}142 \times r^2 \times p \times n \times {\cdot}076.$$

Where r = Airscrew radius, in feet.
p = ,, pitch, in feet.
n = ,, revolutions, per second.
·076 = Weight in pounds, of 1 cubic foot of air, and T is given pounds.

Formula 23.—Efficiency of Airscrew.

A measure of the efficiency of the conditions under which an airscrew is working may be obtained by use of the formula:

$$J = \frac{V}{ND}$$

Where V = Aircraft velocity in feet per second.
N = Airscrew revolutions per second.
and D = ,, diameter in feet.

(Thus when the efficiency is zero, " J " is zero. (As the value of " J " increases (with increase in V) so the efficiency increases until it reaches a maximum point, after which it falls very quickly.)

Formula 24.—Static Thrust from an Airscrew (Full Size).

An empirical formula often used in *full-size* practice for calculating static thrust is that developed by W. S. Diehl, which states that

$$T = 6{,}000 \left[18{\cdot}7 - 9{\cdot}5 \left(\frac{P}{D}\right) \right] \frac{B.H.P.}{r.p.m. \times D}$$

Where P = Airscrew pitch, in feet.
D = Airscrew diameter, in feet.
and T = Actual static thrust developed.

FORMULA 25.—H.P. REQUIRED TO DRIVE AN AIRSCREW.

$$\text{B.H.P.} = \frac{T \times \text{r.p.m.} \times D}{6{,}000\left(18{\cdot}7 - 9{\cdot}5\left(\frac{P}{D}\right)\right)}$$

Where P = Airscrew pitch, in feet.
D = Airscrew diameter, in feet.
and T = Actual static thrust developed.

The following formulæ may be used in estimating the performance of RUBBER-DRIVEN model aircraft:—

FORMULA 26.—DISTANCE A MODEL WILL TRAVEL UNDER POWER.

$$D = \frac{K\ WR}{W}\ \text{feet}$$

where WR = Weight of rubber motor.
W = Total weight of model with motor.
K = Approx. 3,000 for models with high lift wing sections and not specially streamlined—4,000—5,000 for streamlined models.

FORMULA 27.—NUMBER OF TURNS A RUBBER MOTOR WILL STAND.

$$N = \frac{KL\sqrt{L}}{\sqrt{W}}$$

where L = Length of skein unstretched in inches.
W = Weight of rubber per skein in ounces.
K is usually taken as 4, but if the motor is stretch wound may be safely increased to 5.

FORMULA 28.—PROPELLER PITCH (ALLOWING 25 PER CENT SLIP).

$$P = \frac{D}{N \times R \times {\cdot}75}\ \text{feet}$$

R = gear ratio = 1 if the propeller is driven direct.

APPENDIX 2.

DESCRIPTION OF THICK AIRFOIL SECTION PRODUCING HIGH LIFT, AND POSSESSING GOOD SLOW-FLYING CHARACTERISTICS.

THE main characteristics are the thick nose, the deep under camber at the trailing edge, and the fairly fine angle of taper between the upper and lower surfaces at the rear half of the wing.

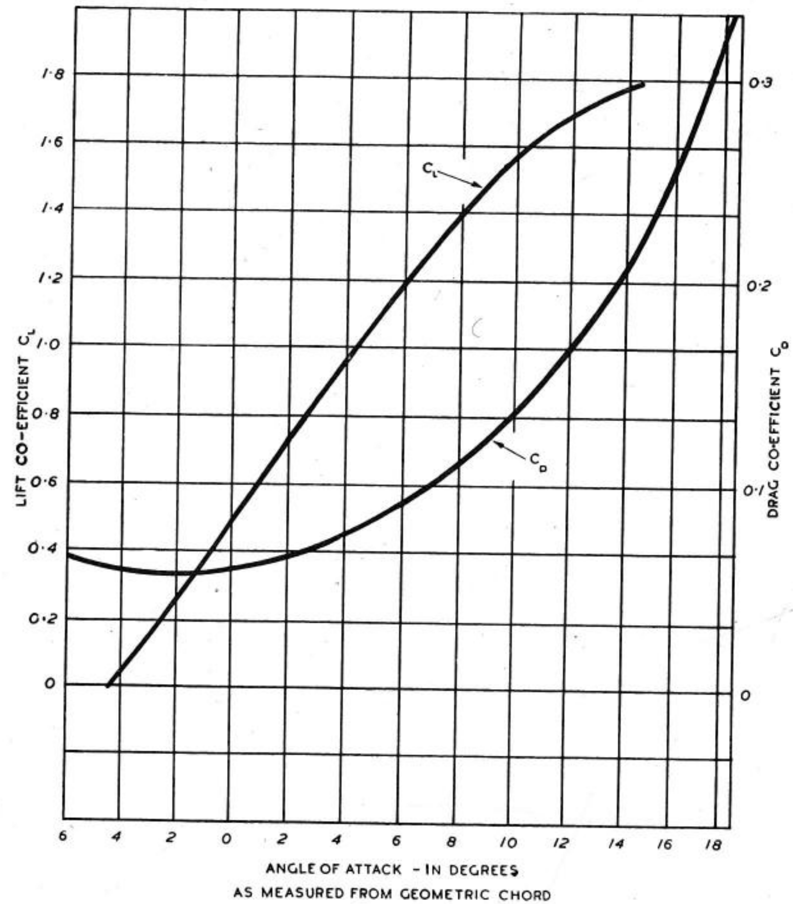


FIG. 121.

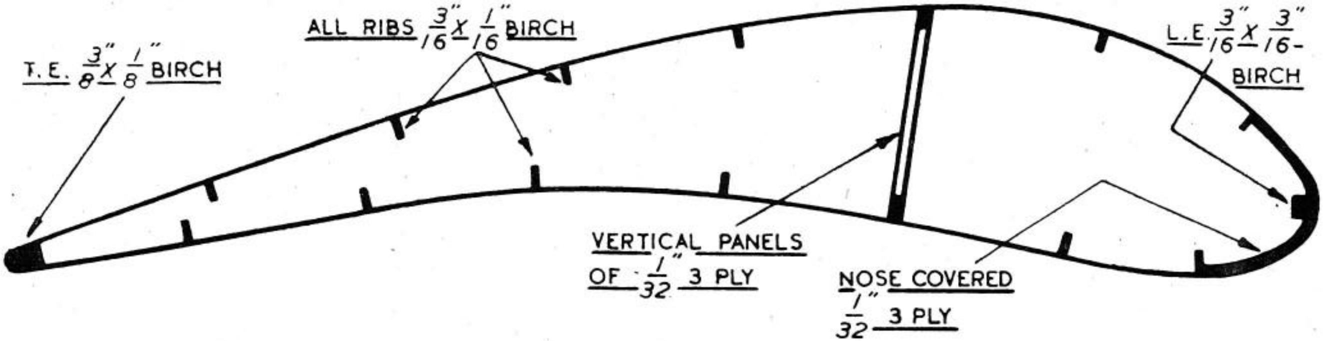
P

The considerable under camber was introduced to give the wing section a " slow flying " characteristic, in effect similar to that produced by a " flap."

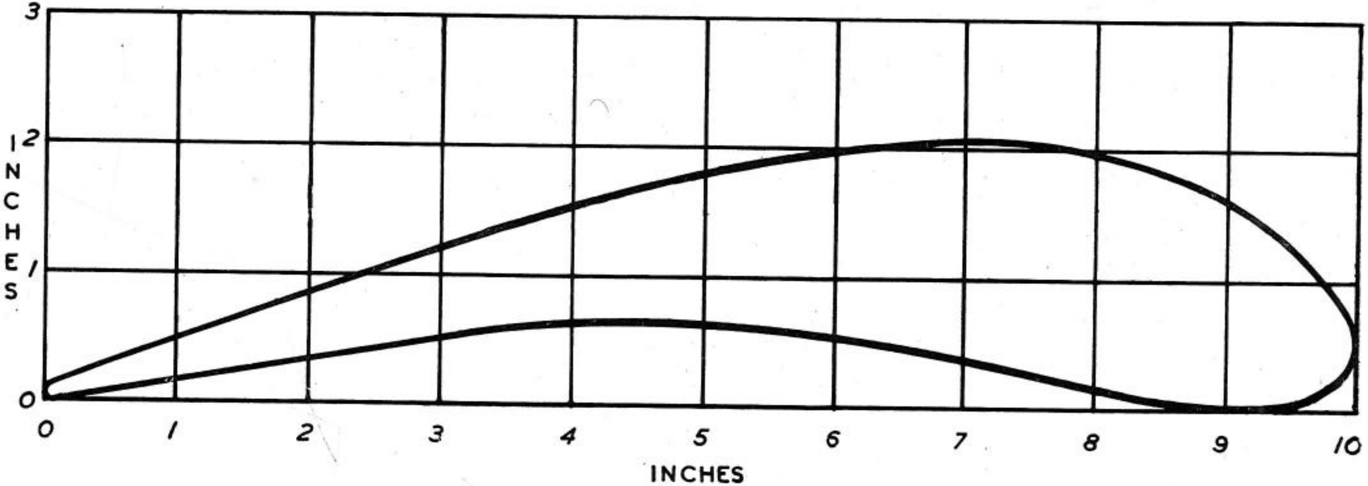
The thin section towards the rear results from the requirement that " breakaway " of the air-stream from the upper surfaces of the trailing edge shall occur at as high an angle of attack as possible; and as the type of wing section is essentially one meant to operate at a fairly large angle of attack, it is necessary to keep the upper surface as *nearly parallel* to the lower surface as is reasonably possible.

This does not weaken the section really, as due to the under camber, the nose drops, and thus it is still possible to obtain a fairly thick section near the leading edge.

Fig. 121 shows lift and drag curves for this section; they represent the averages of a number of tests made at different angles of attack, and tests made with a model in my wind tunnel. I cannot guarantee the dead accuracy of these latter, as I am unable to correctly assess the appropriate correction factor to allow for scale effect. However, a number of flight tests have been made with different wing settings, and these two curves may be taken as reasonably accurate.



ALL RIBS $\frac{3}{16}'' \times \frac{1}{16}''$ BIRCH
T.E. $\frac{3}{8}'' \times \frac{1}{8}''$ BIRCH
L.E. $\frac{3}{16}'' \times \frac{3}{16}''$ - BIRCH
VERTICAL PANELS OF $\frac{1}{32}''$ 3 PLY
NOSE COVERED $\frac{1}{32}''$ 3 PLY



INCHES
0
1
2
3
0
1
2
3
4
5
6
7
8
9
10
INCHES

APPENDIX 3.

NOTE ON THE "ANGLE OF INCIDENCE" OF AN AIRFOIL.

WHEN an airfoil is set at an "angle of attack of zero lift," i.e. when the zero lift chord is parallel to the line of flight, no lift is generated.

The geometric chord of an airfoil is really an arbitrary dimension, and is specified by the designer. Broadly speaking, it may be defined as the greatest distance between the leading and trailing edges, measured as between two perpendiculars. Thus, in any airfoil of curved section, it would be at a *negative* angle when the airfoil is set at the angle of zero lift.

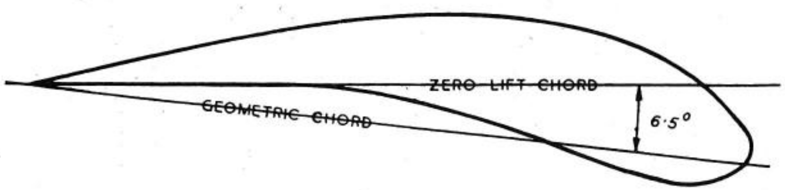


FIG. 122.

In the case of the airfoil shown in Fig. 122 the angle between the two chords is approximately 6·5 degrees.

It is very important that this feature of airfoil nomenclature should be understood, as otherwise confusion may result when considering various wing settings.

A description to the effect that "The wing is set at an angle of incidence (or of attack) of 5 degrees," is not of much use if no indication is given as to whether this is measured from the zero lift chord or geometric chord.

It is the *usual* practice to measure the angle of incidence as from the geometric chord. Thus, the actual effective angle is increased by the amount of negative setting of the geometric chord below the zero lift chord.

For example, when the angle between the two chords is 6·5 degrees, and the angle of incidence is given as 7 degrees, the effective operating angle is 6·5 + 7 = 13·5 degrees.

APPENDIX 4.

SOME NOTES ON THE DESIGN OF THE 10-FOOT SPAN LOW-WING MONOPLANE DESCRIBED IN THIS BOOK.

THIS 'plane was built entirely as an experiment. No attempt was made to obtain a "sparkling" performance—in fact, the reverse was the case, as all the time the 'plane was kept loaded up to the maximum to tax the engine to its utmost.

The design was completely worked out, and an estimate of performance made, before a start was made on the construction.

The wing area was 10 square feet, and the designed weight 13·5 pounds—and some folk said that the 'plane would never fly! However, it *did* fly!—but not before the author had had some good fun, and learnt a lot that a 'plane doing 20 m.p.h. on the ground can do! Once, one of its wheels seized on the axle, causing the aircraft to suddenly swing round, and the airscrew to "bite" the legs of the unfortunate constructor; who, by a superhuman effort, was equalling the best "100 yards-in-ten-seconds" style of an Olympian sprinter, and was close behind at the end of the ubiquitous piece of string!

(1) The power required to fly an aircraft may be calculated from the formula:—

$$\text{H.P.} = \frac{DV}{375}$$

where D = drag of the aircraft, in pounds, and V = the speed of the aircraft in m.p.h.

(2) A well-tuned 18 cc. "Comet" engine will develop a good ·5 h.p. So, rewriting the formula in the form

$$D = \frac{375 \text{ H.P.}}{V}$$

and taking a value for V of 25 m.p.h.

$$D = \frac{375 \times \cdot 5}{25}$$

$$= 7 \cdot 5 \text{ pounds.}$$

i.e. at a speed of 25 m.p.h. ·5 h.p. will fly an aircraft whose total drag does not exceed 7·5 pounds.

(3) My bench tests have shown that a metal airscrew $17\frac{1}{2}$ inches diameter × 12 inches pitch, running at 3,800 r.p.m., will develop a static thrust of 6·2 pounds, which means that under correct flying conditions the effective propulsive thrust will be approximately 5·1 pounds.

(4) The difference between the figure of 7·5 pounds drag (as that which—theoretically—could be dealt with by ·5 h.p.), and that of 5·1 pounds (as the effective propulsive thrust available) represents, of course, the sum total of the engine and airscrew losses,

$$\text{i.e. } \frac{5{\cdot}1}{7{\cdot}5} = 68\% \text{ efficiency.}$$

(5) Assuming a figure of 65 per cent for the efficiency, the forward flying speed is calculated to be ·65 × 63·3 (revs. per sec.) × 1 (foot pitch) = 28·2 m.p.h.

Thus, *theoretically*, it is shown that a speed of over 25 m.p.h. could be obtained by an aircraft powered with a ·5 h.p. engine, provided the total drag did not exceed 5 pounds.

(6) The value of K for a totally enclosed fuselage of the type used is about ·0004; and the maximum cross sectional area of the fuselage = ·66 square feet. Thus, at a speed of 25 m.p.h. the drag is found (from the formula $D = KAV^2$) to be $\cdot0004 \times \cdot66 \times 25^2 = \cdot165$ pound.

(7) The aircraft was originally planned to have a wing area of 10 square feet and a weight of 13·5 pounds.

Rewriting the formula

$$L = C_l \frac{\rho}{2} SV^2$$

in the form

$$C_l = \frac{L}{\frac{\rho}{2} SV^2}$$

and taking a value of 25 m.p.h. for V

$$C_l = \frac{13{\cdot}5}{\cdot001189 \times 10 \times 36{\cdot}7^2}$$

(Note in this formula V is in feet per second).

Therefore $C_l = \cdot845$

(8) Reading from the chart, Fig. 2, the value of C_d (when $C_l = \cdot845$) is found to be ·07.

(9) The drag of the wings is then found from the formula

$$D = C_d \frac{\rho}{2} SV^2$$

Inserting the appropriate figures

$$D = \cdot07 \times \cdot001189 \times 10 \times 36{\cdot}7^2 = 1{\cdot}12 \text{ pounds}$$

(10) With a total drag of 1·28 pounds for the fuselage and main wings it is obvious that the drag of the rest of the aircraft would not increase this figure to much beyond 2 pounds; and since a maximum of 5 pounds was permissible it followed that the proposed power unit should be sufficient to fly the aircraft.

Since a propulsive thrust of some 5 pounds is available, it follows that a *smaller* engine, provided it developed say $3\frac{1}{2}$ pounds thrust (effective) should fly this machine—that it might not do so is also possible, since an airscrew must not only develop a certain thrust, but must do so at the correct forward speed, and under certain conditions the proper combination of these two features is not possible.

Attention is drawn to the fact that a power/weight ratio of 1·33 cc./pound weight is definitely possible; and it is hoped that this figure will be of some assistance to those aeromodellers who are contemplating designs incorporating one or other of the petrol engines now on the market.

(11) The original designs for this aircraft were got out on the basis of a flying speed of 23 m.p.h.; when $C_l = 1{\cdot}03$ and the wing setting was 4·5 degrees angle of attack measured from the geometric chord.

(12) During trials it was found—due to the margin of thrust power in hand—that the angle of attack could be increased to 12 degrees, which increased the C_l to 1·68 and reduced the speed to approximately 18 m.p.h.

(13) Since a test flight with extra load was found possible, wheels of hardwood, instead of balsa, were fitted, with the object of slightly lowering the centre of gravity, which incidentally is some 2 inches below the thrust line; also certain strengthening members were added to the landing chassis anchorages. Finally, a heavier coil was installed, bringing

the total weight up to 14 pounds; this gives a power/weight ratio of 1·29 cc./pound weight.

At this wing loading, the 'plane made several flights after being hand-launched from a moving car, as described in Chapter 17.

The final flights of the 'plane were made at Cranwell R.A.F. Aerodrome in the summer of 1939, where, at an all-up weight of 14 pounds 3 ounces, it took off from the tarmac under its own power.

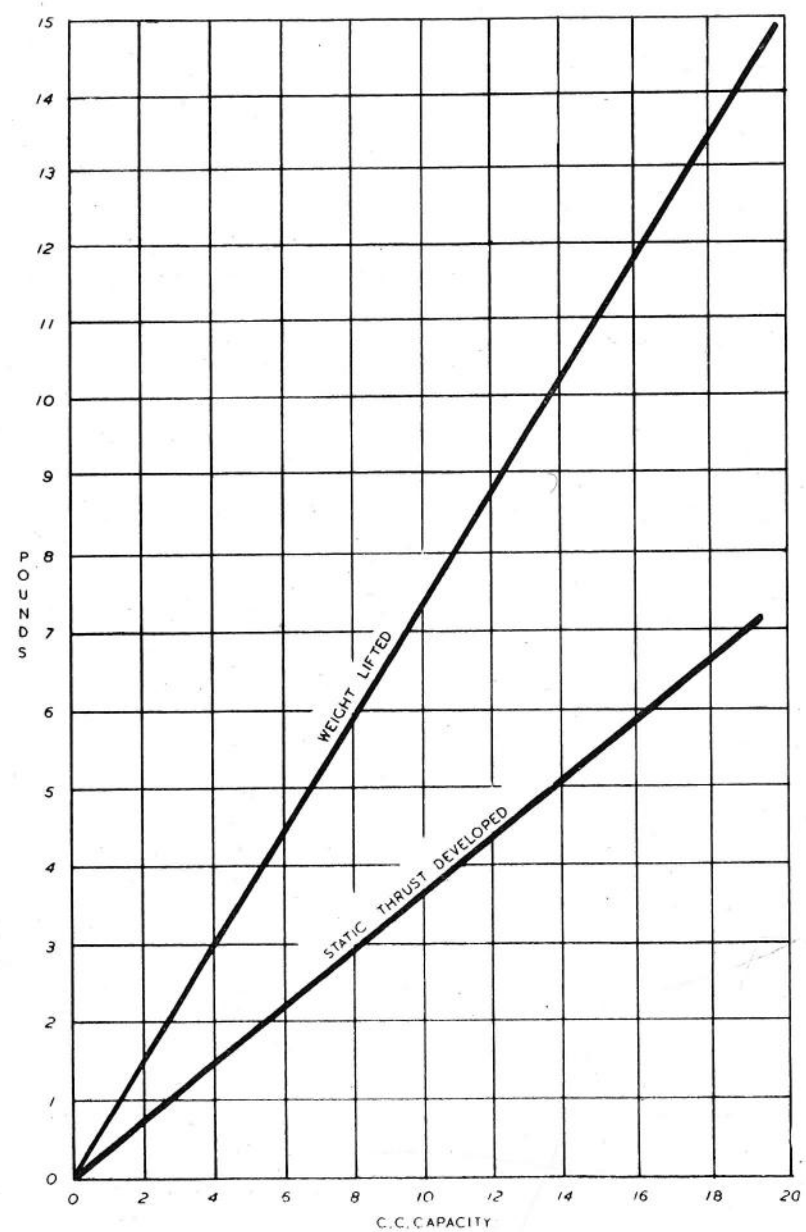
As previously pointed out, this 'plane was built solely as an experiment—to determine whether one of this size and weight could be flown.

In attempting its design and construction, the author was entering an hitherto unexplored sphere of model aircraft construction; and whilst no claim is made that the 'plane was capable of flying in anything but calm weather, owing to its being deliberately loaded up to the maximum, it has been a matter of satisfaction to the author that the performance estimated was obtained; and that, despite the prophecies of the sceptics, the 'plane *did* definitely take off under its own power and fly!

The fuselage has now passed into honourable retirement, very little the worse for several very severe "bumps"; whilst the main wings and engine "live to see another day"—being incorporated in the author's latest 1940 model, for which a new fuselage and tail unit have been designed.

APPENDIX 5.

In the chart on the opposite page is summarised the position as to the relation between power, as represented by cc. and weight to be lifted. From this it will be seen that for every one cc. of "engine size" a weight of approximately ·75 pounds may be lifted, and a static thrust of approximately ·37 pounds developed. These figures represent the average good performance obtainable in the light of present-day knowledge.



APPENDIX 6.

Some Notes on the Design of Airscrews for Power-Driven Aircraft.

An airscrew blade is, of course, an airfoil, and under working conditions produces lift (i.e. thrust) and drag, in exactly the same way as an aircraft wing; and when it is remembered that most airfoils "stall" at angles exceeding 20—25 degrees, it will be seen that any part of the blade of an airscrew which is called upon to operate at an angle exceeding this figure will only do so at a very low efficiency.

That this question of blade angle has a very marked effect on the efficiency of an airscrew may be appreciated from a study of Fig. 123, which shows the static thrust developed by two metal airscrews of same diameter and blade area but of different pitches—these being 12 inches and 22 inches respectively.

It will be seen that despite an increase of nearly 100 per cent in pitch angle the coarse-pitch airscrew develops very little extra thrust "all along the line."

Now it is well known that two-strokes develop their power at fairly high speeds, and the effect of such a coarse pitch as 22 inches is to slow down the engine speed considerably. (An 18 cc. "Comet" engine will drive the 12-inch pitch airscrew at 3,800 r.p.m.; but with the 22-inch pitch airscrew it will only go up to about 2,500 r.p.m., the resulting efficiency, therefore, being a good deal less.)

It will, of course, be appreciated that if the pitch of an airscrew is to be constant across the blade radius of the blade, the blade angle will increase towards the boss, resulting in the lowering of the efficiency of the centre portion of the air-screw—and a series of experiments with airscrews, the pitch of which *decreased* towards the boss, thus keeping the blade angle less acute, showed a useful improvement could be obtained.

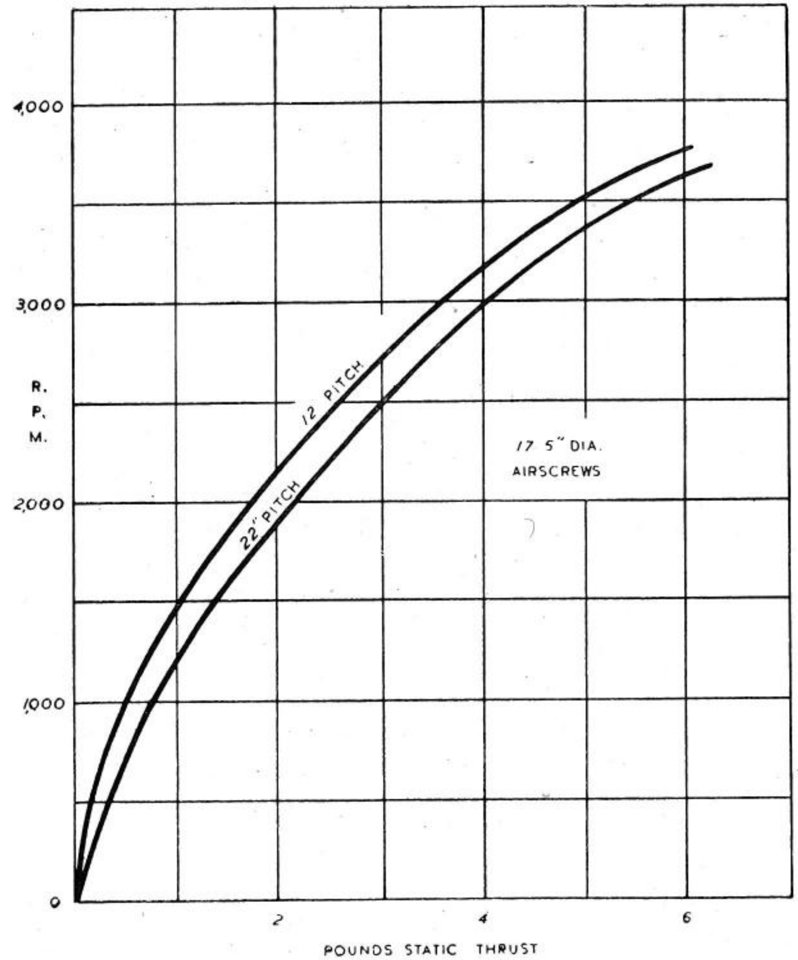


Fig. 123.

One comparison was between a $17\frac{1}{2}$-inch diameter × 12-inch pitch airscrew, the blade of which was twisted to 10 inches at the tips, and a wooden airscrew made with a pitch at the tips of $9\frac{1}{2}$ inches, which decreased to 8 inches at a point ·4 of the radius from the boss. The blade areas and thickness were, of course, the same in each case.

The actual pitch and blade angle at various points along the blades was as indicated in Table A.

TABLE A.

Distance from boss.	17½ in. dia. wood. Blade angle. deg.	17½ in. dia. wood. Pitch. in.	17½ in. dia. metal. Blade angle. deg.	17½ in. dia. metal. Pitch. in.
·4 radius	20	8	28	12·6
·5 "	19	9·1	23	11·8
·6 "	17	9·9	18	11·5
·65 "	16	9·9	18	11·5
·7 "	15	10·0	16	11·0
·75 "	14	9·95	14·8	10·7
·8 "	13	9·9	13·5	10·5
·85 "	12	9·65	12·5	10·3
·9 "	11	9·4	11·5	10·1
Average from ·65 to ·9		9·8 =·816 ft.		10·7 =·89 ft.

The results of static thrust tests from these two airscrews are shown in Table B.

TABLE B.

Airscrew.	Speed r.p.m.	Ideal thrust. lb.	Static thrust. lb.	Propulsive thrust. lb.	Overall efficiency. %
9·8 in. wood	3,900	6·72	5·6	4·65	69
10·7 in. metal	3,900	7·35	4·85	4·03	55

It should be noted that the "ideal" thrust is calculated from the formula given in this book, and the "propulsive" thrust is taken at 83 per cent of the static thrust actually developed.

Noting the efficiencies, the actual forward speed theoretically obtainable may be calculated by multiplying the pitch by the number of revolutions multiplied by the efficiency—which gives speeds of 36·5 feet per second for the wooden airscrew and 31·6 feet per second for the metal airscrew—and, substituting these figures in the formula,

$$J = \frac{V}{ND} \text{ we get } \frac{36{\cdot}5}{65 \times 1{\cdot}46} \text{ and } \frac{31{\cdot}6}{65 \times 1{\cdot}46}$$

which gives values for J of ·385 and ·332 respectively.

To further investigate this aspect of airscrew design two more airscrews, both 17½ inches diameter, the first with a tip pitch of 12 inches, which decreased to 10 inches at ·4 radius distance from the boss; and the second with a tip pitch of 14 inches, which decreased to 11 inches at ·4 radius from the boss, were made. The average effective pitches, therefore, being 11 inches and 12½ inches respectively.

When tested at 3,900 r.p.m., static thrusts of 6·5 pounds and 7·2 pounds respectively were obtained from these two airscrews. These results comparing with the figures of 5·6 pounds from the wooden airscrew and 4·85 pounds from the metal airscrew previously tested.

Tabulated, the results obtained from the four airscrews are as shown in Table C.

TABLE C.

No.	Airscrew details of pitch.	Average pitch inches.	Speed R.P.M.	Ideal thrust lb.	Static thrust lb.	Propulsive thrust.	Overall efficiency.
1	10 in. *increasing* to 12½ in.	10·7	3,900	7·35	4·85	4·03	55%
2	9½ in. *decreasing* to 8 in.	9·8	3,900	6·72	5·6	4·65	69%
3	12 in. do. 10 in.	11·0	3,900	7·6	6·5	5·4	71%
4	14 in. do. 11 in.	12·5	3,900	8·62	7·2	5·96	69%

The original airscrew fitted to the large low-wing monoplane was of 17½ inches diameter × 12 inches constant pitch which, when running at 3,800 r.p.m., developed just over 6 pounds static thrust. Here, now, in airscrew No. 4, is an airscrew of the same diameter, of only slightly larger *average* pitch, which, running at practically the same speed, develops an extra pound of thrust, whilst the efficiency rises to 69 per cent—from the figure of 65 per cent for the original airscrew.

Another way of demonstrating the increased output which may be obtained by decreasing the pitch of an airscrew towards the boss is to compare the results obtained by driving the various airscrews by an engine so controlled as to deliver a predetermined horse-power of exactly the same value in each of the tests.

Results from such a series of tests, on the four airscrews under consideration, are as shown in Table D.

Compare the results obtained from Nos. 2 and 4 airscrews:—

TABLE D.

H.P. absorbed.	Airscrew No. 1. 17½ in. dia. × 10·7 in. p. R.P.M.	Static thrust lb.	Airscrew No. 2. 17½ in. dia. × 9·7 in. p. R.P.M.	Static thrust, lb.
·29	3,460	3·60	3,220	3·6
·5	3,900	4·85	3,900	5·6
	Airscrew No. 3. 17½ in. dia. × 11 in. p.		Airscrew No. 4. 17½ in. dia. × 12½ in. p.	
·29	2,950	3·8	2,730	3·8
·5	3,740	6·2	3,580	6·5

In the first case the ideal thrust at 3,900 r.p.m. = 6·72 pounds, which, compared with the developed *propulsive* thrust (83 per cent of the static thrust, as shown in Table C) = 4·65 pounds: gives an overall efficiency of 69 per cent; and in the second case the ideal thrust at 3,580 r.p.m. = 7·9 pounds, which, compared with the developed *propulsive* thrust = 5·4 pounds, gives an overall efficiency of 68 per cent, i.e. although the average pitch has been increased from 9·7 inches to 12·5 inches—due to the new design—the efficiency has not dropped by any amount which matters—*but a gain of approximately 1 pound of effective thrust has been obtained*, from 4·65 to 5·4 pounds, an increase of 16 per cent.

Finally, the actual flying speeds may be calculated to be, in the first instance, equal to—

65 (revs. per sec.) × ·815 (pitch in feet) × ·69 (efficiency %) = 25 m.p.h. and in the second case equal to

60 (revs. per sec.) × 1·04 (pitch in feet) × ·68 (efficiency %) = 29 m.p.h.

Summed up, No. 4 airscrew gives a speed increase from 25 m.p.h. to 29 m.p.h., and propulsive thrust increases from 4·65 pounds to 5·4 pounds over No. 2 airscrew, *whilst absorbing*

no more power from the engine (whose speed is reduced from 3,900 r.p.m. to 3,580 r.p.m.).

Next, the investigation was extended to cover a family of airscrews of 13 inches diameter, as used on the 6 cc. "Baby Cyclone."

First of all, experiments were carried out with an airscrew 13 inches diameter × 6·6 inches average pitch—the actual pitch at various radii from the boss being shown in Table E.

TABLE E.

Distance from boss.	No. 1 airscrew pitch.	No. 2 airscrew pitch.
	in.	in.
·4 radius	5·5	4·5
·5 ,,	5·8	5·4
·6 ,,	6·2*	6·2*
·7 ,,	6·5*	6·5*
·8 ,,	6·8*	6·8*
·9 ,,	6·8	7·1
Tip	6·9	7·4

* *Average between ·6 and ·8 radius* 6·5 inches in both airscrews.
Average of No. 1 = 6·36 inches.
Average of No. 2 = 6·27 inches.

The actual static thrust developed by these two airscrews, tested over a wide range of speeds, is shown in Table F. No. 2 airscrew was made of same diameter and *average* pitch, but, as will be seen from the table, the tip pitch was slightly greater, whilst (and this is the important point) the pitch decreased considerably from ·6 to ·4 radius from the boss.

(The most operative part of an airscrew blade is that part which lies between ·6 and ·8 radius from the boss, and the "average" pitch of this family of airscrews is calculated as between those points.)

From a study of these figures it will be seen that there is approximately a 10 per cent increase in static thrust throughout the speed range—without any increase in power required.

As a "Baby Cyclone" engine in good fettle will run up to some 5,000 r.p.m., driving either of these airscrews, it

TABLE F.

Airscrew No. 1.		Airscrew No. 2.	
R.P.M.	Static thrust.	R.P.M.	Static thrust.
	lb.		lb.
2,600	·55	2,600	·65
3,120	·86	3,100	·98
3,900	1·25	3,910	1·4
4,540	1·7	4,500	1·88
5,140	2·15	5,100	2·38
5,580	2·7	5,600	3·0

will be seen that a good $2\frac{1}{4}$ pounds of static thrust may be obtained at this speed—or about $1\frac{7}{8}$ pounds propulsive thrust in actual flight.

Now calculations for the "ideal" thrust gave a figure of 3·22 pounds at 5,100 r.p.m., whilst taking 83 per cent of the static thrust developed (2·38 pounds), gave a figure of 1·97 pounds as the maximum propulsive thrust, the resulting figure for efficiency being 61 per cent—rather on the low side. (Calculations for the value of J give a figure of ·3, also low).

It, therefore, seemed as if the decreasing of the pitch had been carried out *too* drastically; and after a consideration of all the information which had been obtained throughout this series of experiments, four more airscrews—all of 13 inches diameter and same blade area as before—were made.

In these airscrews the decrease in pitch was not so great; and, as will be seen from the results given in Table A, a considerable increase in static thrust developed was obtained.

For comparative purposes, the results obtained from the tests on the second of the first two airscrews tested are given in column 1 in table G.

Comparing airscrews Nos. 2 and 3 it will at once be seen that the less severe decrease in pitch has resulted in a useful increase in static thrust developed; with a consequent increase in efficiency from 61 per cent to 74 per cent.

The average pitch, be it noted, is the same for each airscrew; as was also the power absorbed at the speed of 5,100 r.p.m.

Examining the results obtained from the rest of the airscrews, it will be noted that whilst the static thrust developed increases, it does not do so at the same rate as the "ideal" thrust—i.e. above 7 inches to 8 inches average pitch, the blade angle is becoming too coarse, and the efficiency falls off.

TABLE G.

	Airscrew 2.	Airscrew 3.	Airscrew 4.	Airscrew 5.	Airscrew 6.
Pitch at tip ..	7·4 in.	7 in.	8 in.	9 in.	10 in.
Pitch at ·4 rad. from boss ..	4·5 in.	6 in.	6·875 in.	7·75 in.	8·625 in.
Average pitch ..	6·5 in.	6·5 in.	7·4 in.	8·4 in.	9·3 in.
Speed, R.P.M. ..	5,100	5,100	5,130	5,090	4,960
Static thrust ..	2·38 lb.	2·9 lb.	3·0 lb.	3·12 lb.	3·3 lb.
"Ideal" thrust..	3·22 lb.	3·32 lb.	3·7 lb.	4·2 lb.	4·5 lb.
Propulsive thrust	1·97 lb.	2·4 lb.	2·5 lb.	2·6 lb.	2·75 lb.
Efficiency ..	61%	74%	67%	62%	61%
J = ...	·30	·37	·38	·4	·44

To sum up, the following conclusions seem to be indicated:—

1. The *average* pitch of an airscrew should be not less than half the diameter, nor more than 7/10 the diameter.

2. Matters should be so arranged that the value of J is not less than ·35; greater, if possible.

3. If the *average* pitch of an airscrew is to be half the diameter, then the tip pitch should be 1·1 × the average; whilst that at ·4 radius from the boss should be ·9 × the average, i.e. if the diameter is 16 inches and the average pitch is 8 inches, then the above-named limits should be (8 × 1·1) = 8·8 inches; and (8 × ·9) = 7·2 inches respectively.

4. If the *average* pitch of an airscrew is to be 7-10 the diameter, then the tip pitch should be 1·13 × the average; whilst that at ·4 radius from the boss should be ·87 × the average, i.e. if the diameter is 10 inches and the average pitch is 7 inches, then the limits are (7 × 1·13) = 7·9 inches; and (7 × ·87) = 6·1 inches respectively.

ACKNOWLEDGMENT, WITH THANKS, IS MADE TO THE FOLLOWING MODEL AIRCRAFT FIRMS WHO KINDLY LOANED BLOCKS OF THE UNDERNOTED ILLUSTRATIONS FOR USE IN THIS BOOK.

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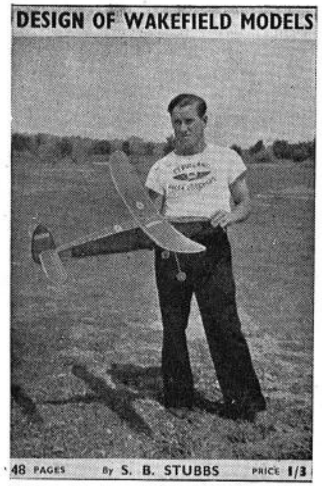

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