MARSHALL'S PRACTICAL MANUALS No. 12

The MODEL AEROPLANE MANUAL

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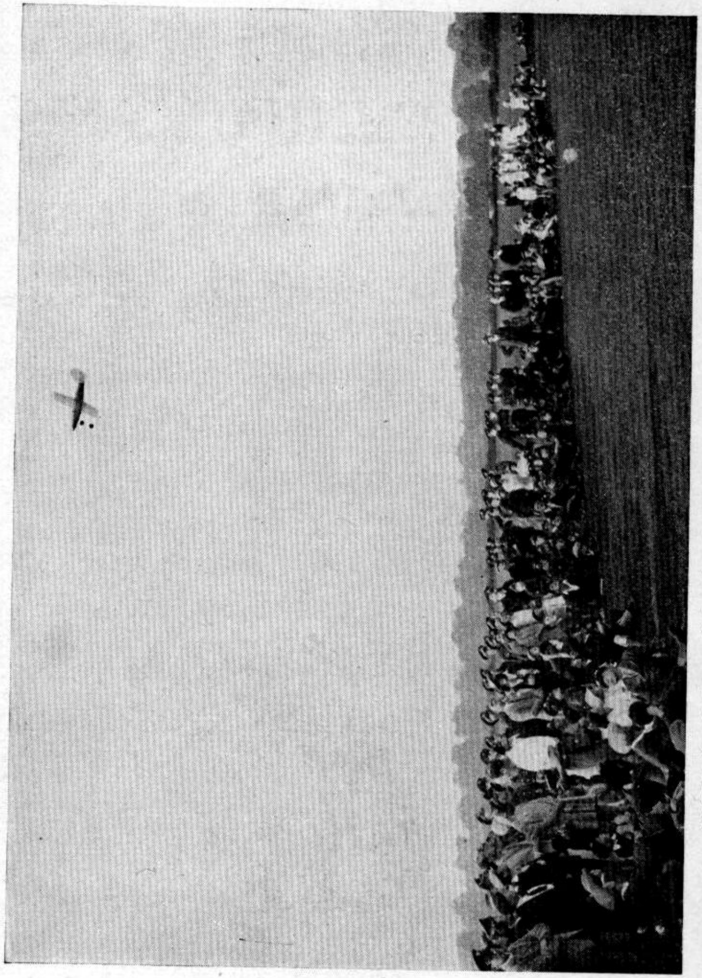
A Complete Guide to Building & Flying

PERCIVAL MARSHALL & Co. Ltd LONDON W.C.

THE MODEL AEROPLANE MANUAL



International Competition for the Wakefield Cup at Halton Aerodrome

Marshall's Practical Manuals.—No. 12.

THE MODEL AEROPLANE MANUAL

A Practical Handbook on the Building and Flying of Model Aeroplanes.

Fully Illustrated.

EDITED BY
R. LANGLEY.

Second Edition. Revised and Enlarged.

LONDON:
PERCIVAL MARSHALL & CO., LTD.,
13-16, Fisher Street, W.C.1.

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MADE AND PRINTED IN GREAT BRITAIN.

PREFACE TO REVISED EDITION

THE success of this book during the few months it has been before the public has justified a second edition. When it first appeared towards the end of 1930 I mentioned the great progress which had been made during the previous three years. Since then further progress has been made and new records have been set up. While the greater part of the book remains unaltered, several small corrections have been made, and new matter has been added, including a description of a very popular machine. As before a certain amount of overlapping has been eliminated, but as each chapter is written by a specialist, and differing opinions on the same subject are often worth retaining for their own sakes as offering equally tenable aspects of the same problem, this elimination has not been carried to the extreme.

The Editor is very grateful to the following model builders who contributed the original articles, or provided material for articles, and without whose labour this book could never have appeared: R. N. Bullock, W. E. Evans, J. E. Pelly Fry, J. van Hattum, B. K. Johnson, M. R. Knight, T. H. Newell, D. A. Pavely, W. J. Plater and R. J. Trevethick. He also wishes to thank many members of the Society of Model Aeronautical Engineers for their very helpful suggestions.

THE EDITOR.

THE MODEL AEROPLANE MANUAL.

CHAPTER I.

MODEL AVIATION AS A HOBBY.

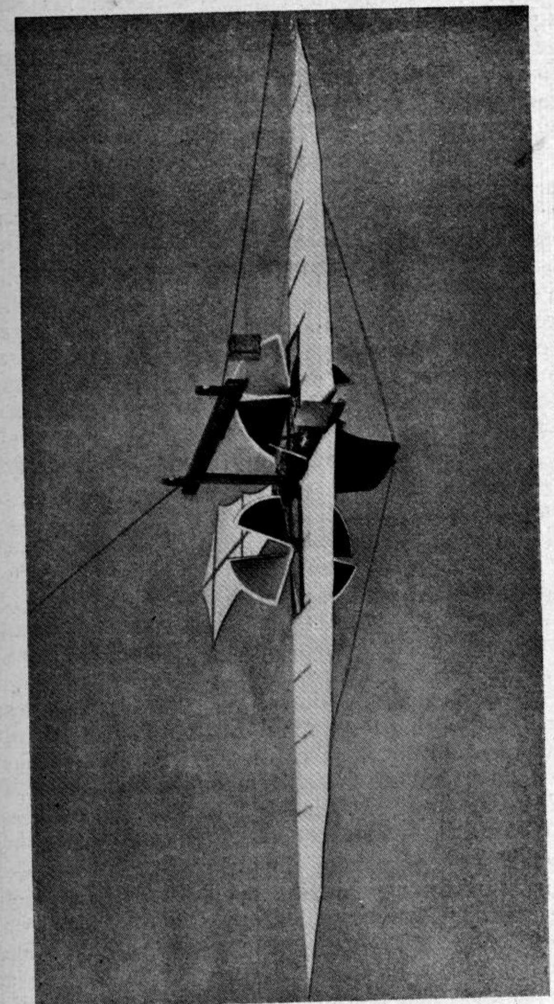
MODEL AVIATION may be said to date back to 1848, when Stringfellow built his model, which was the first actually to fly; a replica of this historic model is illustrated on page 9. The actual remains of the machine are still to be seen in the Science Museum, South Kensington. Later, in 1890-1894, models were used in experiments connected with the work of Maxim, but it was not until 1907 that the first model aeroplane competition was held, this being won by Roe (now Sir A. V. Roe) with a model using rubber as a motive power. A few years after this, model flying began to come popular, and by 1910-11 many individual clubs came into existence, and their general interests were cared for from that time up to 1914 by a body known as the Kite and Model Aeroplane Association. The war (1914-18) brought about a cessation of activities in model flying, but at its termination a small band of enthusiasts again assembled, which, under the name of the Society of Model Aeronautical Engineers, has kept alive the interests of model aviation during the somewhat trying but nevertheless eventful post-war period up to the present day.

Such is a very brief outline of what has been done in model flying since its earliest days, and which it is of interest to look back on occasionally in these days of such highly developed flying models.

Model aeronautics, like other forms of model engineering, has the enjoyment of original design and the pleasure of constructional work incorporated in it, but it also has the very great additional interest of testing the result of one's work in the form of free flight. This is probably the greatest appeal in favour of model aviation for to see a model aeroplane rise off the ground under its own power, climb steadily to sixty or seventy feet in the air, circle overhead for some time, and then (when the power is run out) to commence a long, graceful glide, and finally to land, is a sight which must be witnessed in order to be fully appreciated.

Such a sight is a fairly common occurrence at any model flying meeting of the present day, but the difficulties of obtaining such success must not be overlooked, for it must be remembered that a certain amount of knowledge in aircraft matters is necessary in order to build a successful model. Such knowledge, which has accrued from several years of experience of some of the best aeromodellists in the country, has been brought together in this book by the joint efforts of members of the S.M.A.E. with the idea of helping the cause of model aeronautics generally.

Those who have only had a little experience with model aircraft, and indeed those of us who have some, will find these pages full of helpful suggestions as to the building of varied types of modern model aeroplanes; and to the former the writer would urge that they do not attempt to construct too difficult a model at first, for this may result in a certain amount of disappointment when it comes to testing the flying capabilities of the machine, owing to the fact that an early "crash" (quite a likely occurrence to one who is commencing model flying) may result in a large number of hours of work being spent on repairing the damage. From this point of view, therefore, a machine of the "spar" type is the one to be strongly advocated as a first model, whilst the more complicated fuselage type can be attempted later, when some experience has been gained. To the uninitiated perhaps a few words of friendly advice may not be out of place, for whilst not wishing to damp any enthusiasm, it should be pointed out that there are difficulties which may beset the newcomer to model flying, and therefore it is better at the outset for him to copy carefully some design, such as is given in these pages, which is known to give reliable results rather than to build a machine which one might imagine would be "better" than that described.



Replica of Stringfellow's Model Aeroplane, 1848.
(In the Science Museum. Reproduced by permission.)

When once the aeromodellist has achieved his aim in producing a successful model the "adventure" has commenced, for he is immediately spurred to go on, and one of the incentives in this direction is the desire to compete with other aeromodellists. This undoubtedly is the true enjoyment of model flying, hence the reason for the existence of clubs and the arrangement of competitions of various kinds. As an example of how really delightful a flying competition can be no better example could be given than the International competition for the Wakefield Cup held at Halton Aerodrome on July 14, 1929, a photograph of which forms the frontispiece to this book.

The presence of large numbers of models, the fact of three different countries competing, the keenness and friendly nature of the competitors, a glorious flying day, and the general sporting spirit that prevailed all combined to make an ideal setting for what was one of the finest model flying meetings yet held. An equally successful meeting was held in 1930.

When the stage is reached that the aeromodellist feels that he can produce a reliable and consistently flying fuselage model his limitations are by no means at an end, for there are many lines along which he may still exercise his originality. For instance, several of these are self-suggested by looking through the different types of competitions which are organised by the Society of Model Aeronautical Engineers; amongst these he will find, besides the competitions for pure duration, such interesting events as competitions for speed, for seaplanes, for gliding, weight-carrying tests, flying round a triangular course, and so on. Then he may turn also to the construction of compressed air-driven machines, or even petrol-driven models, so that the field for exploration is indeed wide, and does, I venture to say, offer more scope than most forms of model engineering.

There is a possible objection which non-aeromodellists sometimes raise against model flying, and that is that it is limited to the summer months of the year; in this connection they should be assured that the winter months give good opportunities in which to contemplate the design and build a model or models (a good model taking many weeks of spare time), and, moreover, the recent introduction of indoor flying

competitions should do much to keep interest alive in the dark evenings.

An important side of model flying, and one which is not to be overlooked, is the setting up of new records. This list will, it is hoped, induce some to make attempts at breaking these. It is a side which calls for quite exceptional skill and resource, and is ideal for those who delight in undertaking a really "stiff job"; nevertheless, the recent knowledge freely contributed by technical members on such subjects as efficient wing-section design, systematic studies of the energy obtainable from rubber motors, methods of construction employing new materials—to quote only a few—should make it not impossible for some of the figures in this table to be raised in the near future.

LIST OF BRITISH RECORDS (1931).

FUSELAGE MACHINES ...	Off ground ...	*A. T. Willis	155 secs.
,, ,, ...	Off water ...	*A. M. Willis	64.6 ,,
,, ,, ...	Hand launched	*G. F. Salter	190 ,,
,, ,, ...	Speed	R. N. Bullock	30 m.p.h.
,, GLIDER ...	Hand launched	*T. H. Ives	59.8 secs.
SPAR TWIN PUSHER ...	Off ground ...	S. C. Hersom	247 ,,
,, ,, ,, ...	Off water ...	S. C. Hersom	65 ,,
,, ,, ,, ...	Hand launched	T. D. C. Chown	145 ,,
,, AUTO-GYRO ...	Hand launched	D. A. Pavely	25.8 ,,
,, TRACTOR	Off ground ...	D. A. Pavely	111.2 ,,
,, ,, ...	Off water ...	S. C. Hersom	43 ,,
,, ,, ...	Hand launched	D. A. Pavely	110.6 ,,
,, FARMAN TYPE ...	Off ground ...	C. A. Rippon	32.4 ,,
,, ,, ,, ...	Hand launched	C. A. Rippon	37.8 ,,
,, GLIDER	Hand launched	C. J. Burchell	53.4 ,,
COMPRESSED AIR-DRIVEN	Fuselage (off ground)	D. A. Pavely	67.6 ,,
,, ,,	Non-fuselage (off ground)	D. A. Pavely	70 ,,
PETROL DRIVEN ...	Off ground ...	D. Stanger ...	51 ,,

(*New records made in 1931.)

In conclusion, it is hoped that these few remarks may go to illustrate in some small way the possibilities of model flying as a scientific hobby and as a sport of no mean order, and that this book may prove of value to all those interested in model aeronautics, whether they be potential aeromodellists or experienced model-flyers.

CHAPTER II.

WORKSHOP EQUIPMENT AND TOOLS FOR MODEL AEROPLANE BUILDERS.

MODEL aeroplane building as a hobby is quite inexpensive, and, except for the tools required to build the more elaborate types, need not run to a great deal.

In the early days many good model aeroplanes were built with very few tools and any old material that came to hand; the tools used by some of the early model builders amounted to a pocket-knife, a pair of scissors, a triangular file, an archimedean drill and a pair of pliers, but, like every other hobby, much more elaborate and much more efficient and interesting models can be built with a properly equipped workshop. Therefore in this chapter it is intended to give a full list of the tools, etc., needed to build model aeroplanes, but not engines, as this is rather a subject in itself and needs metal-working tools, such as lathes, drilling-machines, grinders, etc., which cost more than the simpler hand-tools which form the subject of these notes.

The suggestions made here are almost ideal, and the reader is left to adjust his particular needs to meet his own circumstances as near as possible.

The Workroom.

The room in which the work is done should be about 12 ft. by 10 ft., with one or even two windows in the 12-ft. wall. It should be well ventilated and heated with a gas stove for preference, so that a Bunsen may be run off it for soldering, hardening, sweating, tempering, bending, steaming, drying, etc. The room should be sufficiently lit with electric lights hanging at convenient points over the bench, fairly near the window side of it. It is also preferable that the workroom should have a water supply.

The Bench.

The bench, which is illustrated herewith, should stand in such a position that it is possible to get all round it, but also in such a position that the light from the windows lights

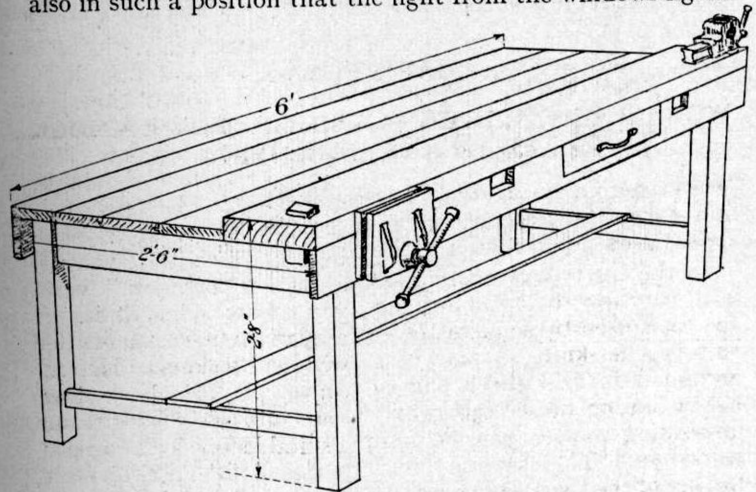


Fig. 1.—Work Bench for Aero Modellers.

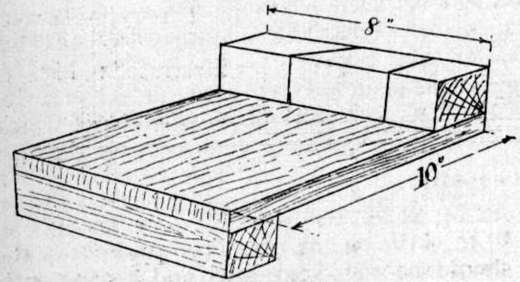


Fig. 2.—Bench Hook.

it thoroughly. The gangway on the window side of the bench need not be very wide and the side at which you intend to work should be at the opposite side to the window, so that you do not get in your own light. The bench (Fig. 1)

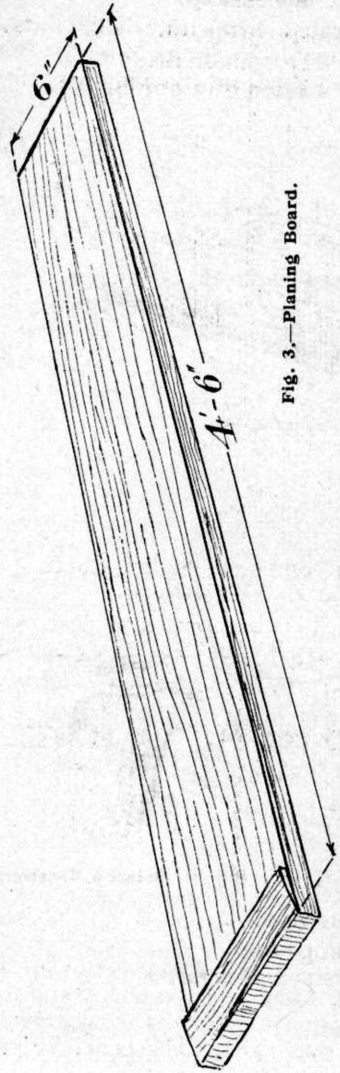


Fig. 3.—Planing Board.

should be about the dimensions given, or larger. It should have a woodworker's vice and a fitter's vice at opposite ends, an adjustable planing stop and cramp holes cut into the front board, just below the thick piece running along the top of the working side. The feet should be attached to the floor, particularly if it is a small bench, otherwise it will not always "stay put" when you are working at it. It may advantageously be fitted with end lockers and a front drawer in which to keep tools, etc. Failing to procure a suitable bench a table may be rigged up to take its place, but a real bench is always best.

Three simple wooden additions to your bench are illustrated: Fig. 2, a broad type of carpenter's hook or sawing board, which can be hooked over the bench edge. This is a great help in sawing small pieces of wood across the grain at right angles, or 45°. Fig. 3, a planing board with a very shallow stop, to be used in light, delicate planing. Fig. 4, a fretting vee, which can easily be screwed or cramped on to the bench.

Tools That May be Found Necessary.

Joiner's hammer, not too heavy (Fig. 6).
Tack hammer, very light, with thin shaft.
Fitter's hammer, light (illustration of head, Fig. 5).
A small fine-set rip-saw.
A small very fine tenon-saw.

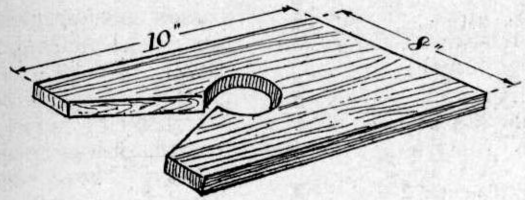


Fig. 4.—Fretting Vee.

A fretsaw.
A hacksaw, 10-in.
A key-hole saw and a set of blades.
A small metal square, 6-in.
A large wooden, metal or composite square, 10-in.
A bevel, 6-in.

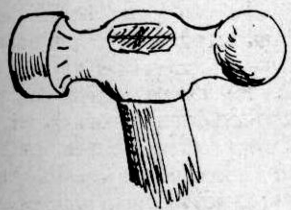


Fig. 5.—Fitter's Hammer.

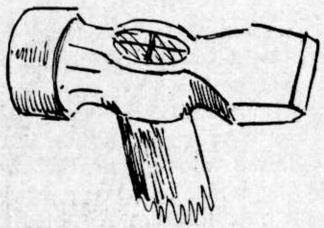


Fig. 6.—Joiner's Hammer.

A marking gauge, woodworker's.
A pair of 6-in. joiner's compasses.
A pair of inside and outside calipers.
A scriber.
A 4-ft. steel tape.
A 12-in. steel rule.

A joiner's 4-ft. folding rule.
A wheel brace.
A belly brace with ratchet.
Screwdrivers, large and small.
Bradawls, a few different sizes.
Twist drills and centre-bits (from 1/32nd-in. to $\frac{1}{4}$-in.).
A good pocket-knife with two blades and a handle which will not hurt your hand.
Chisels, $1\frac{1}{4}$-in. bevel edge, $\frac{1}{2}$-in. and $\frac{1}{8}$-in. (Fig. 12).
Two or three paring and scooping gouges (paring Fig. 13, scooping Fig. 14).
Planes, a jack, and a small metal block plane, Stanley No. 220 (Fig. 7), 6-in.

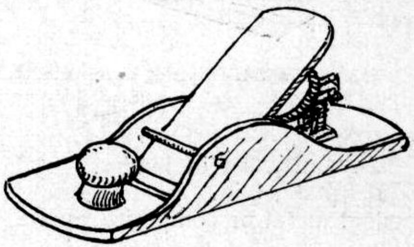
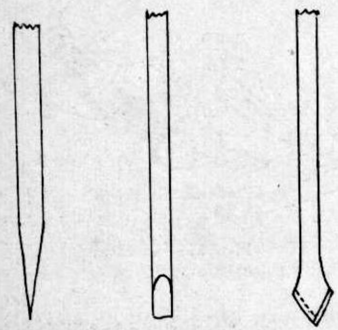


Fig. 7.—Small Iron Plane.

Six small cramps (Fig. 11).
About half a dozen small needle files.
A glue-pot.
About half a dozen 8-10-in. files, flat-round, half-round, square, triangular, etc.
Three wood rasps, flat-round and half-round, smooth and 8 ins. long.
A few handles for files and rasps.
A pair of fairly strong scissors, a pair of metal snips.
About half a dozen pairs of pliers of assorted sizes and types, namely, ordinary flat-nosed, round-nosed, pointed, and pincer-headed for cutting fine wire ; none of these need be very large, about $3\frac{1}{2}$ to 4 ins.
A pair of music-wire cutters, with replaceable blades, would be very helpful, and a pair of strong flat pliers for strenuous occasions.

A small soldering bolt.
An oil-stone, a gouge slip and a mechanical grinding wheel, hand operated.
A centre-punch, a vee-block and perhaps a small micrometer, and a standard wire-gauge.
Then there are a few drawing instruments, large compasses, spring bows and dividers, a protractor, a scale or two, a 45° and 60° set-square and a few curves, a tee-square and a drawing-board.

The foregoing list of tools, etc., if bought right out and new would cost a good deal, but if accumulated over a year or two do not seem to cost so very much. With these tools and equipment almost any type of model aeroplane can be made from the usual sorts of aeroplane material.



Figs. 8, 9, and 10.
Types of Piercing Tools and Diamond Point Drill.

Extra Tools.

Many other handy tools can be devised, such as small bradawls, from different gauges of piano wire, drills from the same material. These last are done by cutting off the required length and softening in a flame and shaping to whatever type of point may be wanted, such as those illustrated, greatly enlarged, in Figs. 8, 9 and 10; Fig. 8 being a piercing point to make fine holes in thin sheet metal, paper, etc., Fig. 9 being a chisel point chiefly useful for piercing holes in wood, and Fig. 10 being a diamond or mitre point for drills. These may all be hardened to the required hardness by heating to a dull red and quenching in water, the hardness being increased by getting the wire brighter red as required, but in most cases a sufficient hardness is obtained with a dull-red heat, and in some instances even this is so hard that the wire becomes brittle.

These wire punches, bradawls, etc., are bent and fitted to hard wood handles or sweated into pieces of flattened tube. Sand-paper blocks of various shapes and sizes are always useful and can be made from cork, balsa wood or linoleum; shapes of flat, half-round, round, triangular, etc., always being useful.

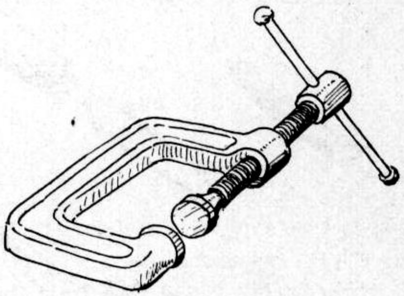


Fig. 11.—Cramp.

Soldering.

Soldering is generally a source of great trouble to beginners, and so a few words on this subject may be found useful.

The bolt, which is copper and shafted in any suitable manner with iron or steel and attached to a wooden handle, should be most carefully tinned thus: Heat to just below colour showing, file the nose absolutely clean and apply solder dipped in flux (paste) or spirit (zinc chloride) until a bright film is produced over the complete nose of the copper bolt, this, of course, being possible only when the bolt is hot and clean and entirely free from oxide.

"Killed spirits" is strongly recommended for soldering, and this is made by dissolving zinc in hydrochloric acid until no further chemical action is produced, when the liquor is strained off. The dissolving process is done in a jam jar or glazed pot, and the liquor kept in a glass bottle, a little at a time being put into a saucer as needed.

When once the soldering bolt has been tinned it should never be allowed to get red hot, or the tinning will be burnt off and will have to be done again. Parts to be soldered must be absolutely clean and bright; paint both parts to be soldered with spirit and apply a hot soldering bolt well tinned and absolutely clean; it may need a smart wipe with a cloth or a dip into spirit to make it perfectly clean after heating, as even at fairly low temperatures solder or the tinning on the bolt oxidise slightly.

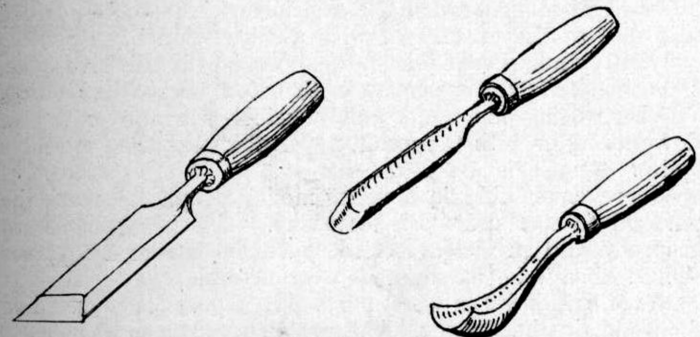


Fig. 12.—Type of Suitable Chisel. Figs. 13 and 14.—Types of Gouges.

Parts to be soldered and at times held in position should be bound with fine copper wire; or florist's wire can be used in an emergency. Difficult soldering may at times be accomplished by tinning the parts to be soldered separately, then holding the parts together and applying a Bunsen or blow-pipe flame. This is termed "sweating," and is suitable for plate work, sleeves on tubes, etc.

Working in Sheet Metal.

When cutting metal sheets, three-ply or any wood parts where exact pairs or any number is required it is helpful to make a template, or to fasten a number of pieces of wood or metal together and cut out all at once.

When cutting metal sheets with a hacksaw chatter can be reduced to a minimum by putting the metal to be cut between two sheets of thin wood.

Glued Joints.

When glueing up large wood joints scratch or score the level clean surfaces, use thin glue, rub well and cramp tightly, and work in a room of high temperature, say, 75° F.

Processes and Methods of Working.

When planing or sand-papering thin wood strips or sheets hold in tension and work away from point of holding.

When drilling metal mark position of hole to be drilled and dint at the exact spot with a centre-punch.

When binding coat joint to be bound with adhesive, glue, seccotine, cellulose or cement both before and after binding.

When using fine nails and clinching them over flatten down along or with the grain, never across as this produces splits.

Wherever possible, in building model aeroplanes, mark the part off to size and work to marks. This is conducive to accuracy and precision. Metal parts on model aeroplanes should always be as small as ever possible.

Never drill holes in wood parts if it is possible to avoid so doing as this has been the cause of many structural failures. Whenever drilling holes in wood see that you allow the drill to cut, do not push the brace, and also see that the underside is resting on a firm smooth surface; this produces a clean finish. When it is necessary to drill a hole very near the end of a piece of wood safety in this operation may be got by soaking the end to be drilled in glue size and allowing to dry absolutely hard, when splitting will be practically obviated.

Whenever a model or part of a model is to be made be sure to think it out carefully before you start; make drawings, full size if possible, and half size if this is not possible. The habit of scheming or designing on paper before you actually start work is absolutely essential as you can keep these schemes, put notes on them after trial, and so develop your ideas.

Never try to cut wood with blunt tools: it is dangerous, even more so than with sharp ones.

Even after having schemed and drawn your ideas on paper it is necessary to mark out on the material used the exact shapes and sizes of the parts to be made. This is called setting-out, and can be of great assistance if done carefully.

When attempting to build model aeroplanes it is essential to know first what you want to build, how you are going to build it, what it is built of, exactly what is required to do the job, and a place to do it in and on. So now a few notes on materials will not come amiss.

Choice of Woods.

The best woods for model aeroplanes are:—

Silver spruce—spars, ribs, longerons (29 lbs. a cu. ft.).
Birch—ribs, spars, longerons, etc.
Cane—main plane, outlines, tails, rudders.
Balsa wood—ribs, spars, etc. (7 lbs. a cu. ft.).
Canary—spars.
Satin walnut for carved propellers.
Three-ply—formers, bulk heads, wheels, ribs, etc.
Deal for propellers.

Covering and Other Useful Materials.

Silk, proofed, moderate performance.
Silk, unproofed, moderate size (to be doped with cellulose dope).
Tissue paper, Japanese, Imperial (to be doped with cellulose dope).
Glue, Croid, Seccotine, Scotch glue, etc.
Binding, cotton thread, linen thread, fine wire, strips of unproofed silk, etc.
Metal sheet, brass, steel, aluminium, dural, and tinned iron.
Wire—chiefly piano wire, or wire of almost the same high tensile strength for any part of the model.
Elastic—strip, $\frac{1}{4}$ in. by 1/32nd in. for large models; small models $\frac{1}{8}$ in. by 1/32nd in.; very small models 3/64th in. by 3/64th in. square.
Collets (cup washers), steel sheet, also fine tube.

CHAPTER III.

WING CONSTRUCTION.

THIS subject is one very rarely touched in books on model aeroplanes, which is rather surprising, for the wing is easily one of the most important parts of a flying machine. In fact, it is the wing of an aeroplane which differentiates it from other mechanical means of transport from one place to another.

In full-sized practice, of course, it is dealt with fully, but for some reason or other the aeromodellist is usually left to his own resources in this matter. This chapter is written in an effort to give to those who are just beginning to build model aircraft some idea of the various methods of wing construction and their respective good points.

Assuming in the first place that we are dealing with monoplanes, these can nowadays be divided into two classes: (1) Cantilever monoplanes, and (2) semi-cantilever monoplanes (Figs. 15 and 16). A cantilever monoplane is one in which all the strength of the wing is due to its internal structure, and a semi-cantilever monoplane is one in which the wing is partially supported by external struts, usually running from a position along the wing to the fuselage.

The general trend of model design to-day veers towards the cantilever type as it is more efficient, having less resistance and also being much easier to construct. One advantage of the semi-cantilever type is that the two sides of the wing can be made as separate units and are, therefore, easier to pack, but this is balanced by the fact that the braced wing has to be in a fixed position, and, unless the design of the model is exceptionally accurate, it will mean that a small piece of lead will have to be added to the model in order to get the correct balance. This, of course, is where the cantilever wing scores, as it is only necessary to slide the

wing along the fuselage to get the true position, without adding any unnecessary weight. The last few remarks will perhaps explain why one sees so many non-braced models to-day.

Having outlined the two types of wing used on aeroplanes let us now turn to the construction of cantilever wings. In the first place the wing span and the weight of the model complete largely determine the strength of wing necessary, but one of the most important factors to take into consideration is the aspect ratio. This is obtained by dividing the span by the chord, or, if it is a tapering wing, the mean

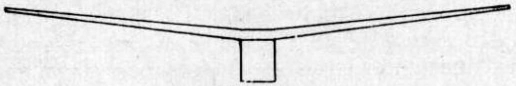


Fig. 15.

chord. Thus, a wing with a span of 48 ins. and a chord of 6 ins. has an aspect ratio of 8. Of the half a dozen odd stresses set up in the wing of an aeroplane we need only consider three. (1) Lift stresses due to the lifting force equal to the weight and carried by the main spars running from tip to tip. (2) Drift stresses, taken account of by the fabric covering of the wing, and, if any, internal wire cross bracing. (3) Landing stresses due to the shock of alighting. Of the three the first and the last are the most important stresses

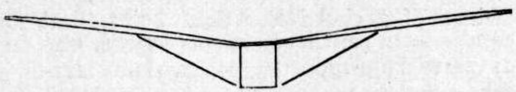


Fig. 16.

to consider, as the second is amply taken care of by the wing covering, no further strengthening being necessary except in the case of very large models, and even then it is hardly necessary. Sometimes, though, a wing is weak in this second item before covering, and one has found cases where the covering of the wing has disfigured the shape of the wing in plan view due to stretching the silk unevenly. Of course, the finished article was strong enough in all conscience, but just a trifle crooked! However, careful wing covering will soon eliminate trouble there.

As the lifting forces and the landing forces are more or less running together it is usual to make one set of spars serve both purposes, or, rather, to counteract them. One might add at this point that with the average model, weighing not more than a pound (or even more), and with a medium thickness wing section, there is very little tendency for wing-flutter to set in as here, again, the wing covering (in the case of double-surfaced wing, *i.e.*, covered both top and bottom) takes all the stresses. The only wings able to develop wing flutter in flight are those which are single-surfaced and with small spars.

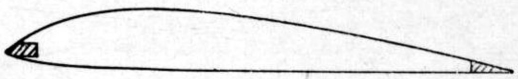


Fig. 17.

The next item to be considered is the wing section employed. The greater the camber of the wing section the smaller the spars necessary. One of the most successful wing sections used on models is the "Clark Y." This section has a maximum depth of nearly one-ninth of the chord. It will, perhaps, be best to take this section as a standard. Now comes the next problem, the position and the number of the wing spars and their dimensions. Fig. 17 shows the side view of a wing having one spar on the leading edge and one on the trailing edge. This type of construction is quite useful in wings of a chord less than 3 ins., but for larger

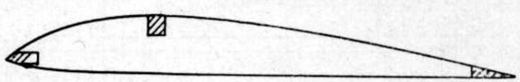


Fig. 18.

chords is rather weak. A better system is shown in Fig 18, where the leading and trailing spars are retained with an additional one inserted at the point of maximum camber. Here, again, the wing will not be very strong and also will be heavier than the two-spar system. Fig. 19 shows a step further onward, and is used by some aeromodellists. It has the advantage of being easily adapted to low-wing models, where the camber is reduced at the fuselage to the thickness of the spars in the centre section. It also has

the advantage of allowing a smooth surface of the top portion of the covering, which is sometimes spoilt by a spar on top of the camber. The construction shown in Fig. 20 is, from an engineering point of view at least, better than that shown in Fig. 19, because the material is more economically used. Weight for weight, a wing built up on the lines of Fig. 20 is much stronger than one built as shown in Fig. 19. Of course, as mentioned before, some model makers prefer No. 19 type to No. 20, but one has found from past experience that the last-named method of construction is the best.

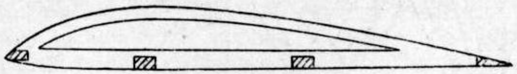


Fig. 19.

There is yet another alternative wing construction, and that is the use of a wire leading and trailing edge, either or both. Aerodynamically a wire trailing edge is better than a wooden one, for the simple reason that it is thinner and does not cause so much air-eddying behind the wing. Similarly a wire leading edge has the effect of reducing the total resistance of the wing. Pointing the nose of an aerofoil to a streamline shape (often called a "Phillips Entry") is advantageous in decreasing the resistance slightly at high speeds; which means at small angles of attack.

Fig. 20.

Thus a wing with a wire leading edge and trailing edge is more efficient than with corresponding wood spars, and it seems that the best form of wing construction is one with two main spars, one above the other at the point of maximum camber, and a wire leading and trailing edge. The size of the wire is largely dependent on the distance between the ribs, but usually is 24 S.W.G. steel wire.

Having outlined the principal ways of spacing the wing spars as seen in a side view let us now turn to the wing as a complete unit. The ribs, or fore and aft members that

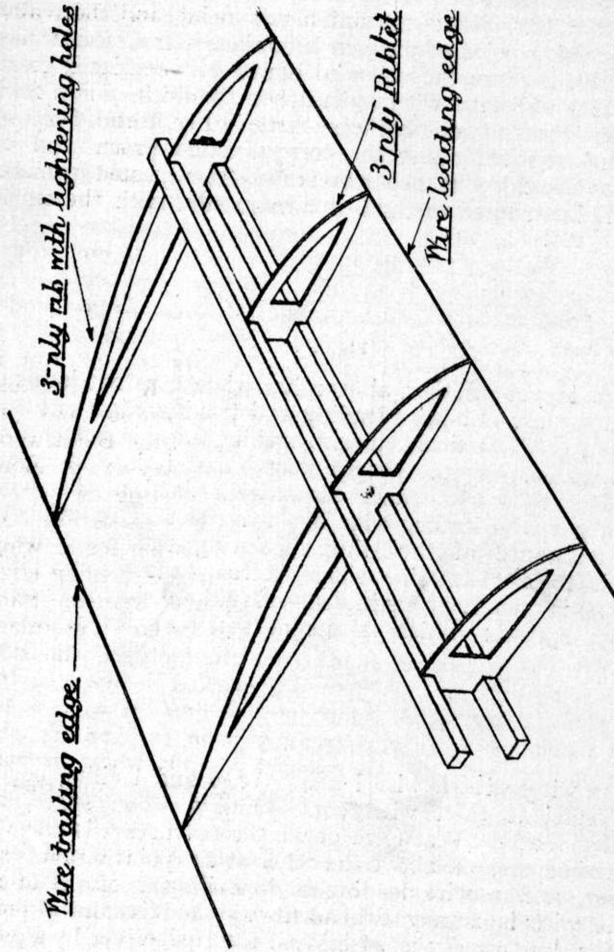


Fig. 21.—Wing Construction, using Wood and Metal.

form the wing section, should be given careful consideration. As every aeromodellist knows the total weight of a model aeroplane is the most important factor of all, and the really efficient model is one in which all unnecessary weight has been avoided. Wing ribs offer to the model designer a great opportunity of saving weight, and they should be made very carefully. First of all ribs serve little other useful purpose than that of maintaining the correct wing section, and as they have to take only the slightest load, they should be made as light as possible. The principal material used is three-ply, either 1/16th in. thick, or, for lighter and smaller models, 1/32nd in. thick. It is strongly advisable to lighten them by fretting out the inside portion as much as possible, even though it may entail a certain amount of work. Some model makers have successfully used Balsa wood for wing ribs. A notable example of this wood being used for this purpose is in the low-wing monoplane designed by Mr. R. N. Bullock. This model was the winner in 1929 of the International Cup presented by Lord Wakefield. In this model the Balsa wood ribs are about $\frac{1}{8}$ in. thick and spaced about every 2 ins. along the wing. They have been lightened by cutting away that portion of the rib where the wing surface is quite flat, i.e., the rear portion of the under surface. This particular wing, by the way, is fitted with a wire leading and trailing edge. The three-ply rib is, of course, much stronger than the Balsa wood rib, but is not nearly so light. It is better to use many Balsa ribs closely spaced than a few three-ply, as this does not allow the silk to sag to such a marked degree. In this connection a very useful addition to a finished wing is the use of riblets or small ribs running from the leading edge to the main spars. They are especially handy when the main ribs are rather far apart. Two examples of wing construction are given in Figs. 21 and 22.

The wing tips offer a variety of ways of construction. The simplest, of course, is the square tip consisting of one of the ribs. This is both ugly and bad from an aerodynamical point of view. It is much better to taper the tips, either by a piece of wire (or thin wood) connecting the leading and trailing edges, or by a piece of three-ply, suitably lightened, glued on to the underside of the end rib and spars. The wire

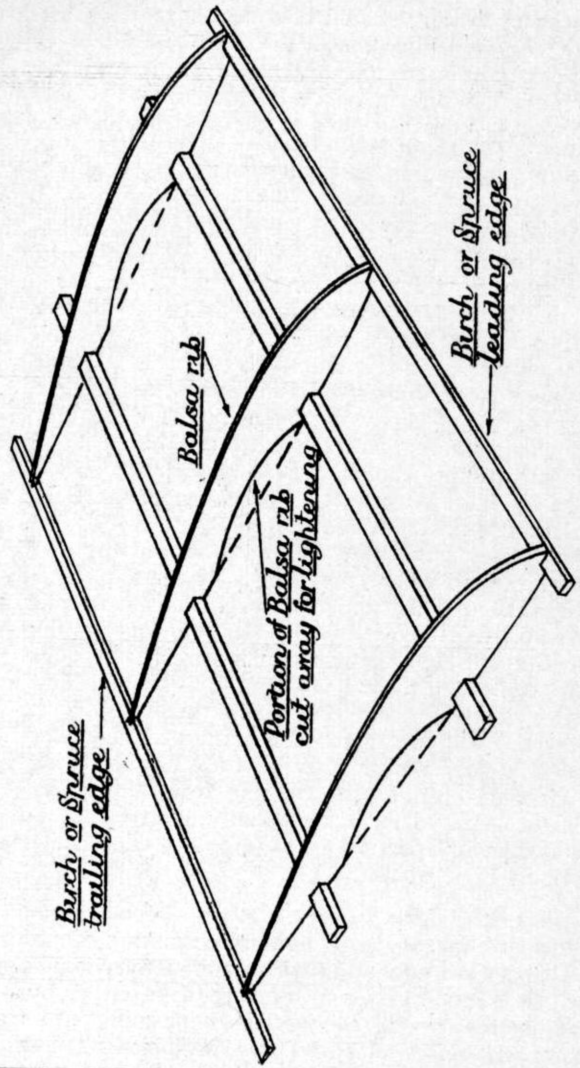


Fig. 22.—Wing Construction, using Wood.

method is the one which has been most widely used, and is strongly recommended. The wire—steel, of course—also acts as a shock absorber in the event of a bad landing on a wing tip. The main spars may be of birch or spruce. The latter is lighter though not so strong, and must be of larger section than birch if the same strength is to be obtained.

And now, last, but by no means least, comes the subject of wing covering. It is almost unnecessary to state that for a wing to attain any efficiency at all the fabric must be taut, with a minimum of sagging between the ribs. This is a golden rule, and should be followed carefully. For material proofed silk is quite satisfactory, but far better results are obtained by covering the framework of the wing with Japanese silk (the finest possible), and giving it a coating of dope. It is really remarkable how strong a wing becomes when once it has been covered in this way. One has to be careful, though, not to give too many coats of dope as this may cause the wing to warp on warm days. Two coats are usually ample.

Just a word on fixing the wing to the fuselage. It is inadvisable to fix a wing permanently by nuts and bolts. The most successful method is to make two wire saddles bound to the leading and trailing spars and bent to fit the fuselage at the widest point. The wires run about half-way down the depth of the fuselage and hooks are formed in the ends so that the wing can be held in position by rubber bands, which pass under the fuselage. This system serves two purposes. First the wing can be moved along the fuselage to get the correct position. Secondly, the rubber bands act as shock absorbers when the machine makes a wing-tip landing.

CHAPTER IV.

FUSELAGES FOR ELASTIC - DRIVEN MODELS.

THE fuselage for an elastic-driven model aeroplane presents to the uninitiated a very complex problem, which can only be solved after considerable experiment, which takes time and costs money.

This chapter does not intend to illustrate how to do the actual construction of the fuselage, but to give the beginner some idea of the shape and proportion, size of members and alternative methods for the construction of a fuselage which has proved to be reliable, serviceable and aerodynamically fairly good.

It will be noticed from Fig. **23** in the general arrangement of the complete fuselage that it is symmetrical about its horizontal and vertical centre line in both planes, and it would be well to mention the value of this. In most, or, one might say, every case a fuselage is symmetrical about its vertical centre line as seen in plan view, but many fuselages are not symmetrical about their horizontal centre line as seen in side elevation, and this is a very important factor because any fuselage on an elastic-driven model aeroplane which has its rubber motors enclosed within the fuselage is subjected to a considerable compression, which is nearly sure to produce distortion if the fuselage is not rigid, and to make a fuselage rigid takes a lot of material and this will be heavy.

Now the fuselage illustrated herewith has this advantage: its side elevation is symmetrical, its motors can be arranged so that their compressive forces are equidistant either side of the horizontal and vertical centre lines, and this should avoid distortion in a very lightly constructed fuselage. The next advantage is that if distortion is not present in the fuselage of an elastic-driven model aeroplane its trim is less likely to alter in flight due to the lessening of motor compression; a very important point if reliability is to be got in flying.

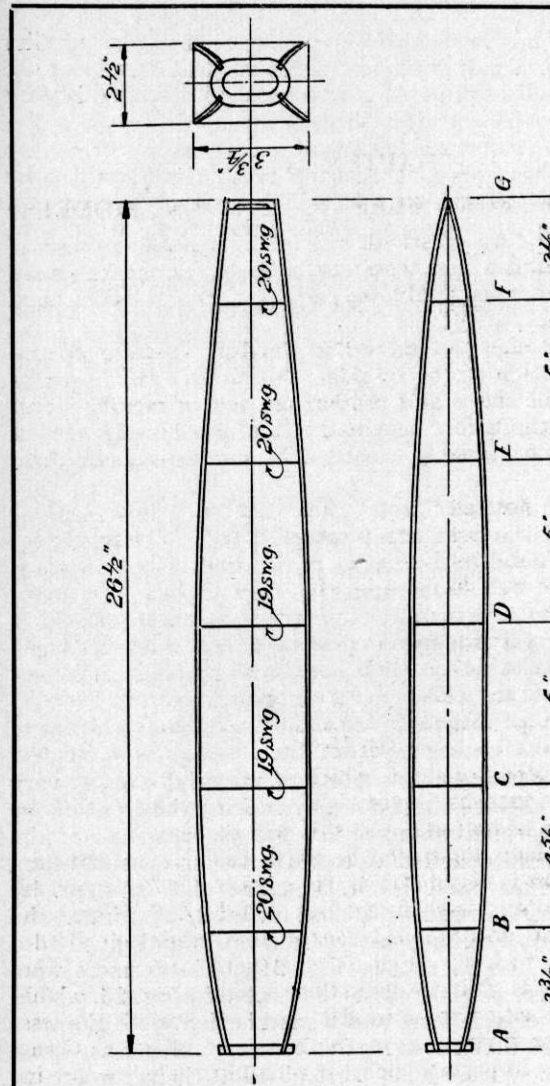


Fig. 23.—Elevations and Plan of Fuselage for Elastic-Driven Model.

The next point about this type of fuselage is the parallel bay C.D. in both plan and side elevation, this bay being on or about the position the plane or planes will be fitted is very helpful, as it does not alter the riggers incidence when the plane or planes are moved backward or forward to correct for C.G., also this bay, being parallel top and bottom, enables the fuselage to be fitted with either a high or low wing, or as a biplane, being parallel in plan, enables the fitting to be simplified.

Model aeroplane fuselages do not require complicated bracing; in fact, no bracing other than that of the silk covering is necessary in moderate-sized elastic-driven models. If the fuselage is carefully covered and well doped it is a very stiff box girder of a very low weight.

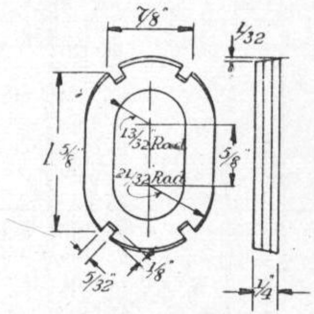


Fig. 24.

In fuselage construction grading of material sizes is very advantageous, and it is best done by making the front of the longerons of the maximum section and the rear end of the minimum. In this particular fuselage under consideration, of the length illustrated birch longerons of 5/32nd in. by ⅛ in. at the front, tapered to 3/32nd in. by 3/32nd in. at the rear were used. The longerons were let into and glued to a ¼ in. multiple nose-piece (see Fig. 24). The formers were music wire bent and soldered, as illustrated in Fig. 25, which, by the way, is suitable for C and D, and is 19 S.W.G. Formers B, E, F, were 20 S.W.G., made in the same manner as G and A. These formers were bound and glued at their corners to the longerons which fitted into the bends as shown in the

example former in Fig. 25. The longerons may be advantageously reinforced just behind the nose-piece (Fig. 26) by gluing and binding on the little tapered pieces, which also prevent the nose-piece from moving back if subjected to severe impact, which it is nearly sure to be at some time of its existence, besides being subjected to the motor compression every time the motor is wound up.

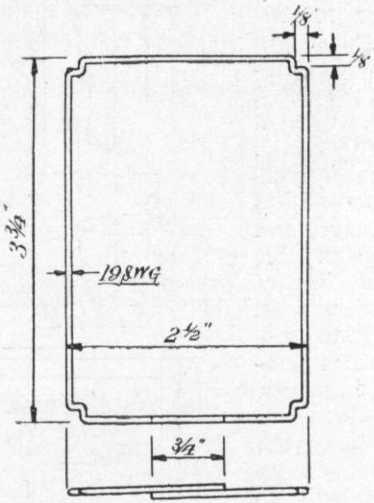
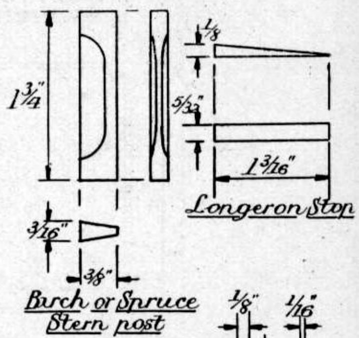


Fig. 25.

Stern posts can be of many different types, and fitted in all sorts of ways, depending entirely on how the builder intends to put in his rear hooks. So in this fuselage only a very simple type is shown, as in Fig. 27; this can be glued, bradded and bound into position.

In Fig. 28 is shown a three-ply former and a method of reinforcing across the grain by sticking on thin pieces of wood. Then also is illustrated a built-up former (Fig. 29), which is very quickly made and cheap, and has proved to be quite strong enough. It is also very easy to lighten this type by cutting away on either the inside or the outside, besides different grades can be produced by the size or thickness of the wood employed. Wire formers go best with birch longerons, spruce longerons should have either three-ply or built-up formers. The spacing of the formers, as shown here, has turned out well for one particular model, but might have to be altered for a model built by anyone else.

Fig. 27. Fig. 26.



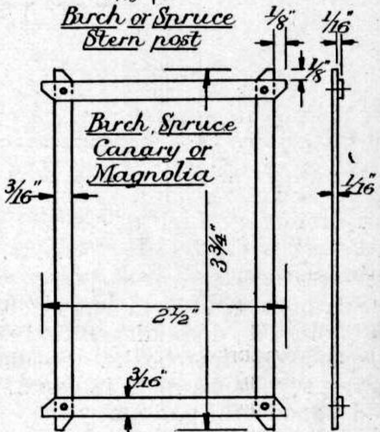


Fig. 29.

Extra strength can be got in this fuselage by adding another former thus reducing the length of longeron between formers which are subjected to compression, which, in turn, produces bending. The use of wire formers in preference to wood has but one advantage, and this is they are capable of withstanding impact without fracture but bend when heavily stressed, but, as they are of tempered steel, i.e., music wire, they return to normal unless the impact has been so severe as to bend them enough to leave a permanent result, and this seldom happens if the sizes are right.

A fuselage constructed to the dimensions illustrated and described here is strong enough to stand two 10-strand elastic motors of ¼ in. by 1/32nd in. elastic wound up to breaking, but only if used with a twin gear in which the motors revolve in opposite directions and thus neutralise each others torsional stress on the fuselage. In other words, this fuselage is not suitable for a single-skein motor, or a

motor of an uneven number of skeins unless they be very light. It was used with two skeins of eight strands most of its time and showed no signs of weakening or distortion.

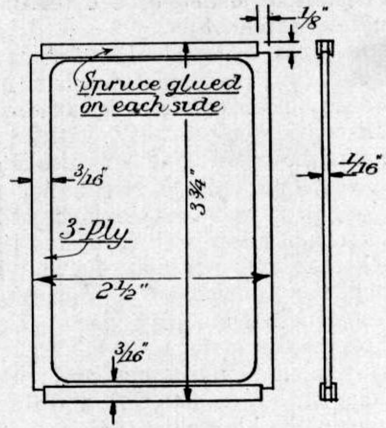


Fig. 28.

Following the general principles of this fuselage triangular and multi-sided fuselages can be constructed, but these both have serious disadvantages. The triangular fuselage is so bad in torsion that when one elastic motor snaps it is very often strained to such an extent that a noticeable slackening of the silk is the result. Multi-sided fuselage of the elastic-driven aeroplane, if constructed on the longeron and former principle, is generally heavy unless extraordinary light longerons are used, and this instantly reduces the impact-standing capabilities of the fuselage and increases, first, the building difficulties, and, secondly, the attachment of under-carriage, planes, rail surfaces, etc.

Now leaving the longeron and former type of fuselage there are many other types, but up to the present a lot has not been done with them. Under the heading of Monocoque comes the simple tube, the truncated cone of veneer or three-ply, celluloid or papier mâché. Then comes the carved-in-two-halves type, glued together afterwards. The cross laminæ type, which first of all necessitates a complicated disassemblable former to build it on. There is the barrel construction type, which is an expert's job. Then comes the papier mâché, celluloid or fibre moulded type, and last, but not least, a fuselage of the future, the electrically deposited on a disassemblable fusible or soluble mould or former.

If, however, the reader feels that this fuselage is not in keeping with his ideas of construction let the shape still have influence over his ideas of construction, because, apart from its recommendations with reference to the withstanding of shock and compression without distortion it is also a type that even though not of a very high order of stream-line shape has the advantage of a long entry and a maximum cross-section placed at about the correct position with regard to its length. Its side area is such that with moderate fin and wheel areas it can be expected to produce an aeroplane without any directional or longitudinal stability vices. This, of course, partly depends on the complete model having its fair share of dihedrals, both lateral and longitudinal, and reasonable weight and surface placing with regard to C.G. and thrust, also wash from main planes in the high wing type.

In concluding this chapter it should be said that the fuselage here described in detail more than fulfils the rule imposed by the Society of Model Aeronautical Engineers, which states that the greatest cross-sectional area of any fuselage must at least equal $\frac{\text{length}^2}{100}$ The use of this formula has made it possible to eliminate from the rules for individual competitions any other restrictive condition and throw all competitions open to models of any size.

CHAPTER V.

UNDERCARRIAGES.

UNDERCARRIAGES, as every aircraft designer will tell you, are a d—— nuisance (to put it mildly). With the possible exception of certain single-seat fighters from the neighbourhood of Cheltenham, which have a habit of attaching themselves to the undersides of airships, the only leg (or should it be legs ?) that undercarriages can stand on is the fact that all aircraft have to spend the greater portion of their lives on the "carpet." The result of this is that the performance of aeroplanes is reduced not a little, simply because they have to carry about with them a contraption which will enable them to "take off" and land with safety.

It is not proposed here to suggest any means of doing without undercarriages or to try to make them collapsible or removable (excepting for transport). All these devices will no doubt be used on both models and full-sized aircraft in due course. For the moment we must content ourselves with the type of undercarriage used on model aircraft to-day.

And here one would like to impress model aircraft builders of the importance of careful design. There are some aeromodellists who fit undercarriages for appearance rather than for utility, and others who fit them without giving them as much consideration as a tail-skid. One has known of models built by quite competent builders that were fitted with undercarriages both useless and heavy. In fact, one might even add that the models in question would have been far better off if the undercarriages had been removed altogether.

Before we go any further in this subject it would be interesting to consider the undercarriage purely from an aerodynamical point of view. One would like to refer to the lecture given by Mr. C. R. Fairey before the Royal Aeronautical Society, on "The Range of Aircraft." Mr.

Fairey said that if the Fairey long-range monoplane could be made to fulfil the conditions of Professor Melville-Jones's ideal streamline aeroplane, that is, the total resistance consisted only of induced drag and that due to skin friction, then, if the same engine were used, the machine would have a range of 8,500 miles. The discrepancy between the achieved results and the ideal, he said, was mostly due to the turbulence produced by the undercarriage and the radiator, which accounted respectively for one half and one quarter of the total parasitic drag of the whole machine.

(Parasitic drag, as the name implies, is that part of the resistance of an aircraft coming from elements of the structure which experience no useful aerodynamic reaction. The drag of a fuselage, for example, or that of a wire, is a net aerodynamic loss. In that respect they are unlike the drag of a wing, which is the price that has to be paid for the beneficial part of the aerodynamic reaction on the same surface, the lift that supports the machine in flight.)

One must apologise here for so much reference to full-sized aircraft rather than to models; the reason for this is that there is practically no data for model aircraft to be had at present, as no one has yet attempted to test them in wind tunnels. The Fairey monoplane, though, is a very near approach to the general trend of model aircraft design, and so one can almost consider it as a model and not as a full-sized machine.

As the undercarriage of the Fairey monoplane accounted for one half of the total parasitic drag it follows that the drag of model aircraft undercarriages would amount to almost as much. Fortunately, we are able to make more efficient undercarriages on models than can be put on full-sized machines because the factor of safety is so much lighter on models. Even so, one can quite easily conceive models putting on a few seconds to their duration by being fitted with more efficient undercarriages.

Owing to the fact that the undercarriages of modern models are usually very long in comparison with the length of the fuselage (owing to large propellers), the wheels are situated well away from the lateral turning point or fulcrum of the model in flight. This means that the side area of wheels is a

careful point to be remembered. Thus a model with wheels of large diameter and fairly well forward of the centre of pressure of the combined fuselage and fin will have a tendency to be upset by every small pressure on the sides of the wheels. In general, it is best to fit a fairly high fin on to models with long undercarriage legs. The size of the wheels should be sufficiently large to enable the model to "take off" without much trouble. The landing does not count for much (excepting for very large models); nine models out of ten will not make a three-point landing, as the surface of the ground is usually much too rough. The exception to this rule is the model designed purely for speed. In this case the wheels should be abnormally large, not only to assist in the "take off," as the "take off" speed is usually very high, but also the landing. It is essential to fly racing model aeroplanes on perfectly flat ground (e.g., a cricket field), and it is also essential to get them to land as well as possible. Consequently large wheels are the order of the day for racers.

The position of the undercarriage in respect to the fuselage, although of seemingly minor importance, is one that should be given due thought. From the aerodynamical standpoint there is very little difference where the landing gear is placed, although it is slightly more efficient placed far back. The reason for this is that the turbulence caused by the various units in the undercarriage does not begin until the air is well past the nose of the machine and thus the drag occurs farther aft, which improves the general stability.

From a practical standpoint there is a great difference in the position of the undercarriage "fore and aft."

We can assume an undercarriage to perform two functions:

(1) To assist in the "take off."

(2) To assist in the landing.

In the case of No. 1 the ideal position is as near to the C.G. (centre of gravity) as possible. It should be pointed out that there is a limited distance in which to place the wheels, as they have to be in front of the C.G. of the whole machine and cannot extend far past the propeller. Now it follows that with No. 1 the nearer the wheels are to the C.G. the less load the tail has to carry (Fig. 30). Consequently, when the machine is taxying along prior to taking off the tail goes up quickly, the speed is increased, and the result is a very quick take off. On the other hand the model is very liable to tip over on its propeller if the ground is rough and the pressure on the tail-plane not sufficient to overcome the momentum of the model turning round on its axis (in the form of wheels).

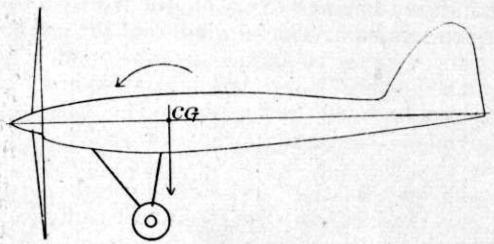


Fig. 30.—Wheels near C.G.—Tendency to nose over on rough ground.

On the other hand an undercarriage placed well in front of the C.G. prevents the model from nosing over during the take off, and, further, prevents the propeller shaft from becoming badly bent on landing. In addition to this the rubber-driven model exerts its greatest thrust at the beginning, and so can accelerate very quickly. Thus it does not matter where the wheels are placed—the take off is almost the same in any position. Again, placing the wheels well forward has the effect (indirectly) of improving the longitudinal stability greatly, as the C.G. moves forward with the undercarriage and the wing moves forward with the C.G. Needless to say the farther forward the wing is the greater will be the leverage exerted by the areas at the tail. This means that their size can be reduced with again a forward movement of the C.G. along the fuselage. Thus the simple act of moving the wheels forward produces some quite startling results.

The question of placing the wheels in front of the propeller is open to discussion. It cannot be denied that this position is excellent from the landing point of view. The propeller is absolutely protected from the ground (excepting when the model is upside down) and is therefore very useful for power-driven models where the propeller shaft is direct from the engine. In this case a damaged shaft usually means a

damaged engine. On the other hand an undercarriage that is swept forward of the propeller disc is a much more complicated structure, and this means extra weight and extra resistance. And that is how the matter stands to-day. Some aeromodellists prefer something after the style of Fig. **31**, and others lean towards Fig. **32**. Personally, one considers that the ideal position of the undercarriage is just behind the disc formed by the revolving propeller blades.

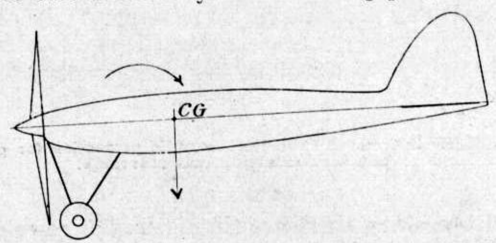


Fig. 31.—Wheels just behind Propeller.—Tendency to settle backwards in rough landing.

The next item for consideration is the size of the wheels and the springing of them. Their size naturally varies with the size and weight of the machine. No hard and fast rules can be laid down in respect of size, but one has found from past experience with fuselage models (and spar models for that matter) that the sizes given below work quite satisfactorily :—

Weight of Complete Model.	Diameter of Wheel.
0— 1 oz.	1 in.
1— 2 ozs.	1½ ins.
2— 5 ozs.	1¾ ins.
5— 8 ozs.	2 ins.
8—16 ozs.	3 ins.
16—30 ozs.	3½ ins.

It must be remembered, of course, that these figures can only be applied to those models which, for want of a better term, one can call general-purpose models. The size of wheels on ultra-light duration 'buses can be reduced owing to the slower speed. On the other hand racing models (as already stated) require exceptionally large diameter wheels to give them a better chance of taking off and landing again.

While on the subject of wheels it might perhaps be as well to go into the subject more deeply and consider the various types and their construction.

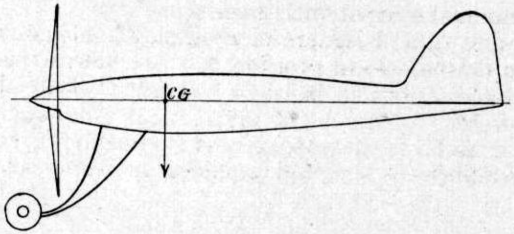


Fig. 32.—Wheels in front of Propeller.—Ample protection for propeller, but very unwieldy undercarriage.

Wheels.

Generally speaking there are three types of wheels—

(1) Metal disc wheels.
(2) Wooden wheels with rubber tyres.
(3) Three-ply wheels covered with silk.

Type No. 1 is usually an aluminium pressing after the style of Fig. **33**. The two halves are secured one within the other on the rim while a tube is inserted in the hub. The

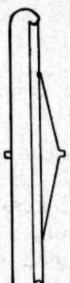


Fig. 33.—Aluminium Disc Wheel.
Fig. 34.—Silk Covered Wheel. Note Concave Sides.

type is usually fitted to commercial models owing to ease of manufacture. These wheels are quite light and easy to put on the axles, and are to be recommended to those who would rather purchase ready-made wheels than make their own.

Type No. 2, although very much like the real thing, are quite unnecessary and useless. They are very heavy (being practically solid and of the same shape as No. 1, Fig. **33**), and spoil the performance of any model aeroplane that has the misfortune to be fitted with them.

The up-to-date designers now employ some form of construction on the lines of type No. 3. The system employed is roughly as follows: A piece of 1/32nd-in. three-ply (or for larger models 1/16th in.) is fretted out to shape, suitably lightened, and a small wooden boss is glued on to either side. The width of the boss should be sufficient to prevent the wheel

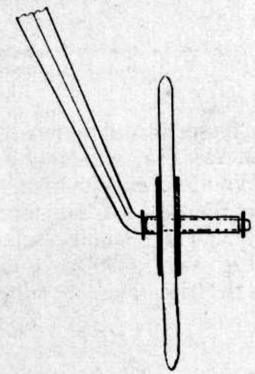


Fig. 35.—Balsa Wood Type Wheel. Note Convex Stream Line Shape.
Fig. 36.—Typical Wheel for Racer. Note Clean Lines and Strong Construction.

"wobbling" when rotating. When the glue is dry a piece of Jap silk is stretched over one side and overlapped about $\frac{1}{4}$ in. When this is dry the same process is repeated on the other side of the wheel until it assumes a shape similar to that shown in Fig. **34**. The two wheels are then finished off with one coat of dope, and, if desired, a coat of paint. This type of wheel is both light and strong, and is to be recommended. One of the most successful forms of wheel construction yet used employs Balsa wood combined with three-ply (Fig. **35**). The wheel is more or less the same as type No. 3, but instead of covering either side with silk Balsa wood is substituted. Two blocks of this very light wood are glued on to the three-ply in the centre, and when dry the surplus is cut away and sand-papered to an even streamline shape. The advantage of this type of construction over the other is that the wheels are convex and not slightly concave due to the sagging of the silk. The difference in weight is almost negligible, and the Balsa wood type is stronger.

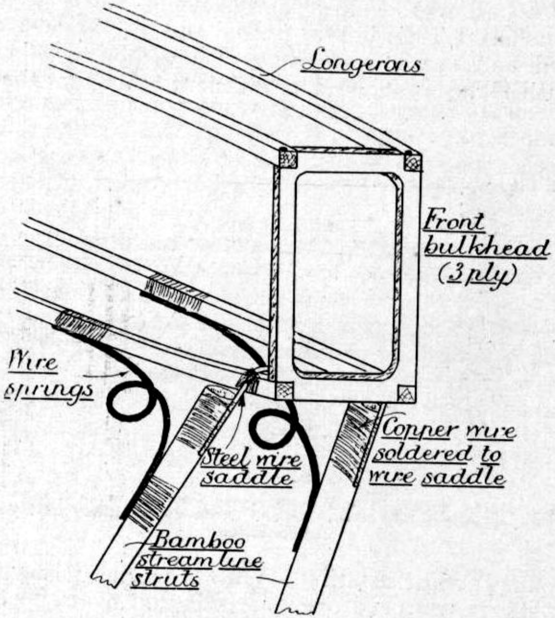


Fig. 37.—Sketch showing Method of Attachment of Undercarriage to Light Duration Models.

Just a few words about wheels for racers. It is quite unnecessary to lighten them in any way, for weight is of small importance. The usual system by Mr. R. N. Bullock is to use $\frac{1}{8}$-in. three-ply with stout metal hubs, and tubing made from sheet tin (see Fig. 36). This type of wheel offers very little resistance, and is sufficiently strong to withstand landing shocks. So much for the wheels.

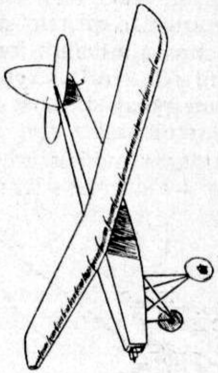
Let us now turn to the second item in undercarriage construction, namely, the struts. The struts, strangely enough, come only second in importance to wheels, for the former exist simply to supply a connecting link between the fuselage (or spar) and the wheels. The struts, though, do most of the work in the taking-off process, and thus it is necessary to find out their exact functions.

Generally speaking the very light spar models are fitted with two legs which take all the loads. On small spar models these struts (or "legs," as they are generally called) are usually made of steel piano wire strong enough to support the model when at rest. The extremities of the legs are formed into small loops and the wire cross-axle is free to revolve with the wheels; the wheels in this case being fixed to the axle. The top of the undercarriage is simply glued into place and bound to the spar.

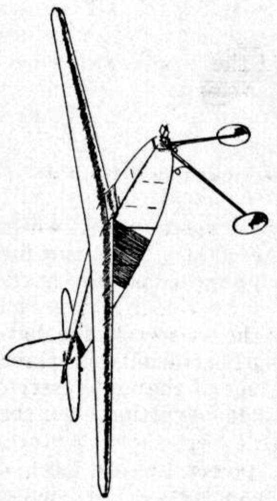
A slightly more complicated construction is used on lightly loaded duration models, also having only two struts or legs. Here the material used can be steel piano wire, but bamboo is preferable, being lighter and less springy. The trouble with this form of undercarriage is that the legs and the wheels have a tendency to swivel round. This can easily be remedied by using fine copper wire instead of thread to bind the bamboo legs to the stub axles. Similarly the short wire attachments that project from the fuselage can be bound to the top of the legs with copper wire and soldered. The soldering should be very quickly done to prevent the bamboo becoming charred with heat.

The short wire attachments at the top of the legs should be explained. They consist of the two ends of the same piece of wire placed in the form of a saddle on top of the lower longerons. This saddle is bound into place with thread before the fuselage is covered. The legs of the undercarriage are then bound on, and the job finished by fitting on a steel wire spring to each leg (see Fig. 37).

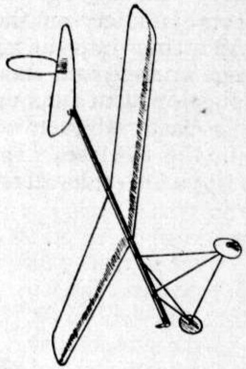
With the larger "general purpose" type of model having a split axle the material employed can either be wood or metal. As weight is not so important as in the case of a duration model steel wire is to be preferred. In this case the complete structure can be sufficiently springy to ease



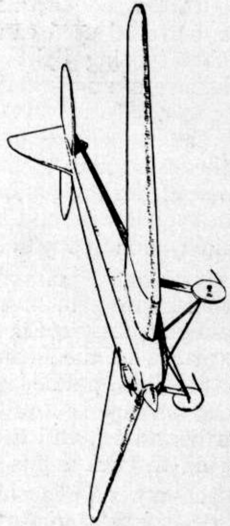
Split Axle Undercarriage for Heavy General Purpose Models.



Low-resistance Undercarriage for Light Duration Models.



Typical Undercarriage fitted to Spar Tractors.



Suggested Undercarriage for Large Power Driven Models.

Fig. 38.

the shock of taxying and landing, and so no special springs are necessary. If the legs are made of wood wire springs after the style of a safety-pin should be fitted to the rear struts.

Going still further into the heavier class a different form of undercarriage should be fitted. In this type the undercarriage arrangement should be fitted. In this type the main compression strut runs up to some point situated away from the fuselage, while two other struts meet the lower longerons in the fuselage. These latter two are in tension. With this type of undercarriage (similar to that fitted to

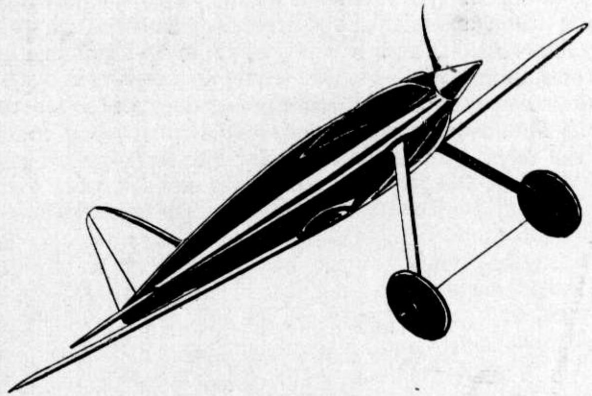


Fig. 39.—Steel Undercarriage fitted to Compressed-air Driven Racer.

the Fairey long-distance monoplane) a much wider wheel track is obtained, which prevents the model from turning over on the ground in a side wind. Four types of undercarriages are shown in Fig. 38.

Last, but by no means least, come the overworked undercarriages on racing models. No type of model aeroplane deserves a very good undercarriage more than the racer. Perhaps this fact will be more vividly explained in the following way: a racer flies usually for a very short distance, due to the very rapidly diminishing power (in the case of rubber and compressed-air driven machines). The model takes more time to taxy, take off, and land again than it does to cover the course, and thus the loads imposed on the complete machine occur before and after the flight. When one considers a model aeroplane taxying along the ground at about 30 m.p.h. or (worse still) trying to land again at 40 m.p.h., it will be realised what a terrific amount of hard wear the struts have to stand. So that while endeavouring to obtain a very stout undercarriage one must at the same time make it as simple as possible to reduce air resistance. There are at present not many ways of building these undercarriages for racers, but with the increasing interest that is being taken in this type of model aeroplane new methods will be adopted. At the moment the two principal ways of building them are with stout steel wire encased in wood of streamline section, and R.A.F. streamline wire as in Fig. 39. (The streamline wire, by the way, is not wire as we know it, but really strips of high-tensile steel of a streamline shape. These strips are sometimes as much as $\frac{3}{4}$ in. wide. Thus the term " wire " is rather far-fetched.)

CHAPTER VI.

RUBBER MOTORS.

TO-DAY the common practice is to take several similar rubber skeins and gear them together to make the complete plant, but for the moment we shall consider only the single skein, for the number of turns remains the same whatever number of skeins be used. The number of turns is the first thing the model flyer wishes to know. How many may he safely give his motor ? The old hands know by the feel of the propeller when winding up or by the tautness of the rubber when it approaches breaking point. There is also an old formula in existence which gives approximate results. Though not accurate it is fairly simple, and many model flyers use it.

It is $R=\frac{KL}{\sqrt{W}}$ where R= number of turns, L= length of motor in inches, W= weight of rubber in ounces, and K is a coefficient which varies from 15 to 20. For all ordinary motors of over 2 ft. long this formula gives results which are on the safe side, but with such a floating coefficient it is not precise.

The more exact formula is $R=\frac{4L^{1.5}}{\sqrt{W}}$ where R, L and W have the same meaning as in the first formula. If 5 be substituted for 4 in the numerator, the number of turns necessary to break the motor is found. The formula is based on winding to 80 per cent. of the maximum and is for ordinary flying. For competition work or record breaking the figure 5 may be approached as nearly as the flyer wants to go, or enjoys breaking his rubber. The only difficulty in using this formula is the calculation of $L^{1.5}$ and $\sqrt{W}$.

In the following two tables are the values of these for the usual range of motors :—

L	24″	27″	30″	33″	36″	39″
$L^{1.5}$	117	140	164	189	216	244
		42″	45″	48″		
		272	301	332		

W	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
$\sqrt{W}$	.5	.61	.71	.79	.86	.93
1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3
1.0	1.12	1.22	1.32	1.41	1.58	1.73

The results, of course, will not be obtained if the rubber is not fresh, is not well lubricated and has had no care taken of it between periods of use. If the model flyer wishes to make his own lubricant it may be made to the following recipe :—

Pure soft soap	70%
Salicylic acid	$\frac{1}{2}$%
Glycerine	20%
Water to make up to 100%	

Good rubber lubricant may be obtained from the model aeroplane supply firms. It should be used freely. After the day's flying all rubber should be washed to clear it of grit (the lubricant makes an excellent lather), dried, and placed in a dusting box (containing plenty of powdered French chalk), and shaken up. Rubber kept thus will last many times as long as neglected rubber.

A point to note is that L, the length of the motor, is not the distance between the hooks. It is the length of the motor when laid down unstretched and arranged in the correct number of strands ; or, to put it another way, it is the exact length of the rubber strip forming one skein, divided by the number of strands. For example, if a motor 30 ins. long is put on to hooks 27 ins., 30 ins. or 36 ins. apart, L always is 30.

The energy which can be stored in 1 lb. of rubber is about 3,500 ft.-lbs., while if 80 per cent. of the full turns are given the energy stored is only 2,000 ft.-lbs. per lb. of rubber. From this it is clear that it is desirable to give a motor as many turns as possible for competition or record-breaking flights, for the last few turns impart so much more energy than the early ones. A motor of new rubber will store nearly

4,000 ft.-lbs. per lb. at breaking. Though the power which can be stored in a motor of previously used rubber is less the motor will fracture at about the same number of turns.

One or two examples may clear up points about which you may still be uncertain.

EXAMPLE NO. 1.—A single skein motor 36 ins. long (composed of six strands of $\frac{1}{4}$-in. strip) weighs $\frac{7}{8}$ oz. How many turns may be given to the motor ?

$R=\frac{4\times36^{1.5}}{\sqrt{\frac{7}{8}}}$. Referring to the tables this is $\frac{4\times216}{.93}$, which gives a result of 930 turns.

EXAMPLE NO. 2.—A motor is composed of three skeins (each of four strands of $\frac{1}{4}$-in. strip), and is 30 ins. long. The total weight of the rubber is $1\frac{7}{8}$oz. How many turns can be given to the motor ?

Each skein weighs $\frac{5}{8}$ oz.

$$R=\frac{4\times30^{1.5}}{\sqrt{\frac{5}{8}}}=\frac{4\times164}{.79}=830.$$

For the quick solving of these problems use the Alignment Chart. Place a straight-edge across any two known values and the third can be read on the third column.

The number of strands and other particulars of the motor are usually decided by past experience or by a rough method of trial and error if the model is of an entirely new pattern. Though the energy stored in any motor can be found this energy is not given out at a steady rate ; in other words the power varies. It is large at first, tailing off to nothing when the motor is fully run down. Fortunately, this helps the aeromodellist. He requires most power at the beginning to lift his model from the ground and make a steep climb, leaving it at a good height with the motor running out and ready for a spectacular glide, which is one of the greatest delights of model flying. Still, it is interesting to know the average power obtained from rubber motors. Taking again the first two examples :

EXAMPLE No. 1.—This motor runs out in 30 seconds (say) when the model is in flight. The rubber weighs $\frac{7}{8}$ oz., and will store $\frac{2{,}000 \times \frac{7}{8}}{16} = 110$ ft.-lbs. of energy. This energy is dispersed in 30 seconds. Therefore the power is given at $\frac{110}{.5} = 220$ *ft.-lbs. per minute.*

EXAMPLE No. 2.—In flight this motor runs out in 40 seconds. The total weight of the rubber is $1\frac{7}{8}$ ozs., and this will store $\frac{2{,}000 \times 1\frac{7}{8}}{16} = 234$ ft.-lbs. of energy, which is dispersed in 40 seconds. Therefore, the mean power of this motor is $\frac{234 \times 60}{40} = 351$ *ft.-lbs. per minute.*

The advantages of geared rubber motors are :—

(1) The reduction of torsion imposed upon the fuselage. With an even number of skeins this torsion disappears, for it is balanced. With an odd number of skeins the torsion is only that due to the odd skein.

(2) The increased number of turns which may be given to the same amount of rubber.

The only disadvantage is the loss of power due to friction of the gears, but practice shows this loss to be very small.

Here are some figures which may be useful when considering the design of such a motor. The formula $R = \frac{4L^{1.5}}{\sqrt{W}}$ shows that the number of turns is *not* doubled if the number of strands in the skein is halved. (Or, in other words, if the single-skein motor is split into two.) But it is considerably increased. *The number of turns increases as the square root of the number of skeins into which any single-skein motor is divided.* That is to say that if a single-skein motor will take x turns, the same motor divided into two skeins will take $\sqrt{2} \times x$ (or $1.41x$) turns, divided into three skeins it will take $\sqrt{3} \times x$ (or $1.73x$) turns, and so on.

Here is an example which may be checked on the alignment chart, which appears in Fig. 40.

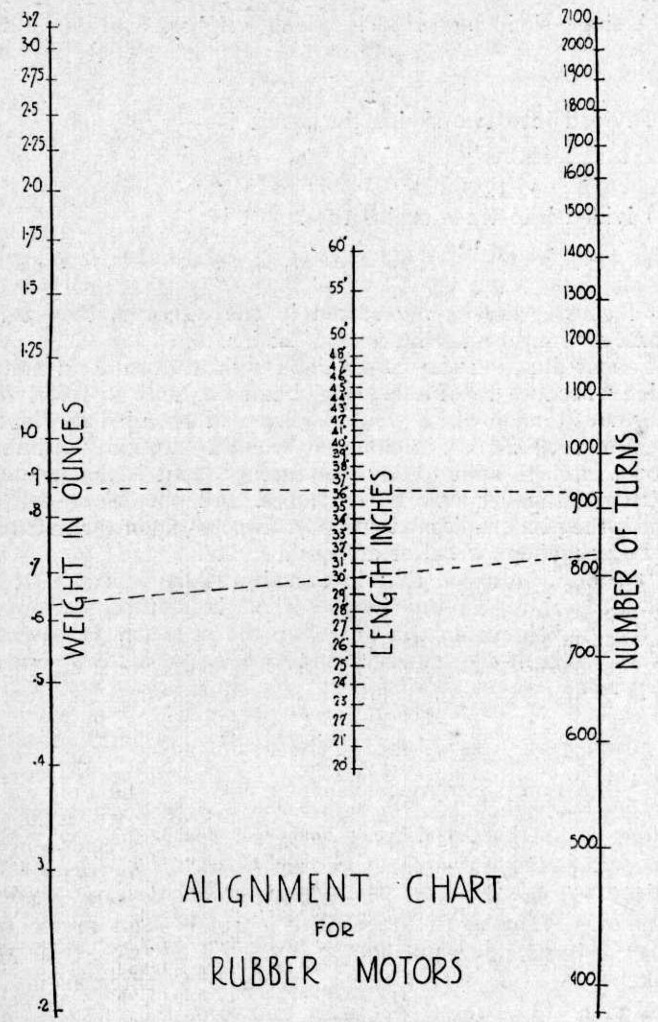


Fig. 40.

A single-skein motor 36 ins. long weighs 2.5 ozs.

$$R=\frac{4\times 36^{1.5}}{\sqrt{2.5}}=546.$$

Divided into two skeins the result is :—

$$R=\frac{4\times 36^{1.5}}{\sqrt{1.25}}=773 \text{ (i.e., } 546\times\sqrt{2}\text{)}.$$

Divided into three skeins the result is :—

$$R=\frac{4\times 36^{1.5}}{\sqrt{.83}}=945 \text{ (i.e., } 545\times\sqrt{3}\text{)}.$$

Of course, the energy stored in the motor is the same, whatever may be the number of skeins.

Longer duration can be obtained with a multi-skein motor chiefly because the fuselage need not be built to resist the enormous torsion which would be imposed upon it by a single-skein motor ; 2½ ozs. in one skein would fold up any ordinary model fuselage built to-day. A further point is that a more efficient propeller can be employed and the lesser torque which the smaller-pitched propeller imposes upon the machine in flight makes for better all-round flying.

It should be noted that in the air the motor runs out in about two-thirds the time it takes when the motor is stationary in the workshop ; in the workshop the propeller behaves as a fan, while in the air each blade meets the air edge-on, or very nearly so.

CHAPTER VII.

PROPELLERS.

AIRSCREWS screw their way through the air like a wood-screw when turned moves through a piece of wood ; but as air is not a solid it gives considerably against the pressure of a propeller blade, which causes the propeller to have a marked percentage of slip. That is to say, if a propeller is designed theoretically to travel 100 ft. forward in 100 revolutions the actual distance traversed may be only 75 or 80 ft. Allowance for slip must, therefore, be made in designing a model propeller for a given performance. This percentage of slip may be kept fairly low by skilful design combined with correct relation between thrust area and resistance of the machine. The success or failure of a flying model depends more upon the suitability of the propeller than many people imagine. A propeller should be correctly designed, well carved and properly balanced to give the best possible results. Bent wood propellers were almost universally in use many years ago, but are now generally discarded as being crude and aerodynamically inefficient. They are, therefore, omitted from this article.

Metal Propellers.

Metal propellers may soon supersede the carved wood propellers for efficiency, but this subject of metal propellers must be left for a future occasion. It seems that because metal propeller blades can be much thinner than wood blades the resistance is less, revolutions are greater and therefore the forward speed and static thrust is greater for the same power applied.

Designing a Propeller.

The propeller of a model aeroplane should be the final part of the complete machine to be designed and made because there are important factors to be considered, and they are—the wing-loading and the resistance of the model at various speeds. These cannot be accurately ascertained from drawings as the materials required cannot be accurately weighed, and, therefore, the wing-loading cannot be known, although this may be fairly well estimated by an experienced builder. Having finished the model excepting the propeller we can find the wing loading by weighing the model and adding the weight of a suitable propeller and measuring the area of the plane; then, by rule of proportion, we obtain the number of ounces per square foot of lifting surface. Suppose a model weighs 12 ozs. and has a wing area of 2 sq. ft., the loading is 6 ozs. per sq. ft.

Flying speeds, that is cruising speeds where a model flies a horizontal course, vary as the square root of loading. Opposite is a useful table of cruising speeds in miles per hour and feet per minutes for various loadings from 4 to 8 ozs.

Then there is very little known at present about the resistance, or drag, of model aeroplanes. For the present we must be content with the bald statement that it is necessary for a propeller to give a static thrust of at least one-quarter the weight of the model, i.e., a machine weighing 12 ozs. must have a propeller which will give a static thrust of 3 ozs. at the number of revolutions at which it should fly the model.

Static Thrust.

About fifty model aeroplane propellers have been tested, all of 10 ins. diameter, to get comparable results. A feature of the testing apparatus is complete absence of friction owing to the motor and revolution indicator; in fact, everything except the scale for reading the number of ounces thrust being suspended by fine wires. Some important results were obtained. First, it was established that when the number of revolutions were increased 50 per cent. the static thrust increased 70 per cent. or more. Similarly, when the revolutions were doubled the static thrust was increased by 170 per cent. Therefore, although a propeller may not fly a model at the usual number of revolutions it will do so if the revolutions are increased sufficiently. But, of course, duration will be sacrificed to attain this end. Secondly, the static

thrust of 10-in. propellers of good design and medium pitch is approximately $1\frac{3}{4}$ ozs. at 1,000 revolutions per minute. Therefore, this size propeller cannot be expected to fly a model weighing 8 ozs. or more at that speed. At 1,500 revolutions the thrust rises to 3 ozs., but this is faster than the majority of propellers are driven. The maximum thrust at 2,500 revolutions is over 7 ozs. This is the result of the maximum output of motor, but graphs indicate that at a still greater number of revolutions the static thrust would still increase at the same rate as before up to an unknown point.

Loading.	Miles per hour.	Feet per min.
4 ozs.	12·0	1,056
4½ ,,	12·7	1,122
5 ,,	13·4	1,152
5½ ,,	14·1	1,212
6 ,,	14·7	1,296
6½ ,,	15·3	1,344
7 ,,	15·9	1,398
7½ ,,	16·4	1,446
8 ,,	17·0	1,494

Blade Width and Diameter.

Thirdly, the best results so far as static thrust is concerned are obtained if the blade width is kept to medium proportions, being neither narrow nor wide. The best width for a propeller of 10 ins. diameter was found to be 1 3/16th ins. Above and below this width the static thrust fell off. This was determined by gradually reducing a wide blade to a narrow blade.

Weight of Propeller.

The weight of a propeller should also be taken into consideration, which few except the ultra lightweight model builders do.

However, the inexperienced model flyer should not start off with a lightweight propeller because he will probably very soon break it, for reasons which need not be gone into here. But an impression prevails that a heavy propeller has a flywheel effect which helps to keep up its speed. This is a fallacy. Any model engineer knows that the heavier the flywheel the more power required to drive it at a constant speed. The same applies to propellers, and consequently a light propeller requires less power to drive it than does a

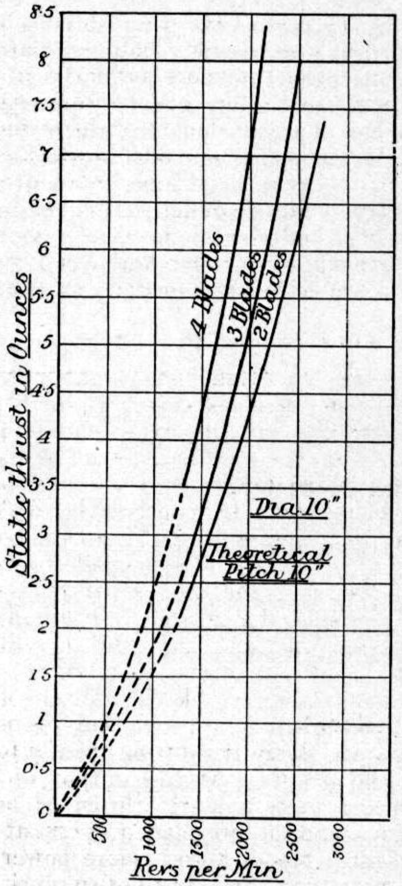


Fig. 41.—Chauviere Type Propellers.

heavy one. What really happens is when the power is shut off a heavy propeller will continue to run for a little longer time than a light one.

The weight of the 12-in. propeller to be described later was exactly $\frac{1}{2}$ oz. It was made of walnut wood, laminated.

Shapes of Blades.

Many designs of propellers have been tested, but none has given such good results as the old Chauviere pattern. This type has been superseded by more symmetrical designs in full-sized work owing to the unequal stresses imposed upon it at high speeds and constant danger of distortion and fracture. But this matters little in model work, as the blades are strong enough to resist all strains imposed on them in actual flying. A symmetrical design is frequently met with on commercial model aeroplanes, the chief reason being its immunity from breakage with rough landings in the hands of those who have never handled a model aeroplane before.

Two, Three, or Four-Bladed Propellers ?

The experiments (see Fig. 41) shed some light on this problem. The propellers used in these tests were of small pitch, viz., 10 ins., which accounts for the exceptionally high static thrusts obtained. The type was Chauviere of 10 ins. diameter. All the blades were as near alike as it was possible to make them. The four-bladed propeller consisted of two two-bladed propellers half-lapped together, a tight fit at the boss, but the joint was not glued. When the four-bladed propeller had been through the test the blades were separated and the two-bladed propellers were tested separately. These gave identical results, which showed that the blades did not differ in size, shape or weight. And, furthermore, a strict comparison can be made between the two-bladed and the four-bladed propeller. The three-bladed propeller had to be made by carving three separate blades and fitting them into a suitable boss. Now for the results. At full output of motor the four-bladed propeller gave a static thrust of as much as $8\frac{3}{8}$ ozs. at 2,150 revs. and the two-bladed $7\frac{3}{8}$ ozs. at 2,750 revs. This shows that three blades absorb more power than two, and four absorb more than three, but not so much more than one might expect. For instance, the four-bladed propeller does not absorb double the power of the two-bladed propeller. At 1,500 revs. the static thrusts were for four blades $4\frac{1}{2}$ ozs., for three blades $3\frac{1}{4}$ ozs., and for two blades $2\frac{3}{4}$ ozs. It would therefore appear that, providing there is a sufficient surplus of power to drive a four-bladed propeller this would give the best results. But, in actual flight, the question of pitch figures very prominently, and it may happen that, although the static thrust is more than ample, the forward speed may be insufficient to sustain the model in flight.

Propeller Pitches.

The static thrust tests show that a small pitch is the most efficient for a given power, but only so far as maximum static thrust is concerned. A small pitch means a small angle of attack from which a greater number of revolutions are obtained. A 10-in. propeller having a pitch of less than $13\frac{1}{2}$ ins. gave a maximum static thrust of $7\frac{1}{4}$ ozs. at full power of motor. When the pitch was 15 ins. or 20 ins., resulting in slower revolutions, the maximum static thrust was only $5\frac{1}{4}$ or $5\frac{1}{2}$ ozs. at most. But this is no criterion of the flying capabilities of the propeller, and it appears that static thrusts are misleading in this respect. It is highly probable that the bigger pitch with resulting smaller static thrust would fly a model best in good weather and give much better duration. However, for flying in very high winds the small pitch is to be preferred, as owing to the high revolutions the speed of the model is increased and greater stability is obtained.

Finding Theoretical Pitch of Propellers.

One might say that not half the model flyers know what pitch their propellers really have. A fine, medium or coarse pitch is about as near as they get to the truth. If a model has a wing-loading of 6 ozs. per sq. ft. the necessary speed required to sustain horizontal flight is 14.7 miles per hour, that is, 1,296 ft. per minute.

If at the first burst of speed the effective pitch of the propeller produces a forward speed of less than 1,296 ft. per minute the model will not fly, however great the static thrust may be. It is, therefore, necessary to know whether you are obtaining the necessary forward speed, also to know that this is not excessive, in which case power will be wasted and duration sacrificed. One might as well attempt to get a

full-sized aeroplane to rise off the ground by towing it with a caterpillar tractor; the power is ample, but the forward speed is lacking. Therefore, it is necessary to know the theoretical pitch of our propellers, and if one allows 20 per cent. for a slip a fair approximation to the forward speed may be obtained, providing we can tell how many revolutions per minute the propeller is being driven.

On page 69 is a table of propeller pitches for propellers having diameters from 6 ins. to 12 ins.

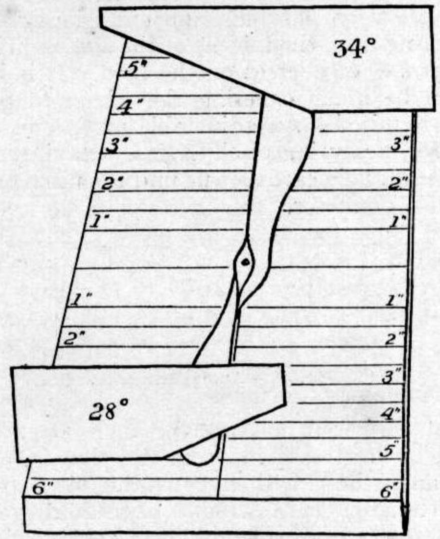


Fig. 42.—Apparatus used for measuring Pitch of Propellers.

A simple device for finding the theoretical pitch of a propeller is shown in Fig. 42. We require for this a *flat* board about 14 ins. long by 7 ins. wide, a nail with head cut off or piece of straight steel wire which will fit comfortably the hole in boss of propeller, and a protractor for measuring angles. It is essential that the board should be perfectly flat, otherwise the angles as measured will not be correct. Drive the nail into the centre of the board and test it with a small set-square to see that it is perfectly upright. If it is not exactly vertical the angles measured will again be incorrect. If a thick propeller spindle is used, then a hole should be bored for this which should be a tight fit in the board. Then draw parallel lines across the board ½ in. apart from the centre to each end so that the angles can be measured at any convenient distance from the centre of boss. Mark at the end of each line its distance from the centre of boss. Now place the propeller on the board with the flat or hollow side of blade uppermost with the nail or pin through the hole. The propeller must run lengthways on the board. Now get some stiff paper or cards (post cards are very suitable), and cut triangular pieces off one side starting from the middle of the side as in **Fig. 43**, and mark the number of degrees on the card. It is best if a set of these can be made covering the whole range of angles likely to be required. An adjustable protractor is the ideal instrument for measuring pitch angles. Having now got the complete set of angle cards let us find the pitch of a propeller of, say, 12 ins. diameter.

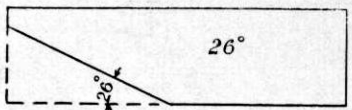


Fig. 43.—Angle Template.

We cannot very well measure the angle at extreme tip of blade, so let us start at ½ in. from tip, that is, 5½ ins. from boss. The angle here will give us the pitch of an 11-in. propeller. The angle here is found to be 26 degrees. Referring to the table of propeller pitches 11 ins. diameter and 26 degrees pitch angle gives us a pitch of 16·86 ins. Now test again at 5 ins. from boss. We find the angle here is 28 degrees, which is equal to a 10-in. diameter propeller with a tip angle of 28 degrees. Referring again to the table we get a pitch of 16·71 ins. at that point. Continuing the same process at 4½ ins. from boss the angle is 31 degrees and the pitch 16·95. At 3½ ins. from boss we get 37½ degrees and 16·87 pitch. At 3 ins. from boss 42 degrees and 16·97 ins. pitch. Averaging these out we get a theoretical pitch of approximately 16·9 ins.

Carving Propellers.

This part of propeller making is rather troublesome to anyone who has no knowledge of the elements of wood carving. But anyone who had wood-carving lessons at school should experience little difficulty in this process.

The paraphernalia recommended for this consists of a bench stop-block as shown in **Fig. 44**; this may be placed on a bench if available or on the kitchen table. A wood-carver's gouge ¾ in. wide with only a slight curve on cutting edge, a small wood rasp or file is useful for shaping the blade near boss, and some sandpaper, medium and fine grades, for finishing off.

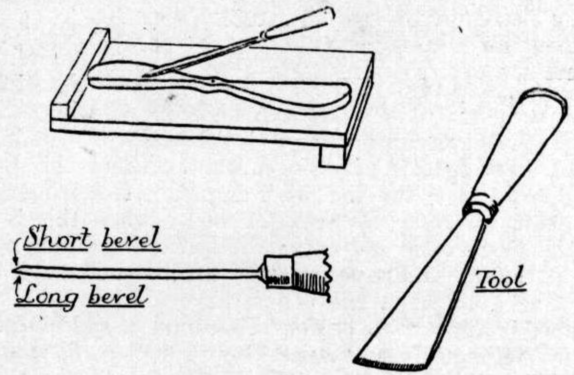


Fig. 44.—Carving Propellers.

Sharpening the Carving Tool.

Anyone able to sharpen a chisel on an oilstone can sharpen a gouge, but in addition to a flat oilstone a shaped oilstone slip is required to sharpen the hollow upper side of tool. This stone should be rounded on one edge, the curve being slightly smaller than that of the tool. A long bevel should be made and maintained on the underside of gouge and a short one on the upper side, the angles being about equal (see **Fig. 44**). The under-side is sharpened on the flat oilstone by moving the tool from side to side instead of to and fro as in the case of the chisel. In doing this a slight turn is given to the handle as the tool is moved along the stone to keep the bevel an even length right across. Anyone not wishing to go to the trouble of sharpening a new gouge may get this done at a good tool shop when purchasing it. It should remain sharp for a considerable time if proper care is taken by keeping it wrapped up when put away.

Carving a Propeller.

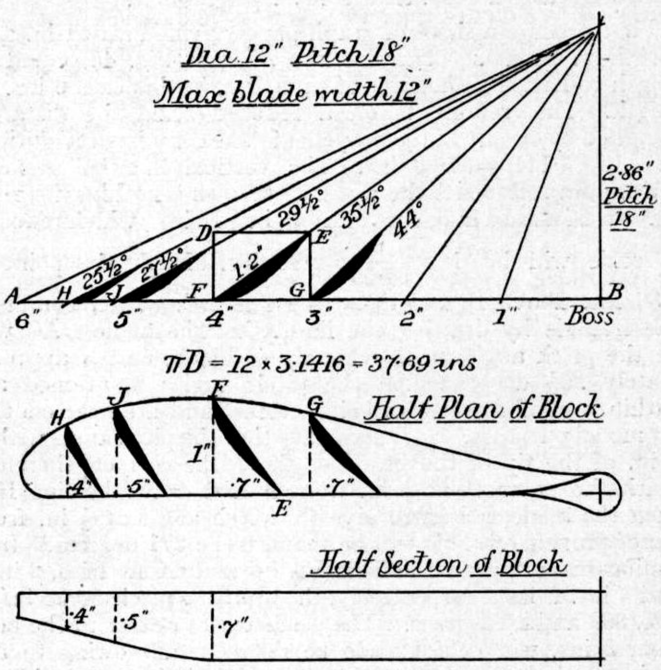
Although some propeller makers make use of a small spokeshave or a small draw-knife to remove the bulk of the waste wood to save time the amateur would do best by sticking to the gouge throughout. Having got the correct size and shape of propeller block, place it against the stop-block as in sketch and pare off the wood from the flat (or concave if preferred) side of blade. Don't take the wood off right down to the top and bottom edges of block before testing the angles, because, if these are not correct, as they are almost sure not to be, this can be rectified while there is sufficient wood left to do so. When the side of this blade is finished carving turn the block round and do the opposite blade likewise, getting the pitch angles correct from the tip to mid-way or more towards the boss; when this is done, turn the block over and carve the streamlined side of each blade. Before sandpapering test for balance, and if one blade is heavier than the other carve a little more wood off where it appears to be too thick until a good balance is obtained. Finally, sandpaper the propeller all over and again test for balance, any slight difference being rectified by sandpapering.

Designing a Propeller.

The design of propeller chosen for this article has been proved to be one of the best, inasmuch as the original propeller won a competition for static thrust in March, 1922, and then in July, 1928, when in the possession of Mr. S. R. Badley, put up a record rise off ground duration of 65 1/5th secs. when this member of the S.M.A.E. won the Pilcher Cup. So that a propeller which is well designed and made and gives a good static thrust should be equally good in practice on a suitable model.

This propeller has a diameter of 12 ins. and a theoretical pitch of 18 ins. The blade width was $1\frac{1}{8}$ ins. at widest part, and probably even better results would be obtained by making the blade $\frac{1}{8}$ in. wider. This would necessitate a block about 1-16th in. wider and 1/32nd in. thicker. The static thrust recorded was 8·26 ozs. at 872 revs. per minute.

First procure a sheet of graph paper divided into 1-in. and 1-10th-in. squares. Draw a line AB (see Fig. 45) equal in length to half the diameter of propeller, in this case 6 ins. in length. This represents on a reduced scale the distance travelled by one tip of the propeller in one complete revolution, i.e., $12 \times 3{\cdot}1416 = 37{\cdot}69$ ins. The vertical line BC is next drawn and represents the distance (allowing nothing for slip) travelled forward in one revolution, i.e., 18 ins., which reduced to scale will be $18 \times \frac{6}{37{\cdot}69} = 2{\cdot}86$ ins. Mark the point C 2·86 ins. above B and draw the line BC. Then complete the triangle by drawing the line AC. The angle BAC will be the pitch angle at extreme tip of blade, and is approximately $25\frac{1}{2}$ degrees. All the pitch angles mentioned are within a small fraction of being correct and are near enough for model purposes. It is necessary that the pitch angle within $\frac{1}{2}$ in. of the tip of the propeller should be correct, therefore mark the point H at $\frac{1}{2}$ in. from A and draw the line HC, then the angle BHC will give the pitch angle at $\frac{1}{2}$ in. from tip of propeller. This will be found to be $27\frac{1}{2}$ degrees. In a similar manner draw the lines JC, FC and GC at 1 in., 2 ins., and 3 ins. from A respectively, the resulting pitch angles being $29\frac{1}{2}$, $35\frac{1}{2}$ and 44 degrees. The pitch angles nearer to the boss than 3 ins. will be found to be not constant owing to the design and shape of wood block, and it is impracticable to make these pitch angles constant. These angles will be too small, but this is of little consequence in practical model work. We require the maximum width of blade to be 1·2 ins. at 2 ins. from the tip, therefore mark the point E 1·2 ins. from F on the line FC. Now FE is the diagonal of the propeller block at 2 ins. from tip. Draw the rectangle FDEG, which is the section of the block at this point. This is 1 in. wide and ·7 ins. thick. This is the basis of the drawing of the half plan of block (Fig. 46). On the half plan mark the point F corresponding with F in Fig. 45, 1 in. above the base line which is the trailing edge. Then draw the shape of blade as desired, but the curved leading edge line must pass through the point F. To mark the blade sections in Fig. 46, proceed thus: Draw the line FE at an angle of 35½ degrees



Figs. 45, 46 and 47.—Design of Chauviere Propeller.

from Fg. If drawing is accurate E will be ·7 in. from g, corresponding with EG in Fig. 45. The other sections at H, J and G should be drawn in a similar manner, with the angles corresponding with those in Fig. 45. In the final drawing (Fig. 47) showing the half-section of block it will be noticed that the block is chamfered off for a distance of 2 ins. from the tip. The thickness of block at 1 in. from tip is only ·5 in., and at ½ in. from tip, ·4 in. This chamfering should be done

before carving, then one is not likely to carve the tip of the blade at too steep an angle, which would spoil it. If the flat face of the blades is carved from edge to edge diagonally of the block the resulting pitch angles should come correct and correspond with the drawing. Care, however, should be taken not to carve down to a knife-edge for two reasons: first, in sandpapering the finished propeller the blade width will be slightly reduced, which is undesirable; secondly, if the block is not quite accurate in measurements of width or depth the pitch angles will either be too large or too small, and a little bit of wood left for trueing-up to obtain the correct angles is a safe plan.

Polishing Propellers.

The simplest and quite effective method of polishing propellers is to brush some french polish on with a camel-hair brush (mop). Give it three coats, and after each coat has become quite hard rub down with a piece of extra fine sandpaper using a little oil as a lubricant. This gives an eggshell finish. All traces of oil must be removed by wiping with rag before another coat of polish is given. Give the polish twenty-four hours to harden.

Concluding Remarks.

Any size model aeroplane propeller can be designed by following the instructions given for the 12-in. propeller and substituting other figures for diameter, pitch and blade width as may be required. The shape of blade may be altered to suit individual tastes, also the width, but in doing so the correct pitch angles must be adhered to. Also, the position of maximum width of blade could be altered as desired either by designing it to be nearer to the tip or farther from it. Whether it would be equally efficient is uncertain.

Table of Propeller Pitches and Model Aeroplane Speeds

Loading ozs. per sq. ft.	Cruising speed. m.p.h.	ft. p.m.	Propeller. Theoretical pitch. Inches.	Propeller. Effective pitch. Inches.
			20 per cent. slip.	At 1,000 r.p.m.
4	12·0	1056	15·9	12·7
5	13·4	1182	17·7	14·2
6	14·7	1296	19·4	15·5
7	15·9	1398	20·9	16·7
8	17·0	1494	22·4	17·9
			25 per cent. slip.	At 1,500 r.p.m.
9	18·0	1584	16·8	12·6
10	19·0	1672	17·7	13·3
11	19·9	1751	18·6	14·0
12	20·8	1830	19·5	14·6
13	21·6	1901	20·3	15·2
14	22·4	1971	20·9	15·7
15	23·2	2041	21·7	16·3
16	24·0	2112	22·5	16·9
			30 per cent. slip.	At 2,000 r.p.m.
17	24·7	2173	18·5	13·0
18	25·4	2235	19·1	13·4
19	26·1	2297	19·7	13·8
20	26·8	2353	20·1	14·1
21	27·5	2420	20·7	14·5
22	28·1	2473	21·1	14·8
23	28·8	2534	21·7	15·2
24	29·4	2587	22·1	15·6
			35 per cent. slip.	At 2,500 r.p.m.
25	30·0	2640	19·4	12·6
26	30·6	2693	19·8	12·9
27	31·2	2745	20·3	13·2
28	31·7	2789	20·6	13·4
29	32·3	2842	20·9	13·6
30	32·9	2895	21·4	13·9
31	33·4	2939	21·7	14·1
32	33·8	2996	22·1	14·4

Speed varies as square root of loading.

Table of Propeller Pitches.

Pitch angle at tip Degrees.	DIAMETER. 6 ins.	7 ins.	8 ins.	9 ins.	10 ins.	11 ins.	12 ins.
18	6·13	7·15	8·17	9·19	10·21	11·23	12·25
19	6·49	7·57	8·65	9·73	10·82	11·90	12·98
20	6·86	8·01	9·15	10·29	11·43	12·58	13·72
21	7·24	8·44	9·65	10·85	12·06	13·27	14·47
22	7·62	8·89	10·15	11·42	12·69	13·96	15·23
23	8·00	9·34	10·67	12·00	13·34	14·67	16·00
24	8·39	9·79	11·19	12·59	13·99	15·39	16·79
25	8·79	10·25	11·72	13·18	14·65	16·11	17·58
26	9·19	10·73	12·26	13·79	15·32	16·86	18·39
27	9·61	11·20	12·80	14·41	16·01	17·61	19·21
28	10·02	11·69	13·36	15·04	16·71	18·38	20·05
29	10·45	12·19	13·93	15·67	17·41	19·16	20·90
30	10·89	12·70	14·51	16·33	18·14	19·96	21·77
31	11·33	13·21	15·10	16·99	18·88	20·77	22·65
32	11·78	13·74	15·71	17·67	19·64	21·60	23·56
33	12·24	14·29	16·33	18·37	20·41	22·45	24·49
34	12·72	14·83	16·95	19·07	21·19	23·31	25·43
35	13·20	15·40	17·60	19·80	22·00	24·20	26·40
36	13·70	15·98	18·26	20·54	22·83	25·11	27·39
37	14·21	16·57	18·94	21·31	23·67	26·04	28·41
38	14·73	17·18	19·64	22·09	24·55	27·02	29·46
39	15·26	17·81	20·35	22·90	25·44	27·98	30·54
40	15·82	18·46	21·09	23·73	26·37	29·00	31·63
41	16·39	19·12	21·85	24·58	27·31	30·04	32·77
42	16·97	19·80	22·62	25·46	28·29	31·12	33·95
43	17·58	20·51	23·44	26·37	29·30	32·22	35·17
44	18·21	21·24	24·27	27·31	30·34	33·38	36·41
45	18·85	21·99	25·14	28·28	31·42	34·56	37·70

CHAPTER VIII.

A TWIN SKEIN GEAR FOR A FUSELAGE MODEL.

The construction of a gear for a model fuselage aeroplane is a subject not easily tackled by an amateur. Unless the constructor has one to copy from or has advice on the matter he is likely to have difficulties.

This chapter is just the general procedure of making a simple twin skein gear of normal proportions with a few tools and materials, obtainable almost everywhere in England.

It might be well to make a few comments on the values of a twin gear so that those who are not familiar with them will not think that it is just an unnecessary addition to the difficulties of the building of a fuselage flying model aeroplane.

From the chapter on rubber motors it will be seen that if two ounces of rubber are used in a single skein of a given length so many turns may be put into it before it breaks, and also from the same article it can be seen that if the two ounces of rubber are made into two skeins and the length kept the same many more turns can be given before either of these skeins break; thus is shown No. 1 advantage of a twin gear—more turns for a given weight of rubber.

Next, it is obvious that when two gears are in mesh and one is turned the other turns also, but their directions of rotation are opposite; if rubber is twisted it produces a reaction on the structure holding it; thus a fuselage with only one skein has a tendency to twist around that skein, but should a twin skein motor be used the two skeins twist in opposite directions, and if of equal length and weight neutralise each other's torsional reactions. Thus the second advantage—no torsion in the fuselage other than that set up by the propeller torque reaction.

Both the advantages mentioned are very important, No. 1 because of the increase in available turns, No. 2 because of the neutralisation of torsion set up in the fuselage. No. 1

means a longer propeller run, No. 2 means a lighter fuselage, and it is now generally accepted as first-rate practice in the construction of elastic-driven outdoor model aeroplanes to use gears, at least so long as one propeller is being used and the model is to assume somewhat the proportions of a full-sized machine. So much for the gear, its uses and value. It may be well to mention that even though a gear weighs a certain amount it is weight well applied.

To begin the construction you need to make a few parts from raw material, other parts can be readily bought from dealers in wire, metal and model aircraft accessories generally.

The list of parts in this simple gear, shown in Fig. 48, which is of a well-tried type of moderate weight, are:—

A. Driver made from 18 S.W.G. piano wire.

B., D. } 16-gauge sheet brass or ¼-in. by 1/16th-in. strip.

C. A piece of silver spruce, deal, pine or any wood, size finished 2 ins. by 1 5/16th ins. by ¼ in.

E., L. } Spring catches 22 S.W.G. piano wire.

F. Propeller shaft 14 S.W.G. piano wire.

H., I. } Three cup washers.

J. ⅛-in. three-ply, finished size 1 9/16th ins. by ⅞ in.

K. Two 11/16th-in. diameter 20-teeth brass gear wheels.

M. 16 S.W.G. lay shaft.

O. Four No. 2 by ⅜ in. brass or steel countersunk wood screws.

P. ⅜-in. tacks or panel pins.

Having got the foregoing list of parts you can, with very few appliances, set about the construction of the gear. Tackle the wood parts first: take your piece of deal C, spruce, or whatever kind of wood you have chosen, plane the front and rear faces smooth, and take great care that the thickness is uniform, because this ensures that the faces are parallel planes; the reason that these should be parallel is that when drilling the solid wood block for the shaft to go through the holes can be got at right angles to the front and rear faces. This block should be a bit bigger than the front former of your model.

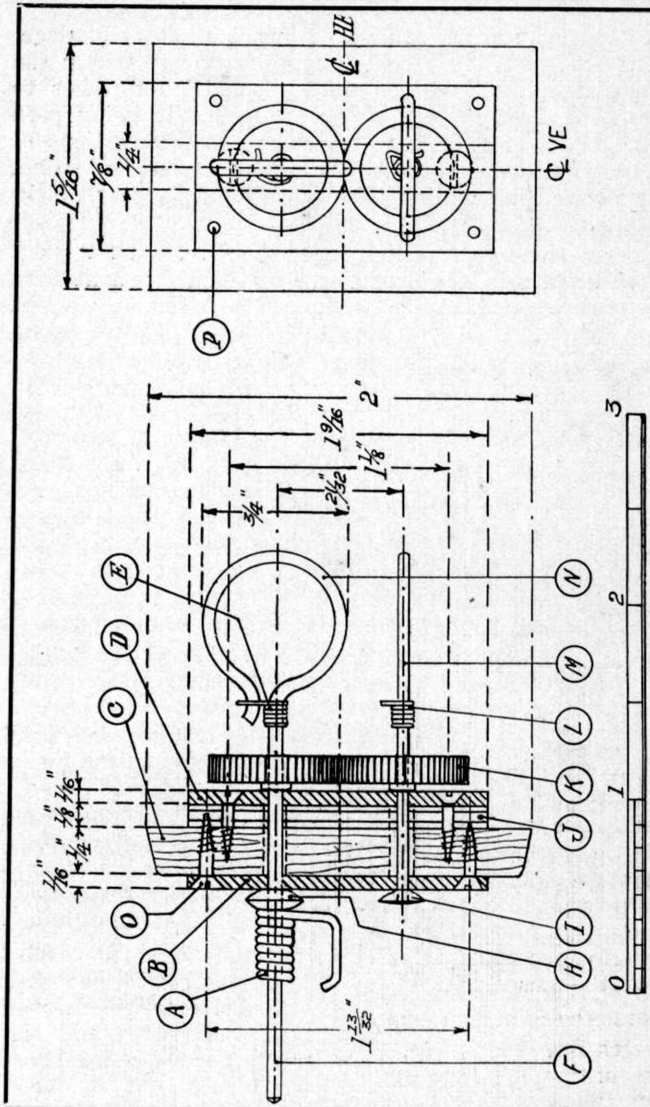


Fig. 48.—Sketch showing General Arrangement and Construction of Twin Skein Gear for Fuselage Models.

Next cut your piece of $\frac{1}{8}$-in. three-ply J to a nice fit inside the nose former of your model, mark centre lines in your block and three-ply, glue or seccotine your three-ply to the rear of the block, set it in position by the centre lines, and then drive in four pins, brads, tacks or panel pins P in the positions shown. Now you can lay your block on its front face and drill the two $\frac{1}{8}$-in. diameter holes right through, taking great care that they are at right angles to the front and rear faces of the complete wood part, now composed of the main block C and the piece of three-ply J.

The holes, which run right through the three-ply and block, are to be drilled on the vertical centre line VE, and must be 21/32nd in. apart and set equidistant from the horizontal centre HE. This distance, 21/32nd in., is variable, and may be more or less, according to the gear you happen to be using. The best way to find just how far apart to drill these holes is to put the two shafts into the gear wheels, put the gear wheels in mesh, with one thickness of tissue paper between the teeth for clearance; measure the distance from the outsides of the shafts with a micrometer, and add together the diameters of the two shafts, divide by two and subtract the result from the total distance as shown on the micrometer; this will then be the distance apart of the holes for the shafts and the two holes through the three-ply and block.

You can now tackle the metal parts, wire parts, and soldering. Take a sufficient length of 14 S.W.G. wire and bend it into a $\frac{3}{4}$-in. diameter hook as shown, N. This can be done with a pair of ordinary pliers and does not necessarily need to be rounded as shown, but may be multi-sided, the number of sides being determined by the size of the plier faces; but it is very important that this hook is cranked back so that the shaft centre line would run through the centre of the hook, and also it is important that the hook should have the little turn up on its end to accommodate the spring catch E. The part of the shaft forward of the hook should be clean, smooth and *straight*. This is very important, as the running of the gear depends very much on the truth of the shafts.

No length is given for either the propeller shaft or the lay shaft, as in the first length is entirely dependent on the propeller thickness and in the second whether you prefer to have the hooks close up to the gears or whether you use a different thickness block C or different gauge bearing plates BD. The lay shaft and hook marked M is made in the same manner as the propeller shaft, but it is of 16 S.W.G., due to it having less torque to withstand and no bending when the model makes a bad landing or comes into collision with an obstacle.

Next, you can make your two spring catches, E and L, E being made on 14 S.W.G. with 22 S.W.G., and L being made on 16 S.W.G. with 22 S.W.G. The procedure is to wind a length of 22 S.W.G. closely round either particular shaft it is to fit about six or eight times, then clip off one end close and bend the other end into a gentle hook with its tail or end turned up, so that when the curved-under side is pressed against the turned-up end of the shaft hook the thin catch wire is bent up and thus springs over and completes the hook; this is to keep the elastic on the hooks, as loose lubricated elastic has a very decided tendency to creep, and would escape if it were not for these spring catches.

To fully understand this description of these catches you will need to look carefully at the drawing of the gear.

Next, make the driver from 18 S.W.G. piano wire. This is done by winding it round the propeller shaft 14 S.W.G. about eight times, clipping off one end and bending the other end at right angles, and then turning the tail in a little towards the shaft. This driver or clutch will hold on a propeller without any further fastening if the holes are a decent fit on the shaft (note that two sizes of holes are needed in a propeller to be used with this type of driver).

There is one very important point about making these drivers, and this is that they must be wound in such a way that the reaction of the motor torque tends to wind the tail shorter, or, in other words, to tighten on the shaft as the load increases.

Next comes the drilling of your bearing plates BD. These may be sweated together (soldered) for the drilling of the shaft holes, one a running fit for 14 S.W.G. and the other a running fit for 16 S.W.G. The two holes are to be drilled on the vertical centre line or on a centre line parallel to the edge and midway from edge to edge. These holes must also

be equidistant about a centre line which is in the middle from end to end; the distance the centres of these holes are apart is determined in the manner indicated earlier when drilling the two $\frac{1}{8}$-in. diameter holes, the only difference being that these two in the bearing plates must be very accurate. The points at which the lines indicating the positions where the holes should be drilled intersect should be very carefully centre popped, and if you are in doubt as to the distance apart these holes should be have a try-out on a piece of tin.

Having drilled the holes for the shafts put the gear wheels on the shafts and try them to see if they will run; if they are too far apart you must start again, but should they happen to be very slightly too near together you can unsweat the plates, and by tapping each plate separately on a hard metal surface with a small hammer you can make the distance between the holes "grow," because by tapping the brass you flatten it; this reduces its thickness, the metal is displaced sideways and longways, thus producing the desired result. This can only be done for small inaccuracies and only when the holes are too near together. If the holes are too far apart it is sometimes possible to reduce the distance apart by cranking or double cranking, or bowing and cranking the plates, but such efforts to get accuracy are not good practice.

Let us assume that you were successful at the first attempt in drilling your holes the right distance apart and the right diameter and your wheels ran quite easily. Then you can unsweat the plates and mark and drill and countersink for the four wood screws which are to hold them in position on the block at the front and on the three-ply at the rear. If you have difficulty in getting drills which produce holes that are a running fit on 14 S.W.G. and 16 S.W.G., drill the holes small for the shafts and make long tapered reamers from piano wire by heating to soften, filing to a square, and then reharden by heating to a dull red heat and quench in water or oil. These reamers will enlarge the holes to the size you require if the taper is very gradual and the wire chosen for their manufacture has been large enough.

It might be well to mention that these reamers, after the process indicated for hardening, are very brittle and must be used very gently and worked a bit at a time from alternate sides of the plate, otherwise the holes will be tapered to an exact fit at one side of the plate and much too slack at the other, or *vice versa*. Use 14 S.W.G. for a reamer for the 16 S.W.G. hole and 12 S.W.G. for the reamer for the 14 S.W.G. hole.

Having drilled your plates for shafts and screws you may, if you find it difficult to hold them in position without allowing movement while screwing on, drill two fine holes, just sufficient to allow two fine pins to go through each plate. These little holes can be used in the following manner: When fitting the front plate place it in position so that the shaft holes come in the centre of the $\frac{1}{8}$-in. diameter clearance holes already drilled, knock in the two small pins; this will hold the plate in position while you use a bradawl or a small drill to make a start for the wood screws. The starting holes for the wood screws O should be very carefully made, and care taken to see that they are exactly in the centre of the holes drilled in the plate for the screws. If they are not, when the wood screw is screwed right home it will bear hard against one side of its hole in the plate and thus push the plate over in that direction, which, if the movement is more than 1/32nd in., may mean that your propeller shaft will be rubbing on the inside of the $\frac{1}{8}$-in. diameter clearance holes drilled through block and three-ply for it.

Having attached the front plate you can now push the shafts into their respective holes and see that they do not bear on the wood. If all is O.K. you can next fit the backplate in a similar manner to the front one, but care must be taken to see that the plate is placed so that the shafts come through the nose at right angles to the front and rear faces of the block and three-ply respectively. This having been done successfully your attention may be turned to another job, the work is progressing all right and you will soon have a good, reliable gear.

Now having attached your front and rear bearing plates, put the nose block on to the fuselage, mark round the outside of the front former on the rear of the block with a pencil, remove the fuselage, cut to this outline and sandpaper smooth and regular. This shape depends entirely on your own

judgment and ideas about your own aeroplane's nose, and does not need to be rectangular as illustrated in this article.

You can now leave the nose with its plates and get on with mounting or soldering the gears on to their respective shafts.

Mention should have been made in case the wheels have holes in them which are too small for the shafts suggested here that these holes may be reamered out with two reamers made for the bearing-plate shaft holes, and great care should be taken in this operation to see that the holes are not too slack and that they are concentric and at right angles or square to the gear-wheel faces.

Let us assume that your wheels are ready to fit. First put your spring catch on to the shaft, then bind on a length of wet cotton; next apply a little killed spirit or soldering flux to the shaft and put a little spirit into the hole in the gear wheel, slide wheel on to shaft; next take a piece of solder, not more than 1/16th in. by 1/16th in. by 1/16th in., or a sixteenth cube, hold it in a pair of tweezers and dip it in the spirit or flux; next hold the wheel and shaft in a flame until hot enough to melt solder, do not heat red hot or blacken, this is unnecessary. When hot enough just touch the shaft at the point where it comes out of the wheel with the small cube of solder held in the tweezers and it will melt and run inside the wheel in an instant. Give the wheel a turn or two while still hot, move it into its exact position, quench with flux or spirit, remove wet thread (which was only to prevent the solder from running and attaching the spring catch to the shaft), and dip the whole lot into water to cool. Take hold of the hook with one hand and the outside of the gear with the other and twist to see if it is well and firmly soldered; if it stands twisting so that the teeth of the wheel begin to hurt your hand then it is all right and can be passed as fit for service. So through the same procedure again with the other wheel and shaft and you are almost ready to assemble the gear.

You might spin the shafts between your finger and thumb and watch the wheels to see that they do not wobble; this is caused by bent shafts or slack holes or even inaccurate wheel drilling or reamering, and if easily noticed should be remedied by straightening the shaft, heating and moving over, or even by buying a new wheel.

Next drill or reamer your collets or cup washers so that they are just a push fit on their respective shafts. Having done this you can thread your shafts into their holes in the plates on the nose block, then put on two wet paper washers at the front, seeing that they are a good fit on the shafts, apply flux or spirit to shafts, put your two cup washers on to the propeller shaft, concave face to concave face, push up so that they nip the paper washer between them and the front bearing plate; next apply some more flux or spirit, then slide on your 18 S.W.G. driver, slide it up and down the shaft a few times, apply a little flux or spirit to the outside of it, then with a clean, well-tinned soldering iron sweat the driver to the shaft and front cup washer, taking care not to burn the paper washer or the cup washers and shaft may become soldered to the bearing plate, and this you do not want to happen. At the time this soldering is being done care should be taken to see that the gear wheel on the propeller shaft is bearing up against the rear bearing plate.

When soldered, hold the hook and driver in different hands, twist until driver hurts; if it holds it can be passed for service.

Next, remove wet paper washer; this will produce a slight clearance between front face of gear wheel and back bearing plate.

The same procedure can now be carried out with the lay shaft and its cup washer I, but the test for this is made by pulling on the hook while holding the whole gear nose.

It might be well to note that the hooks, being of greater diameter than the wheels, would touch when revolving if they were not fitted in the manner illustrated, that is, at right angles to each other. This is done simply in the meshing of the lay shaft gear wheel with the propeller shaft gear wheel before soldering the cup washer on to the lay shaft. If, after soldering, you find the lay shaft sticks too far through its cup washer it should be cut off and filed flush.

In soldering the cup washer on to the lay shaft fill its concave side with flux or spirit and drop molten solder into it and touch as little as possible with the soldering bolt, or

the paper washer will be burnt and the shaft washer and front bearing plate will become soldered solid.

Having tested the lay shaft by pulling to see that its cup washer is well soldered put a drop or two of oil on the points where the shafts revolve in plates, and oil the teeth of the wheels, try the gear for running, and, if it is a bit stiff, chuck the propeller shaft in a wheel and turn it for a minute or two when it will become much freer. Mention might be made that this gear should be oiled frequently when in use, and if used in competitions where results are important watch the two cup washers on propeller shaft to see that they are not flattening out, as impact and wear cause this trouble and duration is lost due to friction at this particular point.

If, when attempting to bend hooks in 16 and 14 S.W.G. wire you find it difficult heat the part to be bent red hot and allow to cool, when it will be easily bent, but take care not to let the heat reach the part of the shafts carrying the wheels as this is best kept hard. Don't try rehardening unless you are an expert at this particular art.

CHAPTER IX.

THE BEGINNER'S TRACTOR MONOPLANE.

THE model here described is one that can easily be made and is recommended to the beginner.

Three difficulties have generally been present in the construction of a flying model: bending the wood (chiefly the wing members), carving or bending the propeller, and the soldering work. These obstacles do not exist in this machine. The method of making the propeller, usually the beginner's stumbling block, is simplicity itself. It is not by any means the last word in efficiency, but is, however, good enough to fly the model 100 yards and over. Of course, better results are obtainable by using a properly carved one. A plan of the machine is given in Fig. 49, and side and end elevations in Fig. 50.

Fancy shapes have been avoided, the main object being a machine that can be made simply and cheaply, but most important of all one that will really fly. The following is a list of materials required, with prices :—

2 ft. of 3/16th-in. by 1/16th-in. birch ...	1d.
8 ft. of ¼-in. by 1/16th-in. birch	4d.
2 ft. of ¼-in. by 5/16th-in. spruce	2½d.
1 yd. of 18 S.W.G. steel wire	1½d.
1 yd. of 20 S.W.G. steel wire	1d.
1 reel thread	3d.
1 tube glue	2d.
3 yds. 3/16th-in. flat strip rubber	4½d.
1 propeller bracket	2d.
5 ins. by 36 ins. proofed silk	9d.
Propeller wood	3d.
Nails and cupped washers	3d.
2 1½-in. diameter disc wheels	6d.
(Finished carved propeller)	2s.

This material is ample for the model, and the prices have been taken from the lists of model aircraft firms.

Now to get on with the construction of the model. Take the spruce spar measuring 24 ins. by ¼ in. by 5/16th in., and taper one end with a plane, as shown at AA (Fig. 51) on drawing. Make sure you get this taper as illustrated. Do not plane any other part of the stick as you are liable to get it too thin,

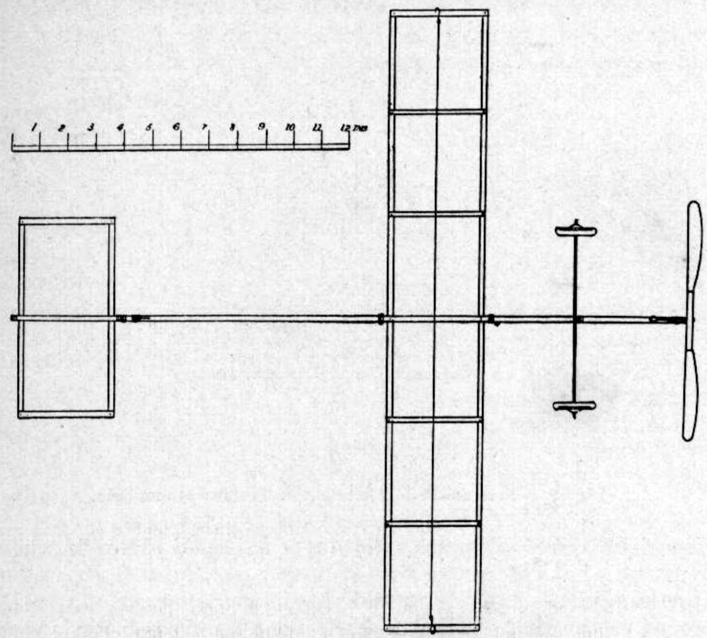


Fig. 49.—Plan View of Tractor Monoplane.

but smooth down with glasspaper. You can now, if desired, polish or varnish this spar. The wing is built up of birch ¼ in. by 1/16th in. for the long spars, the centre and end ribs, and 3/16th by 1/16th in. for the other ribs or cross-pieces. The tail is made entirely of the ¼-in. by 1/16th-in. birch. The best method of doing the job is to mark out with pencil the shape on a piece of flat board, lay the wood in position on the pencil lines and tack the pieces together, driving the nails right into the board, which will hold the whole in position. It will be necessary to drill fine holes for the nails, a fretwork drill will serve, also well glue each joint made. Do not remove the wing and tail from the board till the glue is set. The shapes can then be taken from the board and the nails

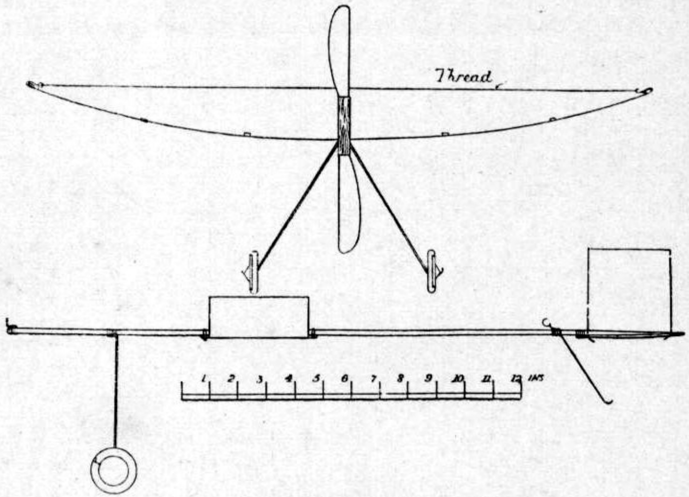


Fig. 50.—Side and End Elevation of Tractor Monoplane.

knocked over without splitting the wood. Note, when making, that the centre ribs of both wing and tail are under the long pieces and are extended to provide means of attachment to the spar. The rudder is bent up of 20 S.W.G. wire to the shape in Fig. 52, and the joints A and B made with thread and glued.

Both wing and tail are covered on the underside only, the procedure is as follows: Cut your silk, allowing a margin of about ½ in. larger than the surfaces. Smear a little tube glue on the undersides of the frames. Next slightly damp the silk and lay it out flat. When the glue is tacky (it requires a minute or so), and not until, lay the frames on the silk with the glued part in contact with same. It is now a fairly simple

matter to work the silk, using fingers and thumbs, tight on the frames. A little more glue is smeared on the top of the wing frames, that is, along the main spars and end ribs. It should be allowed to get tacky, and the margin of silk turned over stuck down on these spars and ribs. The surplus silk can be trimmed off with a sharp knife or razor blade. It will be necessary when covering the wing frames to cut the silk at the ends and centre to allow the margin of silk to be turned over on to the top of the frames. To cover the rudder cut a piece of silk, allowing a margin of about ⅜ in. Put a little glue on the wire frame, lay the silk out flat and place rudder frame in contact. Snick the silk at the corners, smear glue on the margin of silk and turn this margin over and stick same down. Don't forget to let the glue get well tacky first. We will now return to our spar.

Place the propeller bracket in position A (Fig. **51**), drive in a nail and bind tightly with thread. Two clips are required to hold the wing to the spar and to allow its being moved for adjustment. These are illustrated in Fig. **53**, and are made of a piece of soft iron or copper wire about 18 S.W.G. It is important that you make them exact to the size given. They are now slipped on to the spar.

The rear hook and skid are made of one piece of 18 S.W.G. wire bent as shown C (Fig. **51**). A hole is made in the spar for its reception, the job being made strong by binding with thread.

The undercarriage is bent up of 18 S.W.G. wire, as shown in Fig. **54**. The wheels are slipped on and the ends of the wire turned up to secure them in place. The undercarriage is now lashed to the spar. The method of making the propeller can be gathered from the illustration (Fig. **55**). The centre is preferably birch ½ in. by ¼ in. by 2 ins. It is slotted for the blade by means of a tenon-saw, the depth of cut for each blade being ¾ in. Make sure you cut these slots true and from corner to corner of the block A (Fig. **55**). The slots, of course, being at opposite angles. The blades are made of 1/16th in. birch cut to shape shown, and the edges glass-papered sharp. The dimension at the root of the propeller blade should be 9/16th ins. They are then well glued into the slots of the centre piece. A hole is made exactly central and the propeller spindle made of 18 S.W.G. wire put in. It is secured by turning the end of the wire about ⅛ in. back on itself and driving into the wood. It would be as well to varnish the propeller to protect the glued joints from damp.

The tail is lashed with thread on the underside of the spar. The projecting centre rib of same provides for this to be done. Two holes are next drilled through spar and tail centre

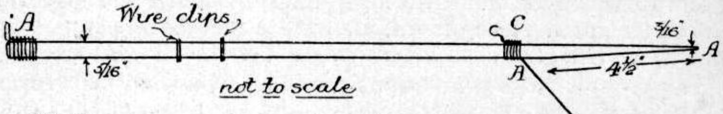
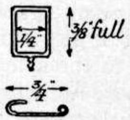


Fig. 51.

Fig. 53.



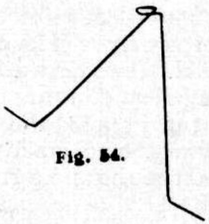


Fig. 54.

Fig. 56.

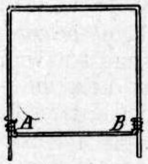
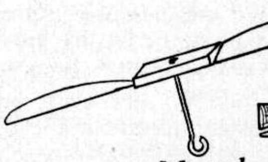


Fig. 52.



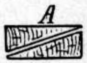
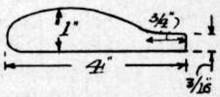


Fig. 55.



exactly the same distance apart as the prongs of rudder. These prongs are then inserted in the holes and the ends bent over, thus securing the rudder in position.

Put a washer on propeller spindle and thread latter through the hole in the propeller bearing. Six strands of 3/16th-in. flat strip rubber form the motive-power, and can now be put on. It should not be stretched between the hooks. If anything, it is better loose. To find the approximate correct position for the wing suspend the model by a thread round the frame and mark the position of thread where the

model balances. Place the wing on the underside of spar so that its front edge is about one-third of its width in advance of the position marked and secure same by means of the clips. Make two hooks, as shown in Fig. 56, and slip one on each of the end ribs at the centre. Now connect them together by means of a thread, making the thread tight so that it pulls the ends of the wing upwards to give it the curve shown in the drawing. Our model is now ready to take the air. Do not wind the elastic fully for a start, about forty turns will do; hold the machine horizontally, not pointing up; and launch gently into the wind. If the nose of the machine rises sharply and the flight is undulating move the wing back along the spar. Should the model go to earth move the wing forward. The model is very sensitive to this adjustment; therefore the wing should not be moved more than a ¼ in. at a time before trying again. Correct any tendency to turn by slightly twisting the rudder. Having got the model in flying trim the elastic may be fully wound, about 230 turns for dry rubber and 350 turns if the rubber be lubricated. The model is capable of rising from the ground, and should be placed on a fairly smooth surface, head into wind, and the propeller released. Pushing the model is unnecessary. The most important point for good results is to see that the wing surfaces are symmetrical, and that one side does not lift more than the other. Any warp can be corrected by moving the position of the hooks on the wings either backwards or forwards.

CHAPTER X.

W. J. PLATER'S TRACTOR FUSELAGE MONOPLANE, "RESURGAM."

THE model here described with working drawings attached was designed and built for duration, and is the tenth of a series of similar machines. During the evolution of this particular type constructional weaknesses have been "weeded out," and aerodynamical efficiency improved until a sturdy, reasonably crash-proof machine has resulted.

The original machine up to date has successfully flown many hundred times, and has to its credit several prizes, including a first in an international competition, and holds the British seaplane record.

The maximum duration attained, checked by stop-watches, is 70 seconds hand launched and 63 seconds rising off ground under its own power. Its speed is approximately 17 m.p.h., and it will fly in winds up to 20 m.p.h.

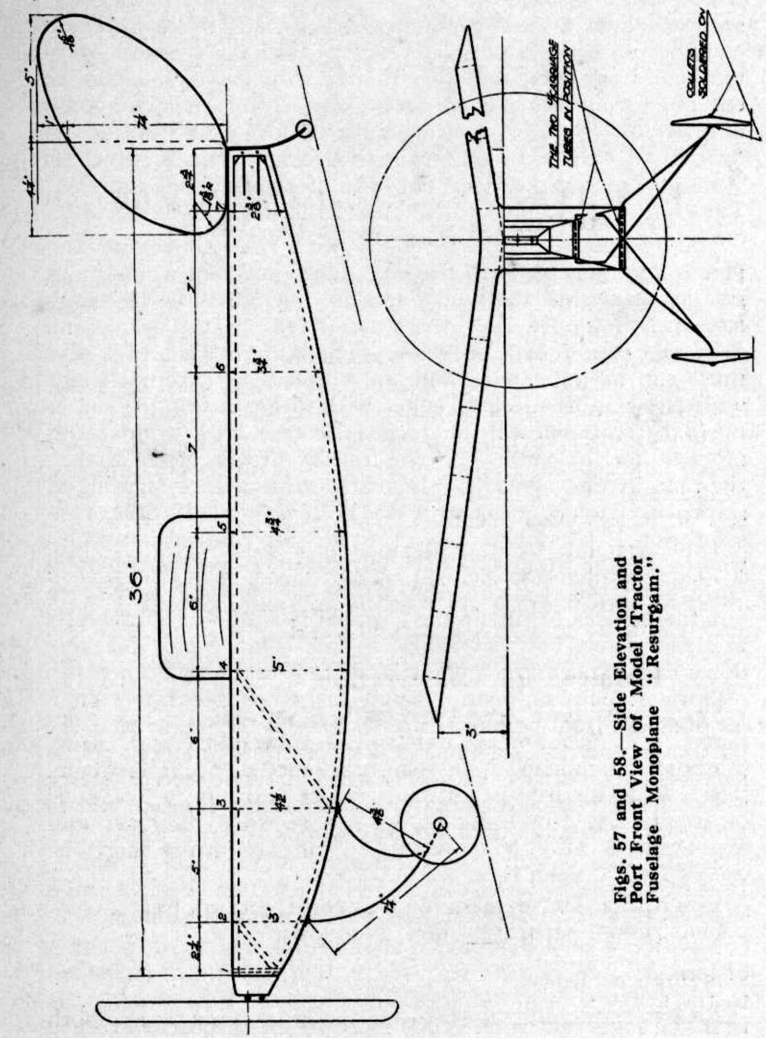
Tools Required for Construction.

Small wheel brace, two twist drills, 5/64th-in. and 1/16th-in. diameter, a "Hobbies" fret-saw, 1-in. wood-cutting chisel, 8-in. half-round smooth file, pair of scissors, pair of side-cutting pliers, soldering iron (small size), solder and flux, a 1-ft. steel or wood rule, 6-in. celluloid set-square, small hammer and fine bradawl, also cocoa or tobacco tin for fittings, and one reel of No. 30 linen thread.

Description and explanation for construction of each component, taken separately, are as follows :—

Fuselage or Body.

Length, excluding nose piece, 36 ins. ; maximum depth 5 ins. ; maximum width, $2\frac{5}{8}$ ins., and these points come at



Figs. 57 and 58.—Side Elevation and Port Front View of Model Tractor Fuselage Monoplane "Resurgam."

No. 4 former. Refer to Fig. 57 (side elevation). The cross-sectional area at this point is therefore $13\frac{1}{8}$ sq. ins., which complies with the formula set by the Society of Model Aeronautical Engineers, and can therefore, when completed, be entered for any British competitions. Fuselage is composed of four longerons of spruce 3/16th in. by $\frac{1}{8}$ in., and seven formers of three-ply, all $\frac{1}{8}$-in. thick, except No. 1, which is $\frac{1}{4}$ in., being composed of two $\frac{1}{8}$ in. formers glued together. The front one is glued to No. 2 after fuselage is made up.

Mark formers out on three-ply with rule, set-square and pencil, commencing with the large ones, inside of which mark smaller ones until the whole area is covered. Fig. 69 shows former No. 4. All the others also have the top part $\frac{1}{4}$ in. deep and sides 5/32nd in. wide. The grain of the outer plys must run as indicated. Cut out formers to external shape with fret-saw, then clean edges with either a wood plane or file exactly down to the lines. Proceed now to cut out notches for longerons. Next fret-saw to internal shape; the radii at the corners can be made either with a farthing or sixpence. Height of stern-post is $1\frac{3}{4}$ ins. Our next consideration is the longerons. The two top ones are straight, whereas the bottom ones are curved. Proceed as follows: On a flat table or board draw a line 36 ins. long, and space out the centres of the formers—given in Fig. 57. Draw lines at these points at right angles to line 5 ins. long. Measure down each, and mark a point indicating the maximum depth of former. Steam-bend bottom longerons separately in a jet of steam from boiling kettle to an even curve, so that the bottom edge of the longerons touch each of the marked points representing bottom end of formers. The correct shape assured, re-steam and increase the curve by $\frac{1}{2}$ in. each end to allow for springing back while drying.

Steam-bend spruce very carefully or it will "kink." It is advisable to well soak in steam jet, then bend a small section at a time between the forefingers and thumbs.

Now mark on longerons from the table, or board, position of formers. Next bend with steam the rear end of longerons to the shape shown in Fig. 67, at the same time cutting the bevel on longerons where they meet the stern-post. Proceed now to lay longerons in pairs, and drive $\frac{1}{4}$-in. pins through

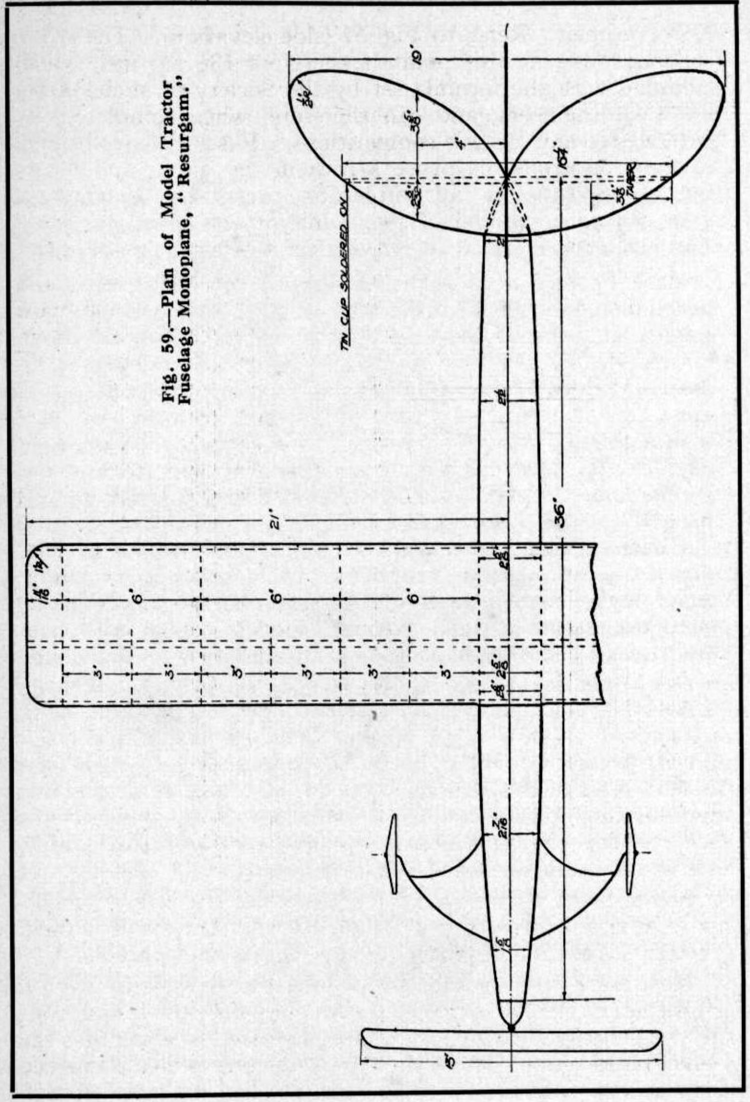


Fig. 59.—Plan of Model Tractor Fuselage Monoplane, "Resurgam."

centre of longerons at the marked points, allowing them to project 1/32nd in. The fuselage can now be assembled by fitting the longerons into the notches of the respective formers, first gluing the joints, then driving the pins hard home with pliers or hammer. During the latter operation

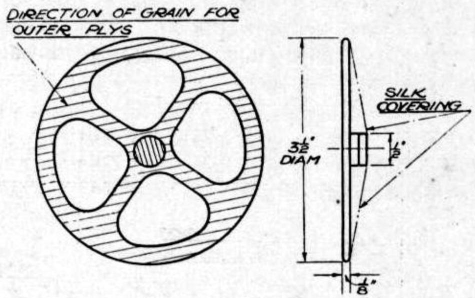


Fig. 60.—Wheel Construction.

hold each former firmly between finger and thumb of left hand. Check formers often before the joints set for being square with centre line of machine in plan view. Now fit stern-post, struts and all packing blocks, except the two small ones at the rear, at the position shown in drawings.

Note the direction of grain in packing blocks and glue only.

The front half of former No. 1 can now be glued and nailed into position, nailing from the inside, ¼-in. pins used. Now make up rear skid as per Figs. 65 and 68, and fix.

The four undercarriage fittings are made of two laminations of tin each. The tin available is about 1/64th in. thick. By laminating and then sweating the two halves together a much stronger fitting is obtained. Drill holes in these last thing before gluing and binding with thread to fuselage. Refer to Figs. 64 and 76.

Rear hooks can now be made, fitting on valve rubber before attaching to fuselage. Refer to Figs. 65, 67 and 81. Valve rubber is fitted to reduce the chafing of the motor on hooks. Slightly round outer edge of longerons and generally clean up fuselage for covering.

Covering Fuselage or Body.

Cover the bottom first. Cut or tear a piece of silk 37 ins. by 3⅜ ins. Damp silk with warm water ; lay it on bottom of fuselage evenly, allowing ⅜ in. over-lap each side at the widest part. First stick silk at bottom end of fuselage for about 1 in. along from stern-post. Allow three-quarters of an hour to set. Now re-damp silk and stick front end, and bring the over-lap round front of nose—pulling tightly. When reasonably dry run glue down the top edge and side of longerons. Gently pull silk over the edges both sides fairly firmly with fingers and with the surplus glue finish sticking on the top side of bottom longerons. When glue is set trim off surplus material with an old razor blade.

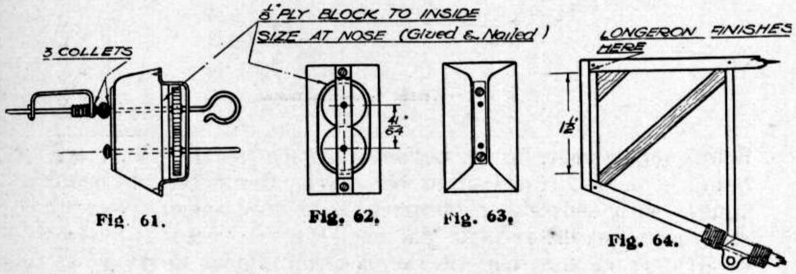


Fig. 61. Fig. 62. Fig. 63. Fig. 64.

Details of Gearing, Nose-Piece and Undercarriage Fitting.

Now tear a piece of 37 ins. by 13 ins. Glue silk first to rear and then front end of fuselage centrally as you did for bottom, then glue the top and sides of longerons, squeezing out surplus glue meanwhile. When nearly set follow a similar procedure on both sides of fuselage, keeping threads in the silk vertical and straight. This latter point is important. Glue silk to sides of bottom longerons, then trim off surplus silk, which can be kept for covering wheels, cutting ¼ in. from longerons to allow sufficient overlap. Glue and fold projecting silk over the edge and wipe surplus glue off with a damp cloth. It is now necessary to run a little glue through the fabric along each edge of each former, so that when dry the whole fuselage is rigidly braced with the silk, which, of course, eliminates complicated internal wire bracing.

"Resurgam" Tractor Fuselage Monoplane.
List of Materials for Construction.

Quantity.	Material.	Sizes.	What used for.
1 Length	Spruce	42″ × ¼″ × ¼″	Wing—Main Spar
5 ,,	,,	42″ × 3/16″ × ⅛″	Fuselage—4 Longerons; Wing—Leading Edge
1 ,,	,,	42″ × ¼″ × 3/32″	Wing—Trailing Edge
2 ,,	,,	24″ × 1″ × ⅛″	Tail plane—Main Spar; Fuselage—Bracing Struts
1 Piece	3-ply	22″ × 3″ × ⅛″	Fuselage—Formers
1 ,,	,,	7½″ × 3¾″	Wheels
4 ,,	Birch	12″ × 2¾″ × 1/16″	Wing—Ribs, Corner Blocks, etc.
1 Length	Piano Wire	3′ 6″ × 18 S.W.G.	Wing Tip, Tail Skid, Airscrew Fixing
1 ,,	,,	9′ 0″ × 16 S.W.G.	Tail Plane, Fin, Hooks, etc.
1 ,,	,,	5′ 0″ × 14 S.W.G.	Under-carriage and Airscrew Spindle
1 Block	Ash	2″ × 1⅛″ × ¾″	Nose-piece
1 Reel	Binding Wire		For strengthening Soldered Joints
12	Collets (Steel)	¼″ diam.	Airscrew Undercarriage and Rear Hook Fittings
3	Collets (Steel)	3/16″ diam.	Soldered each side of Wheel on Rear Skid (one spare)
1	Wheel	¾″ diam.	Tail Skid
4 Tubes	Glue (Bontite)		
1 Piece	Silk (Jap)	44″ × 16″	For Wing Covering
1 ,,	,,	30″ × 9″	For Tail Unit Covering
1 ,,	,,	38″ × 16″	For Fuselage Covering
1	Airscrew	13″ diam., 19½″ pitch	
2	Gear Wheels	11/16″ diam.	Brass
6	Screws	¼″ × No. 0	Brass, countersunk
1 Strip	Steel (Mild)	5″ × ¼″ × 20 S.W.G.	Nose-piece, Bearing Plates
½ oz.	Pins (Steel)	¼″ long	For fixing
1 Piece	Rubber (Valve)	6″ long	For covering Hooks
1 Reel	Rubber (¼″ Strip)	32 yds.	For Motor and attaching Mainplane and Tail Unit

Wing Rib Profile Dimensions.

No.	1	2	3	4	5	6	7	8
Top	0	¾″	⅞″	15/16″	61/64″	15/16″	⅞″	53/64″
Bottom	¼″	0	1/64″	3/64″	3/32″	9/64″	5/32″	11/64″

No.	9	10	11	12	13	14	15
Top	49/64″	11/16″	39/64″	33/64″	13/32″	19/64″	1/16″
Bottom	3/16″	3/16″	5/32″	9/64″	3/32″	3/64″	0

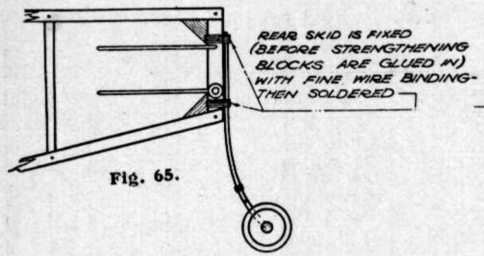


Fig. 65.

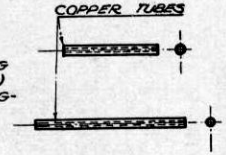


Fig. 66.

The space enclosed by stern-post, No. 7 former, and the top and bottom longerons, each side, can now be removed for easy access to the rear hooks, allowing 3/16th in. beyond former No. 7 and longerons for gluing and turning in.

Main Plane or Wing.

Take measurements from rib profile, Fig. 72, to ensure accurate wing section, blend in the curves and make up template or pattern. Measuring from leading or entering edge to trailing edge distances from base line on vertical ordinates are as in table above.

Make up three ribs exactly to shape from hickory blades, as shown in Figs. 72, 73 and 74, and use them as patterns for the others. Six camber, six nose and two centre section ribs are required. Cut the main spar ¼ in. by ¼ in., leading edge 3/16th in. by ⅛ in., and trailing edge ¼ in. by 3/32nd in. to exact length, which can be checked from Figs. 59 and 70. Space out position of ribs on these components, then cut notches in leading and trailing edges to receive wing tip. Taper main spar from 1½ ins. down to 3/32nd in. on top side at tips. Now cut V in main spar and leading edge at centres half-way through material from the top side. On trailing edge cut two similar V's each 1 5/16th ins. from centre each side. Now on board or table draw a line 42 ins. long, mark centre and raise two perpendicular lines 3 ins. high at each end. Draw a line each side from centre to top of 3-in. lines. This gives us correct dihedral on wings.

Next steam on opposite side of V's until 3-in. dihedral is obtained. Now glue and nail on packing blocks to main

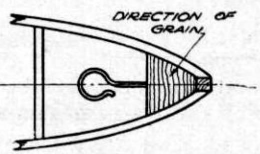


Fig. 67.

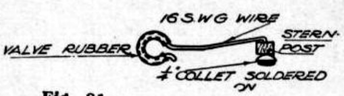


Fig. 81.

Fig. 68.

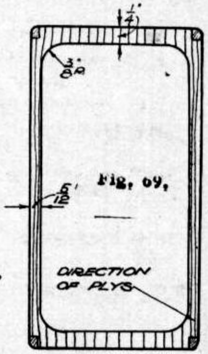


Fig. 69.

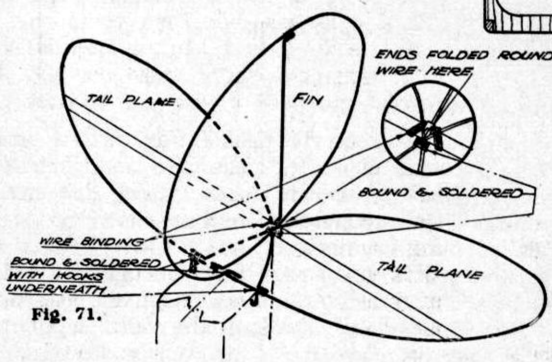


Fig. 71.

spar, one each side, and to leading edge on one side only. No packing blocks on trailing edge as end of ribs come just over the nicks, and, when glued into position, are quite strong. Refer to Figs. 77, 78 and 79. Allow glue to set.

Next operation, thread ribs in their respective positions on one side. Glue into position, and make sure that they are 90 degrees to main spar both in plan and front elevation

except the centre section rib, which is 90 degrees only in plan. Put two weights on main spar approximately 6 ins. from tip and centre to prevent wing moving until glue is dry. After completing opposite side, allowing glue to set firmly. Now fix wing tips as illustrated in Fig. 70.

Gluing will hold ribs firmly without pinning.

Covering Main Plane or Wing.

Tear two pieces of silk, 44 ins. by 8 ins., for bottom and top are covered separately. When covering keep a bowl of hot water handy and piece of cloth, and also a lighted candle to warm and liquefy glue.

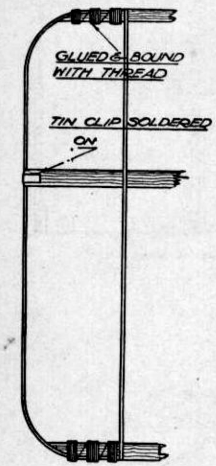


Fig. 70.

Damp one piece of silk for bottom and run glue along left front side of leading edge. Now place one edge of silk on, allowing ¼-in. overlap, stretching silk lengthwise meanwhile, and, with assistance, gently squeeze glue through silk. Rub finger sharply up and down leading edge until adhesion is assured, then press the lap over the top side of leading edge, nicking with scissors where ribs come. The surplus glue will be sufficient to stick this.

Now do the right-hand side in a similar manner. When the glue is dry re-damp silk at centre section, and glue silk to the underside of centre section ribs, keeping the enclosed space taut. When dry stick silk round trailing edge in a similar manner to the way the front was done, meanwhile pulling the silk fairly taut both crosswise and lengthwise. When reasonably dry cut surplus silk off tips, allowing ⅜-in. overlap each end. Glue silk and press over wing tips between finger and thumb.

To make the silk conform to the camber on the under surface of the wing a needle and thread must be used to stitch it. Stitches ¼ in. apart, starting from trailing edge to where the section assumes a convex shape, and note that the stitches go round the flange, and not round the top edge of section. Refer to Fig. 72. In covering top side first damp and glue edge of silk on underside of leading edge to the silk on bottom side, allowing $\frac{1}{4}$-in. lap. Keep silk slightly stretched lengthwise, and, with assistance, gently rub along lap until adhesion is complete. Allow three-quarters of an hour to dry. Now re-damp silk at centre section and glue through silk to top side of ribs, making the silk in the space enclosed as taut as possible, and finish by bringing the silk over the trailing edge and finishing on the underside with a $\frac{1}{4}$-in. lap.

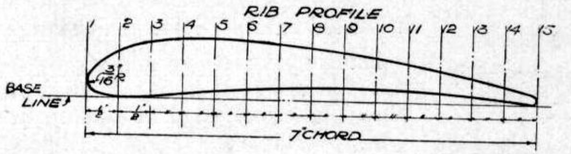


Fig. 72.

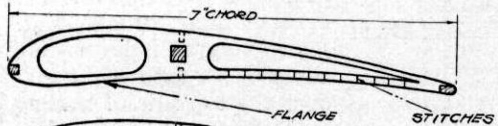


Fig. 73.

Fig. 74.

The remainder of the covering on top side is done in two halves, the left and right side, or *vice versa*, as was the case in covering the bottom. Say, damp the left half first and pull silk taut crosswise and lengthwise to stretch it. Now drive two 1-in. nails into the table, one $\frac{3}{4}$ in. from edge, 5 ins. apart, until the heads are only $\frac{1}{2}$ in. above surface, and butt wing tip against them. Place a weight of about $\frac{1}{2}$ lb. on centre section ribs. Now the trailing edge of the right half projects $\frac{1}{4}$ in. or so over edge of table. Pull silk tight lengthwise, especially over the front portion of plane, which has a bigger camber than the rear, and place about six drawing-pins in

table through the silk $\frac{1}{4}$ in. from wing tip. Now glue along top edge of rib nearest wing tip and keep the silk stretched tight chordwise over this rib. When dry remove pins, etc. Trim silk off $\frac{1}{4}$ in. from trailing edge, glue and gently press over on to the under surface of trailing edge, not too tightly or you will cause a " sag " between the ribs near the nose. Now trim silk round tip, allowing $\frac{1}{4}$-in. lap also, and treat in a similar manner. Next carry out similar operation on other side, and wing is then completely covered.

If wing is properly covered, not applying too much tension on silk, the leading and trailing edges will cut parallel to each other when sighted across the plane.

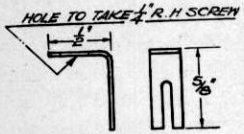


Fig. 75.

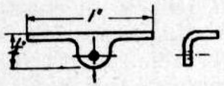


Fig. 76.

Fig. 77.

Fig. 78.

Fig. 79.

Tailplane and Fin.

This is of the one-piece type, being more easily secured to the fuselage. Spar is of spruce, $\frac{1}{4}$ in. by $\frac{1}{8}$ in., tapered and cut to length as shown in Fig. 59. Edges of 16 S.W.G. piano wire, bent to required shape by first setting out tailplane and fin separately on table or board from drawings, and bending carefully to the points marked. Fig. 71 gives an isometric view of joints to be made, also Fig. 75 illustrates clip to be fixed to rear of spar. Remember tin clips each end of spar soldered on to wire edge, also hooks on underside of leading edge 2 ins. apart. Tailplane and fin is fixed to fuselage in the front by means of a band made up from the $\frac{1}{4}$-in. strip rubber supplied, and at the rear by a $\frac{1}{4}$-in. round-headed screw passing through hole in tin clip and screwed into stern-post.

Covering Tailplane and Fin.

First cut silk square to outside widths, i.e., 20 ins. by 8 ins. for tailplane, and $8\frac{1}{2}$ ins. by $9\frac{3}{4}$ ins. for fin. Cover tailplane first. Damp silk and run glue along top edge of spar. Place silk over in position, and gently press glue through by moving the finger from centre outwards, and be sure to keep glue off silk except where it is to be stuck. When glue is dry place tailplane (which, of course, includes fin) on table or board, making holes, if possible, where clips come. Insert drawing-pins into table round tailplane about 2 ins. apart, $\frac{1}{4}$ in. from edges, pulling this way and that way, removing and re-inserting drawing-pins where necessary, until the silk is taut all over. Now run glue through the silk on to the wire, rubbing gently with finger until you have been all round. When "tacky" or nearly dry remove pins, turn tail unit upside down, and trim off surplus silk, leaving 5/16th-in. overlap. Run a little glue round the edges and gently fold over, being careful not to disturb the glue already setting. It is a job that requires patience and the author found it difficult at first, but it is now the generally accepted method in model aeroplane construction. Allow glue to set and proceed to cover fin in a similar manner, allowing $\frac{3}{8}$-in. lap at the point where base of fin meets tailplane.

The main plane, tail unit, fuselage and wheels—when covered—can now be given a coat of copal varnish diluted with petrol, 50 per cent. of each, applied lightly with a camel-hair brush. Allow forty-eight hours to dry and harden, then give another coat, which makes the silk airtight and should give a glossy finish.

Wheels.

These are made from $\frac{1}{8}$-in. three-ply, $3\frac{1}{2}$ ins. diameter, suitably lightened and tightly covered each side with silk.

Two packing pieces on front side of each wheel are glued and nailed on. See that the grain in two of the three-plys runs as shown in Fig. 60, as greater strength is obtained. Now drill holes 5/64th in. diameter at centres. Method of fitting wheels to undercarriage is to first solder inner clip-shaped washers, or collets, then thread on the wheels and secure by soldering on two further collets, one each side at ends of axle (see Fig. 58).

Covering Wheels.

Cut four pieces of silk 4 ins. square. Glue silk to rear side of wheel first, which is flat. Trim round edges, allowing $\frac{1}{4}$-in. overlap, and then stick down. Allow glue to set, meanwhile glue the remaining two pieces at centre of wheels. When glue is reasonably dry damp silk, glue round edges of wheels, and stick silk down over the rear of back side of wheel with $\frac{1}{4}$-in. lap.

Undercarriage.

Both front and rear legs are of **14** S.W.G. piano wire, and are bent at the top ends—front one **90** degrees, rear one approximately **30** degrees—so that the length of the bent ends equals half the width of the fuselage at the point of their attachment; thus the ends of each side butt in the middle. Two tubes are made of tin (Fig. **66**), tightly bound round a straight piece of **14** S.W.G. wire twice, then soldered, and securely hold the ends of the legs in position (see Fig. **58**). The bottom ends of front legs are bent so as to form stub axles, length of stub axles being $\frac{1}{2}$ in. The bottom ends of the rear legs are bent to lay on the top side of front legs for $1\frac{1}{2}$ ins., and bound in three places with binding wire and then soldered. The front legs are crossed near the top, bound and soldered at the point of crossing to give lateral rigidity.

The front leg is $\frac{3}{4}$ in. and rear leg $\frac{1}{2}$ in. longer than side elevation (Fig. **57**) to allow for splay, which gives the wheel track. Measurements can be taken from drawing and the necessary amounts added.

Nose-Piece.

This is of ash. Mild steel plates of **20** S.W.G. $\frac{1}{4}$-in. strip are made up and drilled as shown in Figs. **61** and **62**. Holes

5/64th in. top and 1/16th in. bottom. The bearing holes for spindles are 41/64th in. apart, and these must be accurately drilled; should they be too far apart the teeth on gear wheels will miss; if too near teeth will bind (see Fig. 62).

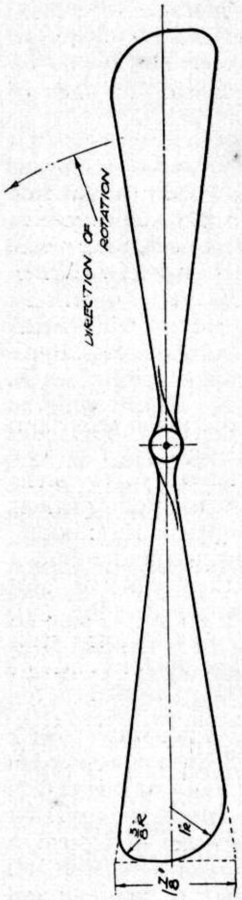


Fig. 80

The 14 S.W.G. wire spindle for airscrew will just fit the hole in gear wheel, while the bottom spindle is slack. Locate position of gear wheel on bottom spindle (Fig. **61**), thoroughly clean with fine emery-cloth, then bend fine wire round it for about 5/16th in. along, and solder. Now with a file reduce diameter until it just fits in gear wheel. Next solder gear wheels on spindles and keep them square, using plenty of flux. Thread hooked ends of spindle through rear bearing plate, then through block, and insert rear screws, which are $\frac{1}{4}$-in. countersunk heads. Thread on front bearing plate and insert screws, $\frac{1}{4}$-in. countersunk heads, and solder on the front collets.

Next make up spindle wire attachment for airscrew in wheel brace, and solder into position. This latter job can be done in the following manner. Place a straight piece of 14 S.W.G. wire 3 ins. long in jaws of brace, tighten; now take a piece of cleaned 18 S.W.G. wire and insert end in chuck at side of 14 S.W.G. wire. Place other end of 18 S.W.G. wire in a vice, pull tight at right angles to brace, meanwhile turning handle. Remove wire, and, with side-cutting pliers, nip off to required length and bend to shape (Fig. **61**). Well lubricate bearing and gear wheels with thin oil, and place valve rubber on hooks.

Airscrew.

The diameter of the airscrew is 13 ins., and it has a pitch of $19\frac{1}{2}$ ins. The pitch angle is constant the last 1 in. at the tip. This gives certain advantages in model practice, though it is not adopted in full-sized practice, for the heavy loads on large airscrews would set up torsional stresses that may result in trouble at high speeds. We refer to this type of model airscrew as one having a graduated pitch.

This can be purchased finished, and is fitted with the flat side facing fuselage, and rotates anti-clockwise as viewed from the front. Plan is shown in Fig. 80. Fit it in position on the spindle, prise up the end of the 18 S.W.G. wire, pulling it over the front side of the airscrew. Then with pliers turn the end once round the spindle and nip off the surplus wire.

Assembling Completed Machine.

Place $\frac{1}{4}$-in. screw through rear clip on tailplane into sternpost, make a rubber band of $\frac{1}{4}$-in. strip rubber, and place on hooks at front, passing it under fuselage. Strap wing in position 13 ins. from front end of fuselage to leading edge with two pieces of $\frac{1}{4}$-in. strip rubber. Now make up two motors as follows: Place two 2-in. nails in table 4 ft. 6 ins. apart, and wind round rubber $\frac{1}{4}$-in. strip ten times, drawing each strand just taut. Nip off end and make a reef knot. Pull knot tight each side by stretching loose end and strand between fingers and thumbs, and, with assistance, tie two knots with thread, one each side of rubber knot. Now tie strands together with thread 3 ins. from each end to keep them even. Next lubricate motor, applying a moderate quantity. Make up second motor in similar way.

Introduce the motive power in the following way: Get a thin stick 48 ins. long, at one end of which tie a fine piece of string. Pass one end of this through the loops at one end of the two skeins, then tie string in a bow. Insert the opposite end of the stick into one end of the fuselage and push it through. Now draw the stick from the opposite end and the rubber will follow. Fix skeins on hooks at each end and tie the "neck" of the loops with waxed thread; this is necessary to prevent twisted skeins from working off hooks, as sometimes happens even when short motors are used.

Weights.

	ozs.
Fuselage with tail skid and rear hooks	3
Main plane	$3\frac{1}{4}$
Tailplane and rudder (one unit)	2
Nose-piece, including gears, etc.	1
Airscrew	1
Undercarriage and wheels	$2\frac{1}{4}$
Rubber motor	5
Total weight of completed machine	$17\frac{1}{2}$

Area of mainplane 2 sq. ft., giving a wing loading of $8\frac{3}{4}$ ozs. per sq. ft.

To Fly Machine.

Take it out into a field clear of trees and obstructions. Check wing for being square with fuselage and in position, i.e., from end of fuselage (13 ins.).

By long experience it has been found best not to too rigidly fix wing and tailplane, as if wing hits an obstacle the rubber holding it on breaks, and not the wing or fuselage.

Well lubricate the rubber motor ; if lubricant is difficult to obtain make your own from the formula given in the chapter on rubber motors.

Wind motor up by turning the airscrew from left to right hand, as viewed from the front. First detach nose-piece and extend rubber motor to its full length. Turn airscrew, and as the skeins are twisting the motor will shorten. It is usual to give about sixty hand turns before refixing nose-piece and applying wheel brace to give the required number. When the motor is just about unwound during the flight it drops to the bottom of the fuselage, disposing itself equally along its length, therefore keeping the centre of gravity constant. That is, of course, why a deep fuselage of that shape in side elevation was used. Give it 300 hand turns. Now hold machine on ground with left hand on airscrew and right hand at No. 6 former, and give machine a gentle push. If in correct trim machine will rise and fly on even keel for about 20 seconds. If it climbs then dives push wing about $\frac{1}{8}$ in. back. If it flies low, push wing $\frac{1}{8}$ in. forward ; with slight adjustments such as these on wing, and if properly made, machine will fly consistently with 600 hand turns for 45-50 seconds. Maximum number of turns on motor is 800, which

has, on the original machine, given consistently over 60 seconds' flight each time. The rubber motor begins to tire after being wound up about thirty times at 600 each time, so it must be rested for at least twenty-four hours. The rubber motors should last for at least 80-100 flights. Should it be desired to fly as a seaplane two more undercarriage fittings must be fitted under No. 5 former. Also two more strands to each motor must be added. Maximum duration as a seaplane is 45-50 seconds, rising and alighting on water perfectly. With 600-800 hand turns machine will rise off ground entirely under its own power.

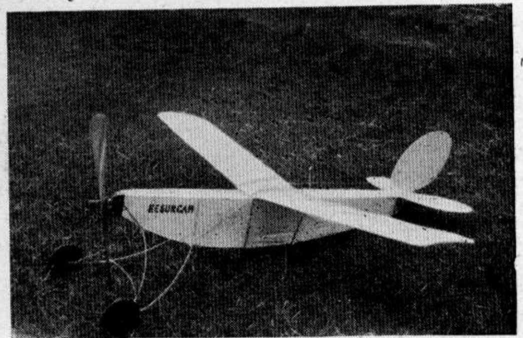


Fig. 82.—"Resurgam."

If it is desirable to get circular flights just slightly, very slightly, bend rudder over left or right. Don't give it too much rudder or the machine will tend to side-slip. If the machine is to be flown as a seaplane use the same mainplane and airscrew, but put on two extra strands to each skein, i.e., four strands in all. Two extra fittings must be fixed on to the bottom side of bottom longerons under former No. 6 to take the rear legs to floats. The floats complete with undercarriage legs weigh $4\frac{1}{2}$ ozs. The main step on the floats must come approximately under the centre of gravity. The machine takes off the water in about three times its own length.

Airscrew, rubber, lubricant, etc., can be obtained at a reasonable price from model aircraft supply houses. Solder, flux, varnish and petrol can be obtained at any ironmongers,

CHAPTER XI.

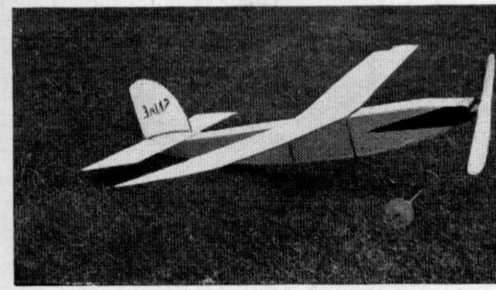
T. H. NEWELL'S MONOPLANE, "FALCON."

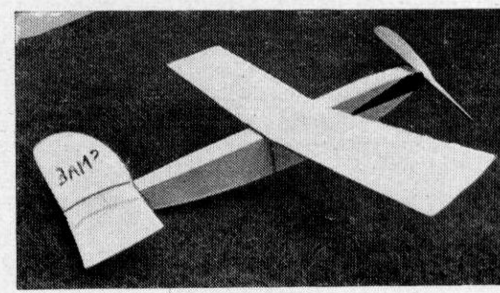
THE extreme simplicity and severity of line would suggest that this is a general-purpose model. But whenever there is a gathering of model flyers and "Falcon" is present others must be on their guard. From the summer of 1928 until May, 1929, it held the British record for fuselage models rising off the ground under their own power, with a flight of 85 seconds. The model (Figs. 83 and 84) is straightforward in every way. The only striking departure from usual practice is in the side by side arrangement of its three rubber motors in place of the usual vertical arrangement. Possibly this gives greater freedom to the skeins when they run out after about 50 seconds' flight.

The Fuselage.

This is rectangular in section, built up of four silver-spruce longerons, 3/16th in. by $\frac{1}{8}$ in., on plywood birch formers 3/32nd in. thick. Slots are cut in each of the four corners of the formers and the formers are fretted out, leaving verticals and horizontals $\frac{1}{8}$ in. wide. The longerons are glued in position in the corner slots of the formers and bound with silk thread. The nose former, measuring $2\frac{1}{4}$ ins. across by 1 in. deep, is fretted out to take the nose-piece and gear. The fuselage is 27 ins. long, and there are formers at 4 ins., 8 ins., 12 ins., 15 ins., 18 ins., 24 ins., and, lastly, at the stern. The outside dimensions of each of these formers (giving the horizontal dimension first) are $2\frac{3}{8}$ ins. by $2\frac{1}{2}$ ins., 2 9/16th ins. by $2\frac{7}{8}$ ins., $2\frac{1}{2}$ ins. by $2\frac{7}{8}$ ins., 2 7/16th ins. by $2\frac{3}{4}$ ins., $2\frac{1}{4}$ ins. by $2\frac{3}{8}$ ins., $1\frac{5}{8}$ ins. by $1\frac{1}{4}$ ins., and $1\frac{1}{4}$ ins. by $\frac{3}{8}$ ins. The last former at the stern is not fretted out, but has two holes $\frac{7}{8}$ ins. apart to take the fitting made of 20-gauge wire, which has the three hooks for holding the fixed end of each of the rubber

motors. This fitting has eyelets which pierce the stern former through the two holes just mentioned, and is fixed in position with a sliding pin. Excepting the last 3 ins. of the top surface, fuselage is covered in Jap silk and doped. This opening gives access to the motor hooks and in flight is covered by the tail plane. For drawings see Figs. 85 and 86.





Figs. 83 and 84.—The Monoplane "Falcon."

The Gear and Motor.

The gear is composed of three $\frac{1}{2}$-in. diameter gear wheels, and these are mounted side by side at the back of the nose-piece. The nose-piece is built up of three pieces of wood. One is that which is fretted out of the nose former. This is glued to a piece of 3/16th-in. plywood, which, in turn, is

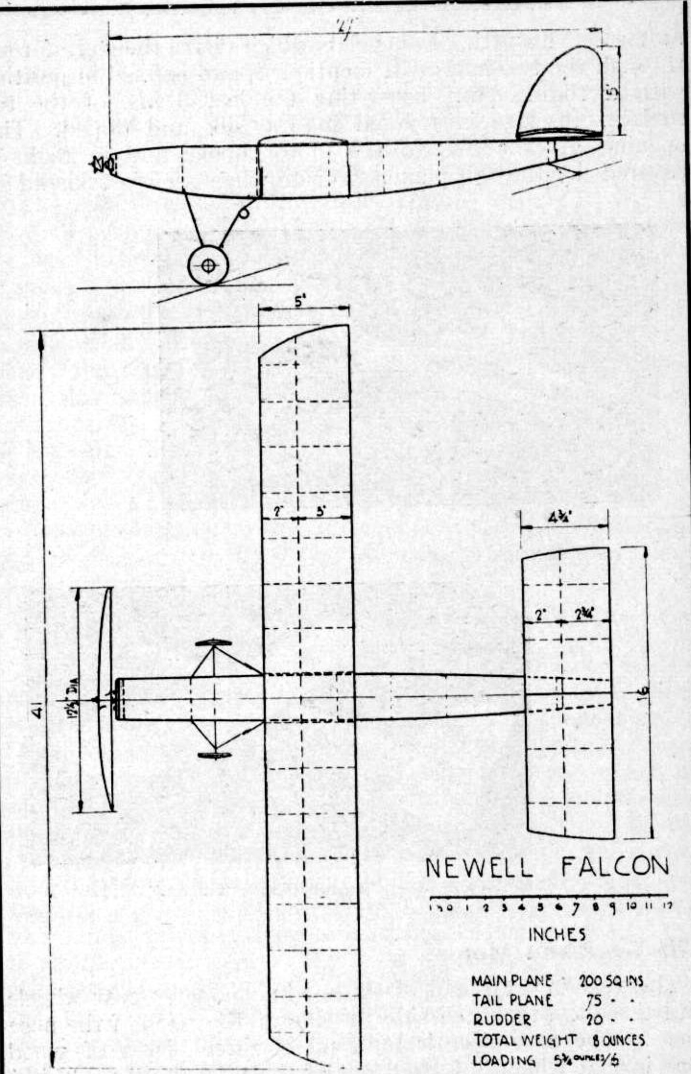


Fig. 85.—Elevation and Plan of Mr. Newell's Monoplane, "Falcon."

faced with a piece of 3/16th-in. satin walnut. This composite unit is shaped to fit the front of the fuselage and carry on the lines. In it clearance holes are drilled for the three spindles and two 10 B.A. plate-fixing bolts. Two steel plates ¼ in. wide are drilled similarly. The centre hole is 3/32nd-in. clearance and the remaining four (two for the shafts and two for the 10 B.A. bolts) are 1/16th-in. clearance. After drilling these plates are separated, one being put on the front of the nose-piece and one on the back, then bolted up and the gears assembled. The propeller spindle is made of 3/32nd-in. silver steel, and is cut sufficiently long to allow 1½ ins. to project forward of the nose-piece when the gears are in position. The two other gear spindles are made from

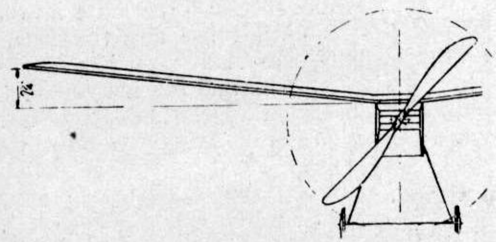


Fig. 86.—Port Front View of the Monoplane "Falcon."

1-16th-in. silver steel and project 3/16th in. through the nose-piece. Collets are soldered on to each spindle with the convex side bearing on the steel faceplate. A short length of 20-gauge steel wire is wound tightly, spiral fashion, round the front of the propeller (or central) spindle and soldered close to the bearing collet. The other end is bent at right-angles, forming a dog for clutching the propeller. The fuselage ends of each of these three spindles are hooked to hold the rubber motors and covered with valve tubing to protect the motors.

The Undercarriage.

This is of V form, and is composed of two pieces of 18-gauge wire, with an axle also of 18-gauge wire. The front struts are in one piece, commencing at the axle, passing through fuselage at 4 ins. from the nose, where the wire is held in small metal fittings on lower longerons, then down to the axle at the other side. Each of these legs is $4\frac{5}{8}$ ins. long. They are soldered at the axle $5\frac{3}{4}$ ins. apart by being turned inwards for $\frac{1}{2}$ in., bound with florists' wire and soldered. The rear legs on each side are also made of one piece of wire, but a single loop $\frac{3}{8}$ in. diameter is formed in each of these and make very efficient shock absorbers. This piece of wire does not pass through the fuselage, but is connected underneath at 8 ins. from the nose by two 10 B.A. bolts passing through tin clips clamped round the wire. The bottom ends of these struts are only looped round the axle so that by releasing the two clips the whole undercarriage folds up and makes packing easy. The wheels are 2 ins. diameter fretted out of the 3/32nd-in. plywood lightened by cutting away unnecessary wood. A disc of $\frac{1}{8}$-in. plywood $\frac{1}{2}$ in. diameter is glued on to one side of each wheel and the centre bushed with $\frac{1}{8}$-in. brass tubing threaded externally. The wheels are then covered with Jap silk and given two coats of dope. After slipping the wheels on to the axle they are held in position by a wrapping of florists' wire sweated to the axle.

The Main Plane.

The main plane is made in one unit from tip to tip, 41-in. span, 5-in. uniform chord, and of approximately "Clark Y" section. The front spar at the leading edge is 3/16th-in. by $\frac{1}{8}$-in. silver spruce, the front edges of which are rounded off. At 2 ins. from the leading edge are two spars of $\frac{1}{8}$-in. square birch. The trailing edge is $\frac{1}{4}$-in. by 1/16th-in. birch. There are fourteen full ribs cut from 1/16th-in. birch plywood. Slots are cut in these to take the spars, one at the leading edge, one at the trailing edge and two (one at the top of the rib and one at the bottom) 2 ins. from the leading edge. The ribs are lightened by fretting out the centres. I can best describe the wing section in this way. The deepest portion is 2 ins. from the leading edge. The under surface from this point is flat to the trailing edge. Forward of this it rises $\frac{1}{8}$ in. to the leading edge. From the round nose the upper surface rises to its maximum height of $\frac{1}{2}$ in. at 2 ins. from the leading edge and then curves downwards to the trailing edge. A dihedral of $2\frac{1}{4}$ ins. is given to the main plane by steaming the spars before assembly. The centre ribs are $2\frac{3}{4}$ ins.

apart and the remainder are at intervals of $2\frac{1}{2}$ ins. At each wing tip and 2 ins. from the last full rib is a half-rib connecting only the leading edge and central main spars. The tips are made of 18-gauge steel wire glued and bound to the ends of the spars.

Two wire saddles secure the main plane to the fuselage. These are 20-gauge steel wire bound to the leading and trailing edges and bent to fit the fuselage at the widest part. The bottom ends of these are hooked as shown in the side elevation of the machine and take small rubber bands which run under the fuselage ; thus allowing the position of the plane to be adjusted and protecting it in case of a bad landing. The plane is covered top and bottom with Jap silk and then doped.

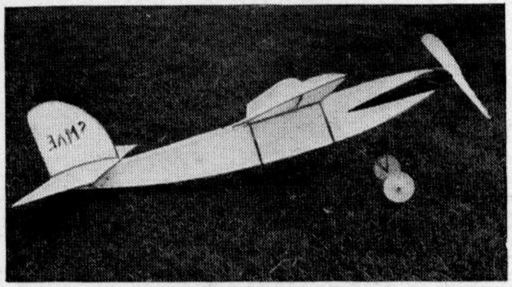


Fig. 87.—The "Falcon" Aground.

The Tail Plane and Rudder.

The tail plane is built in much the same way as the main plane, though of shallower section. The fixing is rather different. Two short 20-gauge steel wire prongs connected to the leading edge slip into eyelets on the top fuselage longerons, while a saddle similar to those used on the main plane is bound to the bottom centre spar, this, in turn, being held to the fuselage by a rubber band. Pieces of 1/16th-in. tubing $\frac{1}{4}$ in. long are bound to the leading and trailing spars of the tail plane to which the rudder is attached. The rudder is a simple frame of 18-gauge steel wire covered with silk and doped. The bottom ends of this wire frame are bent horizontally and slipped into the short tube just described.

The Motor.

Three skeins of rubber each of four strands of $\frac{1}{4}$-in. by 1/32nd-in. strip, 36 ins. long, form the motor. Each skein is attached to one of the fixed hooks at the tail of the fuselage and to one of the hooks on the gear in the nose-piece. The motor can be wound, when fully lubricated, to just over 1,000 turns with safety.

The Propeller.

This is carved from a piece of satin walnut, then covered with Jap silk and doped. The diameter is $12\frac{1}{2}$ ins., the pitch 19 ins., and each blade at its widest point 4 ins. from the boss measures $1\frac{1}{8}$ ins. from leading to trailing edge.

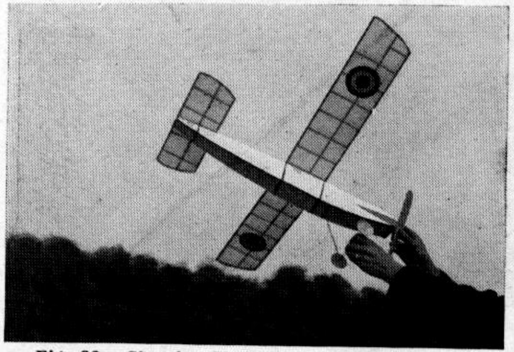


Fig. 88.—Showing Underbody of the "Falcon."

The Weight.

The weights of the units forming the whole machine are as follows :—

Fuselage and undercarriage	$2\frac{3}{8}$ ozs.
Main plane	$1\frac{5}{8}$,,
Tail plane	9/16 ,,
Rudder	3/16 ,,
Nose with gears	$\frac{1}{2}$,,
Rubber	$2\frac{1}{8}$,,
Propeller	$\frac{5}{8}$,,

This makes a total of exactly 8 ozs.

Two other views of the "Falcon" are given in Figs. 87 and 88.

CHAPTER XII.

A SMALL FUSELAGE SEAPLANE.

THE seaplane built by Mr. J. E. Pelly Fry in 1928, which has been slightly re-designed to conform with more recent developments, is the subject of this chapter. The original machine was built chiefly from an experimental point of view. In the first place it was breaking comparatively new ground (in those days) by attempting such a small model with a fuselage ; and, secondly, the model was built to settle the old problem : "Is a small model as good as a large one ?" The good and bad points were as follows :—

(1) A small model, by reason of its greater structural rigidity than a large one, was less likely to be damaged by a bad landing.

(2) A small model is far easier to carry about from home to the flying field.

(3) The cost of making a small model is less than that of a large one, and less time is spent in making it.

(4) The performance of a small model should be as good as a large one.

(5) The possibility of a small model being very difficult to fly owing to its being more sensitive to control than a large one.

The last point seemed to be the only one against small models. It has since been proved that this last item is in favour of them.

One afternoon the seaplane was taken to Wimbledon Common to test it thoroughly in the air. The wing was moved at least an inch up and down the fuselage from the normal position, and the results were practically all the same. The model was also over and under elevated, and still she flew just the same. A slight "kiting" effect was noticed when the wing was pushed far forward, but there was no stall.

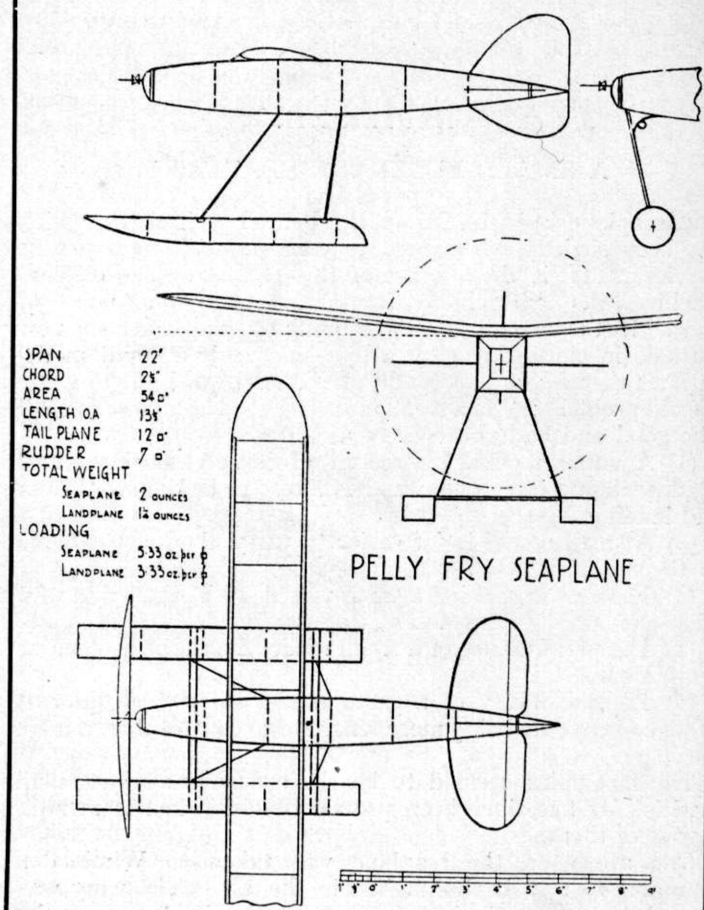


Fig. 89.—Elevations and Plan showing General Arrangement of the Complete Machine.

To move a wing an inch on a fuselage 12 ins. long is more or less equal to moving one 2 ins. on a fuselage 24 ins. long.

As every aeromodellist knows to move a wing even ½ in. on a big machine is asking for trouble. Thus the small model scores. With small models there seems to be an extra reserve of power which pulls them out of a stall during the initial burst of speed, and consequently a small model is ideal for competitions, where reliability is most essential.

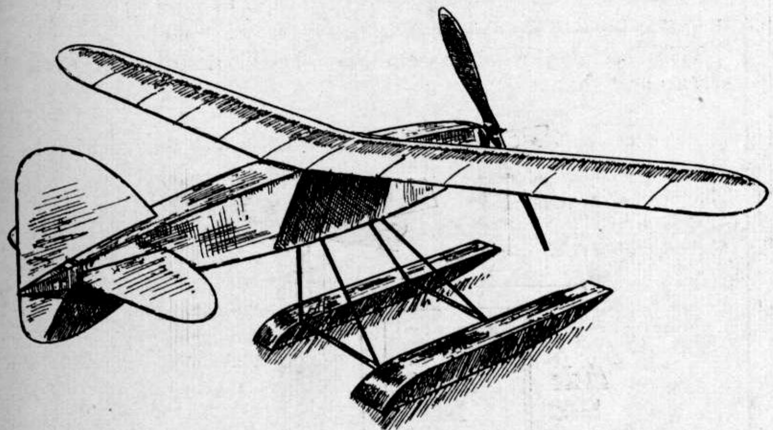


Fig. 90.—The Complete Model. The floats are actually larger than they appear in this sketch.

Before beginning on the description of the seaplane it should be mentioned that although the model appears in a re-designed version yet nearly all the dimensions, weights and areas are approximately the same. In fact (as an Irishman once said), "It's the same model—only different." For the benefit of those who would prefer to build the model as a landplane a small drawing will be given showing the general arrangement (see Fig. 89).

The Fuselage.

This is of rectangular section in the front portion of the fuselage, tapering to square section at the tail. It is built up of four birch longerons supported by seven three-ply formers. The first and the last are cut from three-ply 3/32nd in. thick, their sizes being an inch by ⅝ in. and ½ in. by ½ in. respectively. The sizes of the intermediate formers, which are 1/32nd in. three-ply, can be found by scaling them on the drawing. Slots are cut in each of the four corners of the formers, and the centre is cut away, leaving verticals and horizontals ⅛ in. wide. The longerons, which are of birch 1/16th in. by 1/16th in., are glued to the bulkheads (or formers) and secured with thread (Fig. **91**). The distance between each former and the adjoining one should be 2 ins.

The fuselage, when assembled, should assume an even streamline shape.

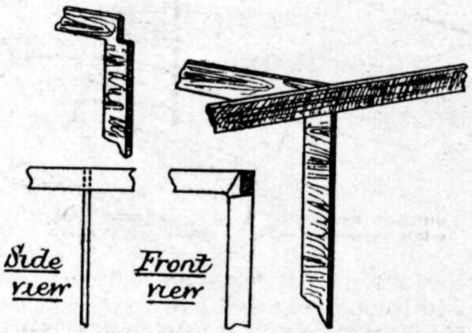


Fig. 91.—Method of attaching Fuselage Longerons to 3-ply Bulkheads.

Behind the fuselage is fitted a little device which is part of the re-designing scheme. This serves the dual (or, rather, triple, in the case of a landplane) purpose of fuselage fairing, fixture for rubber motor hooks, and tail skid for the landplane version.

The method of constructing this unit (which incidentally has been well tried out in later models and is extremely successful) is as follows :—

A piece of 1/16th-in. thick three-ply is cut out which should be a fraction smaller than the rear former (which is ½ in. by ½ in.). Next take a piece of 22 S.W.G. steel wire and bend it at 90° in two places, in such a way that the two

ends of the wire should become parallel. Pierce two holes in the centre of the three-ply the same distance apart as the two right-angle bends and slide the two loose ends of the wire through. When it has been found that the two holes coincide with the bends in the wire (i.e., the vertical part of the wire being flush with the wood) remove the wire again and, using the same gauge wire, shape another length similar to piece B in Fig. **92**. Then take another short piece of wire and bend it once at right angles, having about ¼ in. on the short arm.

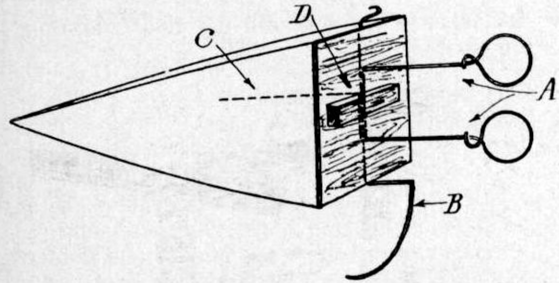


Fig. 92.—Complete Tail Unit. Note short piece of wire " C " embedded in fairing to prevent the rubber motor hooks swivelling.

Now these three separate pieces of wire should be bound together with copper wire and soldered at the point D. The piece of wire C, it should be pointed out, is put in to prevent the two arms A from swivelling in a horizontal plane. When the soldering is finished slide the two arms of wire A through their respective holes and make hoops on their extremities.

Last of all shape a piece of Balsa wood in such a way that the lines of the fuselage are carried to a point at the stern and glue this to the back of the three-ply. A small piece of wood is glued on to the front side of the three-ply to prevent the complete unit from sliding sideways when in position (see Fig. **92**).

The Tail-plane and Fins.

They are made of steel bracing wire of sufficient thickness to remain rigid when covered with silk. For the outline of the tail-plane one piece of wire runs all the way round and is soldered at the centre on the rear. One straight piece of wire runs from one side of the tail-plane to the other, being soldered at the two ends from the centre. This forms the elevators. The complete tail-plane is then bound on to the formers with thread and glued. It will be noticed in Fig. 93 that the tail-plane is placed on the centre line of the fuselage, equidistant from the longerons, top and bottom. This may be altered by binding the tail-plane on to the top longerons,

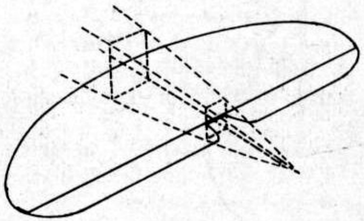


Fig. 93.—The Tail Plane in Position.

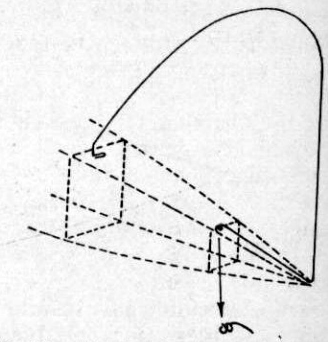


Fig. 94.—The Upper Fin in Position. The Lower Fin is fitted similarly.

underneath in front and on *top* at the back. This gives greater freedom to the rubber, but detracts from the appearance.

The top fin is fitted by taking one end of the same thickness of steel wire and fixing it to the mid-point of the sixth former, passing it through the plywood twice, bending it flat against the wood, and then binding with thread and gluing (Fig. 94). The loose end of the wire is then bent to the desired shape, running down to the tip of the Balsa wood fairing, and back again to the last former where it is passed twice round the top horizontal and glued. The fin underneath is similarly fitted, its area being slightly less than the top one. The tail arrangement is now complete with the exception of the covering, which is put on last.

The Floats.

These are made up similarly to a fuselage, the longerons being 1/16th in. by 1/16th in. birch, and the formers being

1/32nd-in. three-ply 1 in. wide and $\frac{3}{4}$ in. deep. They are lightened in the same way as the formers in the fuselage, and slots are cut in the four corners of each one to take the longerons. The longerons are bent up in the front, underneath, and down in the back on top to the shape shown in the side view of the drawing. A short piece of wood is glued into position fore and aft, just where the longerons (top and bottom) meet and terminate (Fig. 95). The inter-struts, which are birch, $\frac{3}{4}$ in. by 1/16th in., are bound on underneath the top longerons with thread and glued (Fig. 96).

The struts to the fuselage are 20 S.W.G. steel wire. These are bound on to the inter-float struts at one end and secured at the other end by running them up the sides of the formers, passing the wire through the three-ply and down the other side again, the whole being well bound and glued. This method of attachment is the same as that on the leading edges of the top and bottom fins.

In the land-plane version there are only two legs or struts (Fig. 97). These are made of 20 S.W.G. wire and fitted in the form of a saddle just behind the front former. Two "safety-pin" springs are then bound on the lower longerons and soldered to the wire legs. The ends of the legs should be bent

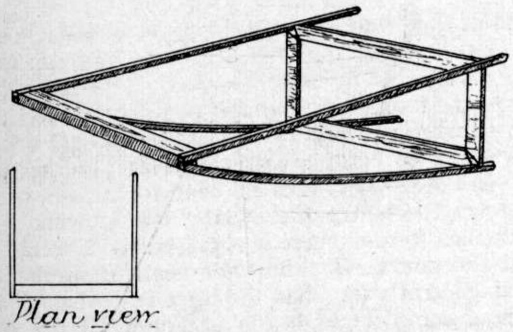


Fig. 95.—Sketch showing Front Portion of a Float.

outwards at the bottom to form axles, and the wheels are then slipped on, being kept in position by a tin washer soldered on outside. The wheels, which are $1\frac{1}{4}$ ins. in diameter, may either be aluminium or three-ply, with silk or Balsa covering.

The method of constructing wheels has been previously described in the chapter on Undercarriages, and need only be referred to here.

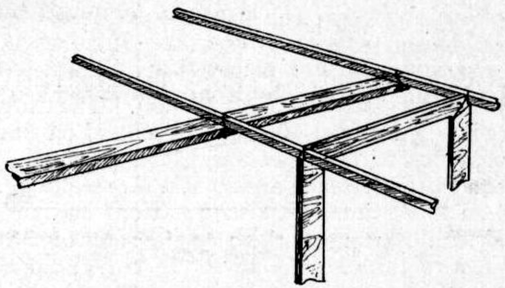


Fig. 96.—Another View of Float Construction showing Bulkhead in position and Method of attaching Inter-float Struts.

Should the model be used as a landplane the lower fin need not be fitted, as it is only put on to increase the side area aft for the seaplane version, where the floats tend to make the model rock from side to side.

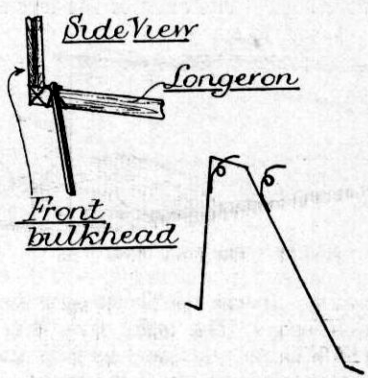


Fig. 97.—The Wire Undercarriage.

The Main Plane.

The main plane or wing is made in one unit from tip to tip, being 22 ins. in span and having a uniform chord of 2½ ins.

There are ten ribs of fairly thick section to allow for the sagging of the silk between the ribs. Actually, when the wing is covered with silk, the *mean* wing-section is medium thick somewhat like "Clark Y." The ribs are made of 1/32nd-in. thick three-ply, which may be lightened by cutting holes in the centre portion. There are only two spars, one in the leading edge and one in the trailing edge, both being ⅛-in. by 1/16th-in. birch. The front spar is held in position

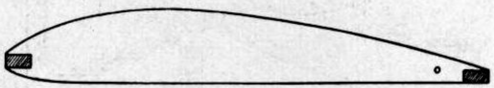


Fig. 98.—Showing Arrangement of Spars and the Wing Section. Note hole for thread binding of spar to rib.

by being fitted into a slot in the leading edge of each rib, while the trailing edge is simply attached to the ribs by thread binding and glue. A small hole should be made in the end of each rib to pass the thread through. Fig. 98 shows a complete rib with leading and trailing spars in position. Before assembling the two spars should be steamed and the necessary dihedral (shown in the drawing) put in. The

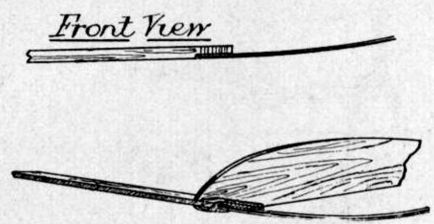


Fig. 99.—The Wire Wing Tip.

ribs are 2 ins. apart. Insert the front spar first to the ribs and then the rear spar. The wing tips (Fig 99) are made of steel wire of the same thickness as that used on the tail-plane, and bound on to the ends of the spars. The complete framework of the wing will probably appear to the constructor to be very weak to withstand torsion and bending loads, but all the necessary rigidity is imparted by the covering, which increases the strength of the wing by about 75 per cent.

Two wire saddles bound on to front and rear spars complete the wing construction. Fairly thin wire is quite sufficient for this purpose. (See Fig. 100.)

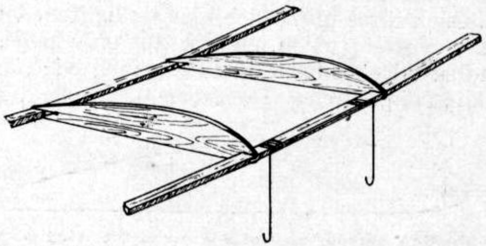


Fig. 100.—Centre Section of Wing. Note wire saddle (illustrated only on front spar) for attaching wing to fuselage with Rubber Bands.

The Nose-Piece and Gears.

The gears are perhaps the outstanding feature of this model. There are two wheels ¼ in. in diameter and 1/16th in. thick. They are mounted one above the other at the back of the nose-piece. The two gear-wheels are soldered on to two shafts of 18 S.W.G. steel wire. A hook is formed at the end

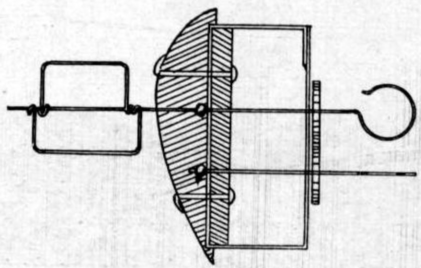


Fig. 101.—Nose-Piece and Gears. Gears are ¼-in. diam. and Shafts are 18 S.W.G. Steel Wire.

of each spindle and the wheels should be placed just in front of them. The bearings consist of a strip of brass 1/32nd in. thick, bent to a rectangular shape and the ends soldered together, the four holes that have been previously drilled coming opposite to each other to take the spindles.

The three-ply adapter is next bound on to the inside of the brass bearing with copper wire and soldered to prevent slipping. The two shafts are then passed through their respective bearings and a nut is soldered on to each to take the tension of the rubber. A nose-piece of satin walnut is then carved out to carry out the lines of the fuselage. This is secured to the three-ply adapter by two nails being driven in from the back and riveted over outside.

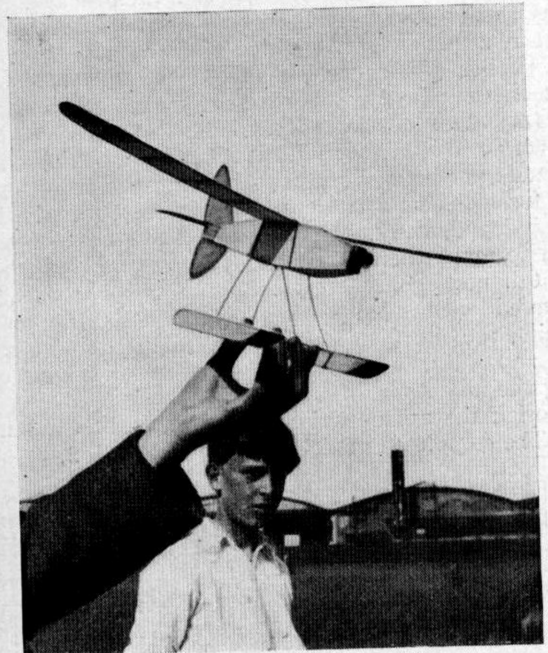


Fig. 102.—The Completed Model.

The clutch that secures the propeller to the propeller spindle is a length of steel bracing wire twisted round the spindle spiral fashion and well soldered. The loose ends are bent round the boss of the propeller and hooked on to the spindle in front. Fig. 101 shows the complete unit, comprising adapter, nose-piece and gears.

The Propeller and Rubber Motor.

The propeller is carved from a block of satin walnut 1 in. by $1\frac{1}{4}$ ins. by 8 ins., the diameter being 8 ins. and the pitch of the propeller being 12 ins. The blades should be fairly thin section with the greatest width about $1\frac{1}{2}$ ins. from the tip. Longer durations might be obtained by experimenting with different propellers having coarser pitch, wider blades, etc. (It will be noticed in the front view of the drawing that the thrust line is taken at the centre point of the fuselage. Actually the line thrust is slightly higher up as the side view shows. The error, although very slight, should be noted.)

The rubber motor consists of four strands of $\frac{1}{8}$-in. strip rubber on each hook. The length of each skein should be about 16-18 ins. long, and if well lubricated will take about 1,000 turns. If necessary the power can be increased to six strands per hook, but this should not be necessary.

The fuselage, main plane and floats are covered with Jap silk and doped, the latter being given one coat of paint or varnish to make them water-tight.

The tail unit, comprising tail-plane and two fins, should be covered with oiled silk. This prevents the sun from tightening the silk (as oiled silk will not tighten so much as doped Jap silk), warping the controls and consequently putting the model out of trim.

The original seaplane weighed $1\frac{3}{4}$ ozs., and as a landplane 1 oz. The completed model is shown in Fig. 102.

CHAPTER XIII.

HINTS ON FLYING A MODEL AEROPLANE.

To launch and to fly model aeroplanes successfully is a much more " tricky " job than an onlooker may assume, especially if one is out to break records or to win a competition.

Each type of model—and there are many—has characteristics of its own, though the method of launching them does not vary much. The tractor fuselage and spar type are most popular with us at present, so we will deal chiefly with these.

Assuming that we have arrived at the aerodrome, or other open space, complete with model we ascertain the direction and strength of the wind with the aid of a strip of silk or cigarette smoke, usually the former. Proceed then to wind up motor by turning the airscrew in the opposite direction it is intended to turn in the air, to about half the maximum permissible turns. Hold the model now at arm's length or nearly so, above the head, the left hand gripping the airscrew boss to prevent the airscrew rotating, and the right hand lightly holding the fuselage or spar at a point just below the centre of gravity of the machine. If the wind is light one can launch up or down wind. Assuming it so tilt the nose of the machine ever so slightly downwards and bring the right arm smartly forward, at the same time releasing the grip on the airscrew boss. Launching at too steep an angle downwards may cause the model to zoom as it gathers forward speed and perhaps stall, especially if it is not highly powered. Launching very slightly downwards assists the machine to get under way quickly and then proceed to climb steadily. Whatever one does never launch the machine with the nose inclined upwards even slightly with or against a slight or rough wind, unless it is a high-powered, stable model. The usual result of such procedure is a nasty stall with a " sticky "

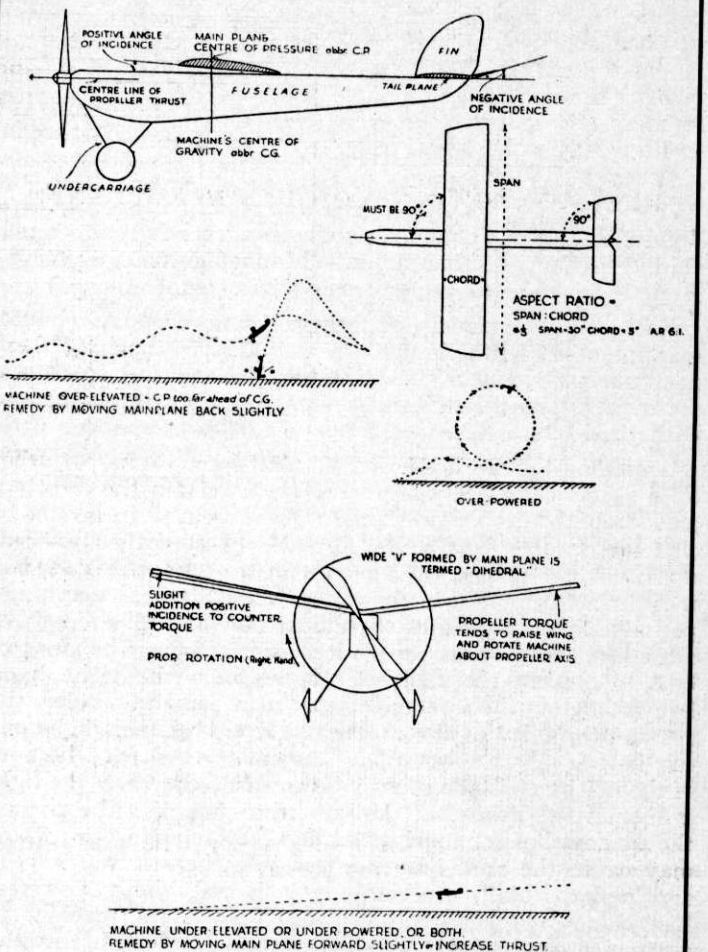


Fig. 103.—Diagrams illustrating the Elements of Model Aeroplane Flying.

ending, if the machine has a not overstrong nose and undercarriage, somewhat like falling over a fence with one's hands in one's pockets. Models have been fitted with slots, and recover from a stall reasonably well. If the wind is fairly strong it is best to launch either down wind or at 45 degrees to the wind, either left or right.

If the airscrew rotates clockwise, "as viewed from the pilot's seat," the machine will climb steadily and turn left, due partly to the airscrew torque and partly to the increased air pressure on the right wing. If launched to the right the airscrew torque will bring the machine head into wind and it will climb to its maximum height. As the power diminishes it slowly turns either left or right down wind.

Fast launching is never advisable with normal machines. The most important part in the art of flying a model aeroplane is to get it and keep it in perfect trim, which requires a little knowledge of theory of flight and rigging, but when it is trim the full number of turns can be given to the motor.

The following hints may be useful :—

If the machine climbs and then stalls, however launched, either the main-plane is too far forward or the tail-plane has a negative incidence.

If the machine follows an undulating path in flight it is from the same cause, only in a minor degree. Should it turn left, opposite rudder may be needed, or the main-plane may be warped, thus resulting in an increased incidence on the right side of the plane towards the tip, and a decrease of incidence on the left wing tip. Again, the tail-plane may be badly warped, with an increase of incidence on the right side, or the fuselage may have twisted in its length.

Power may be too high, and dihedral too little, thus getting airscrew torque and upsetting lateral stability.

The leading edge of the wing may not be at 90 degrees to the centre line of fuselage, i.e., the left wing tip is nearer to the tail than the right wing tip. The airscrew desires to pull the machine straight ahead, and the wing decides otherwise, the net result being a gain for the wing.

If the machine turns right the same corrections are necessary, only on the other side.

If the model "wallows" or rocks from side to side, at the same time losing forward speed, it is suffering from too much dihedral. If it sideslips either way it means too little dihedral.

If the model when launched flies at a fairly steep angle to earth the wing may be much too far back, or an increased positive incidence on the tail-plane may be the cause.

If it be of the tractor spar type, and it dives steeply to earth or tries hard to loop, however launched, the trouble will be most likely due to using a main motor spar having insufficient strength to take the stress of the fully-wound motor, causing the stick to bend up or down.

So for flying model aeroplanes a fair all-round knowledge of them is necessary, but it is remarkable how quickly this may be acquired.

Fig. **103** illustrates some of the points referred to in this chapter.

CHAPTER XIV.

SOME SUGGESTIONS ON MODEL AIRCRAFT DESIGN.

General Considerations.

VALUABLE hints concerning the construction of the parts making the model have been given in other chapters. It is thought that some information on the groundwork that has to be done to design even the smallest model would be of some help. We will confine ourselves to the tractor fuselage model, which is at the present time the most popular, although it is not, perhaps, the most interesting type.

The tractor fuselage model is almost without exception of the monoplane type and the wings are nearly all of the cantilever variety. Thus there is little sense in regarding models according to their layout and appearance, and a classification for weight seems to allow for greater accuracy. We have, then :—

The light-weight general-purpose model up to 5 ozs.
The light-weight duration model up to 5 ozs.
The middle-weight general-purpose model from 5 to 10 ozs.
The middle-weight duration model from 5 to 10 ozs.
The heavy-weight model over 10 ozs.

The duration type of the last class has been left out because although duration is the chief aim its performance is not, generally speaking, comparable to those of the other two classes. It is admitted that a 12-oz. machine is not really heavy and might quite reasonably put up a record, but any classification is necessarily a little unfair when taking examples which are on the border-line. Usually, a heavy rubber-driven model is designed for other purposes than breaking a duration record.

Light-weight Duration Models.

We will now regard the principal features of these types. The lightweight general-purpose model is the best to begin with if one has never built a model before. It is of very simple design, and the great advantage is that it is so light that it cannot smash itself in a rough landing. A description and drawings of a small model designed by Mr. Pelly Fry will be found in this book, and we will therefore not deal with it in detail. A wing-loading of 5-7 ozs. per square foot is most likely to prove successful, as it makes for a small wing and sufficient speed to ensure effectiveness of rudder and tail-plane. The duration with two skeins of rubber is practically equal to record duration a few years ago, viz., 40-50 seconds.

The light-weight duration machine is generally very much similar to the previous type as far as appearance is concerned. But here weight-saving and external refinement in the form of fairings and streamlining have been really carried to a fine art. This makes it possible to obtain a lower wing-loading for the same size of wing. Whereas longerons, wing spars, etc., of the general-purpose machine may be of ⅛-in. cross-section for a length of 24 ins., these are sometimes reduced to 1/16th in. square and less in some duration planes, especially if many spars are used. Even these extremely small sections do not seem to constitute a limit as far as structural strength is concerned, as the machines stand quite a surprising lot of throwing about, and, at the worst, suffer a broken longeron or so. The main reason why these models should be left alone until one is sufficiently at home in the construction is that the parts are of such small dimensions as to be rather difficult to handle. Great care is necessary or the pressure of one's hands is more than the structure will stand. A wing built by somebody who is quite an expert at the job was a beautiful piece of work. Its spars were slightly over 1/32nd in. in cross-section, but after covering and doping this wing was so distorted as to evoke the mirth of anyone who saw it. Its performance, however, contrary to all theory, was just about as good as the best conventional wing one has seen. The next wing built by the same designer had much stronger spars, merely to withstand the strain of the dope. It is advisable to use the diluted variety of the commercial dopes

on all structures which are rather weak in the uncovered state, but the dope should possess sufficient strength to produce a drum-like surface. This diluted dope is the kind supplied by most firms specialising in model aeroplane materials. The structures of small and light models may be extremely weak and easily twisted as the covering and dope add considerable rigidity. If the structure is perfectly strong in every respect before covering it is really too sturdy, and the extra strength of the covering has not been used efficiently. Owing to their small weight, low loading, large propeller and high power-weight ratio both types of this class give remarkably good performances, especially in climbing.

Medium-weight Models.

The middle-weight models form a very interesting class. The distinction between the two types, general-purpose and duration, is mainly the same as explained for the previous class. To the duration-type belongs T. H. Newell's "Falcon." It is a plane of remarkably clean design, fairly straight-forward, but modern in every respect. It weighs about 9 ozs. complete with rubber. Another outstanding type of this class is R. N. Bullock's low-wing monoplane which secured the Wakefield Cup in the 1929 international contest at Halton. These two examples clearly show that one need not necessarily build very small and extremely light machines to obtain good performances. The objection to the duration type of the light class, viz., difficult construction, does not apply here, as in the larger machines the parts are necessarily more robust, and the chief difference between the general-purpose and duration type consists mainly of refinement in detail design and lower wing-loading of the latter. By having two interchangeable wings one can fly the same machine for ordinary work and duration.

The Heavy-weights.

The heavy-weights are a class apart from the previous ones if they are really heavy. They are naturally large machines and their behaviour is quite different from the lighter types. They are slow to take off, and their flying is much more like that of a full-size aeroplane. Owing to the weight, however, a bad landing often results in disaster. As far as construction is concerned one may say that they are *the* type for those who like to display their ingenuity in detail design. It is rather a pity that so few are seen flying nowadays. Whereas the rubber-driven model is heavy and big simply because its designer wants it to be so the compressed-air-driven model has to be large on account of its plant. Its high cost and the work involved in the construction make it a job for the more experienced, and the beginner should not let himself be tempted to choose it as his first model.

A Little Assistance.

The first thing anybody seriously interested in aeronautics should do is buy every aeronautical paper he can get hold of. One assumes that he is a subscriber to THE MODEL ENGINEER. Quite interesting articles on model flying and construction also appear in the monthly journal of the S.M.A.E., information about which can be obtained from the Secretary. The information given in the technical papers is of a general nature, and in most cases relates to full-size aircraft. But they will be found to supply suggestions which, if properly converted and used, will be of value to the aeromodellist. Although the faithful reproduction of constructional methods and details as used in full-size work will only meet with failure the general principles may be quite adaptable. A model built to scale from a full-size design will usually not be successful, even if it flies at all. There are few full-size machines which seem likely to make successful models without considerable modifications, the only type being some low-wing monoplanes, more particularly the single-engined Junkers, and also the Fairey monoplane.

The Choice of Type to Build.

The beginner should build his first model from some well-known design, as it enables him to start with the accumulated experience of others. Having flown this machine a good deal, experimented with rubber motors of different powers, he will develop his own ideas about it, and these should then be laid down in a design of his own.

Having more or less mastered the fundamental principles of aerodynamics he will know how to group his weights most efficiently around the centre of gravity. Before anything

else is done, however, he must make quite sure about the type of machine he is going to build. After deciding upon the class he has to compare the various merits of different layouts, such as high-wing monoplane or low-wing monoplane, lightly loaded or moderately loaded, large or small. There is little point in insisting upon one's own favourite type, because this is largely a matter of prejudice, having built it for a long time and become more familiar with it than with any other. The main point to observe when aiming at duration is that a lightly loaded model has a very good chance. First, the light loading makes for good climbing and therefore a long glide after power has run out ; secondly, because it flies at slow speed and does not need to have a fast-running engine. This allows for less rubber and hence more turns. This does not imply that a model with a heavier loading has no chance. The main drawback to very slow machines is that we can very seldom find a day quiet enough to obtain maximum performance. The heavily loaded model in the hands of Mr. Plater, of Halton, has repeatedly given proof of being indifferent to theoretical disadvantages and almost daily puts up durations of a very high order. So we leave the choice of type entirely to the designer, who will soon take a personal fancy to a particular formula.

There are the problems of shapes and proportions which may easily be an obstacle for the beginner to produce an original design and induce him to copy rather than risk failure. Comparatively little can be said about it here, first because it is too comprehensive a subject, and, secondly, because only little is of use to the aeromodellist. The main thing the beginner should guard against is that his first design should not be *too unconventional*. If he tries a pusher fuselage monoplane, either with tail-booms or with tail in front of main wing, he is perfectly safe, even though he may quite conceivably fail. But if he gears four propellers to one rubber motor he is merely wasting his time. If he has an idea that seems worth while let him think about it for a few days, work it out in his mind, and if he is still convinced of its value let him build it.

Setting About Designing.

Now to shapes and proportions of the conventional fuselage tractor monoplane. The type having been chosen the designer has in his mind a picture of the machine as he would like it to be. The following notes apply to the model in general and not to any specific type.

The Wing.

A suitable wing-section should be selected which is efficient and gives promise of sufficient strength of the wing. Design the wing preferably cantilever. The drag of the wing is reduced by employing a high aspect-ratio, i.e., the ratio SPAN/CHORD. This should not be less than 7 and not so high as to make a flabby and weak wing. Tapering of the wing also increases efficiency, but the minimum chord should not be less than half the maximum chord (Fig. 104).

The wing-section may be the same all along the wing, i.e., all ribs are similar but not congruent. An alternative is to employ a thick section in the centre which tapers to a thin section at the tips. This makes for a really efficient wing. If a section is used in the centre having ordinates a multiple of the "Clark Y" ordinates, and the actual "Clark Y" is placed at the tips, the wing tapering in plan form as well, a good step has been taken towards performance.

Various shapes of wing-tips are employed, the simplest being the sawn-off type (Fig. 105). Here the wing ends with a rib and is rectangular both in plan and front view. It is not, however, very efficient aerodynamically, and should not be employed on any high-performance type of model. The most satisfactory shape is the half-round kind. Some model builders believe in employing a certain amount of washout in their wing. This means that the incidence decreases towards the tips. One might say that its effect is a pressure on the tips, although this is not correct. There can never be any pressure *on* a wing moving through the air at a small angle of incidence. What really happens is that there is less lift from the tips, resulting from the small or negative angle of incidence. The arrangement tends to increase the lateral stability. Increase of the incidence towards the tip is not desirable, although it may have a stabilising action, because it brings the centre of

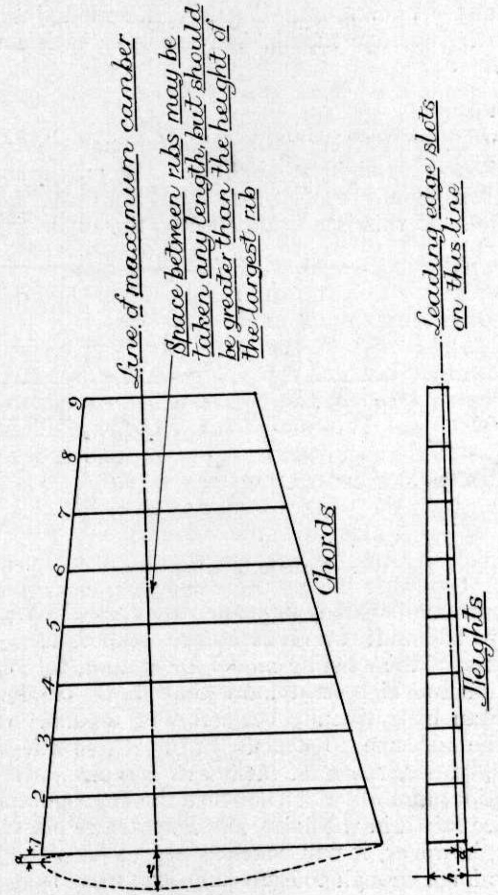


Fig. 104.—Showing how to obtain Proportions of Similar Ribs for Tapered Wing.

pressure of the wing-half far out, thus imposing heavy loads on the structure.

The tapered wing is the most efficient aerodynamically, but the ordinary rectangular wing with rounded tips is good enough for the average model, and will give satisfaction in every way.

The Fuselage.

Not being a supporting part, the fuselage should offer as little resistance in flight as possible. The maximum cross-sectional area should conform to the S.M.A.E. formula : $(\text{length})^2/100$. If this is not adhered to the model is barred

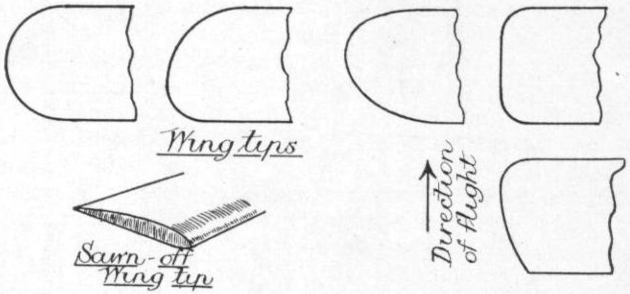


Fig. 105.—Outlines of Wing Tips.

from flying in competitions organised by the S.M.A.E. One would like to add that if a rectangular section is used, as it is in 90 per cent. of the existing model aeroplanes, the rectangle should not be too high—not more than 1 : 2—or the model will require an exceptionally large rudder to offset the tendency of the fuselage to act as such. The most efficient fuselage, or, rather, the least inefficient fuselage, will have a circular section, and all parts meeting the fuselage at abrupt angles will be faired in with silk, Balsa wood and plastic wood. In all cases, however, it will be necessary to keep the nose of the fuselage large enough to leave sufficient space for the gears and rubber hooks. The area immediately behind the propeller should be clean and without excrescences, while the stern post should end in a sharp point, or, alternatively, in a vertical knife-edge.

Tail Planes and Rudder.

Here, too, high aspect ratio tends to increase efficiency, though not as much as with the wing. Tail-planes of very large span may need bracing, and this would add weight. Some conventional shapes are given in the accompanying sketches (Fig. 106) together with a few of more unusual appearance. They are all equally good for all sizes and types of models. Those who have an eye for pleasing lines will find much opportunity to give their model a nice appearance,

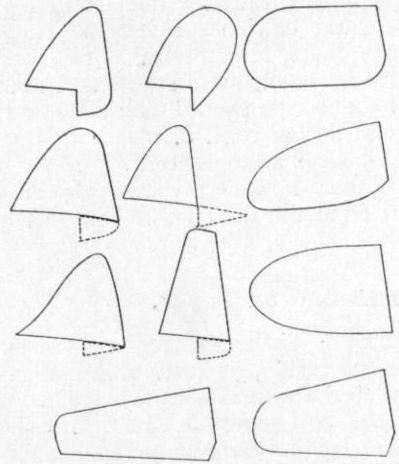


Fig. 106.—Various Shapes of Rudders and Tail Planes. Note : These are not all drawn to the same scale.

especially a rudder of fair shape may make a model very attractive. Usefulness, however, should not be crowded out ; the main reason for the rudder being to work as a rudder, and not as an ornament. Rudder and tail-planes may be designed along the lines of the wing, preferably with a symmetrical section. This is not advisable in small models where weight is more important than refinement in detail, and a simple steel-wire frame covered with silk (proofed silk sewn on or glued on) represents standard practice to-day. It is always best to keep the weight behind the centre of gravity as small as possible, and heavy tail-planes will tend to move the wing back. The action of rudder and elevators is similar to that of a lever: the larger the arm the greater the movement and hence the greater the effect. There should always be at least twice the chord between the C.G. and the leading edge of the tail-plane. If less, the effect of a small deflection will be insufficient and stability will suffer. Models with very short fuselages and large wings, more particularly large chords, are apt to be very tricky to fly and require exceptionally large rudders and tail-planes. If the distance from the main-plane and tail-planes is large the area of the latter may be cut down a little and the same efficiency retained. Rudder and tail-planes are always much larger than in full-size practice, as our model has to be much more stable and manœuvrability does not count. As a rule the tail-planes should be designed for 20 per cent. to 25 per cent. of the total wing area, while the rudder may be taken as 10 per cent. to 15 per cent. of that. In exceptional cases, however, these proportions will not hold, and it is left to the designer to find out how much is needed.

Putting One's Design on Paper.

The first thing to do when producing a model is to prepare a general arrangement design, giving approximate dimensions of the main parts, their shapes and areas (Fig. 107). The drawings may be quite rough and partly freehand, but should convey sufficient meaning to the designer as to enable him to see quite clearly what he is aiming at. They should be quarter to one-eighth scale; not so small as to become inaccurate and not so large as to become clumsy. Then take any important detail, say the fixing of the under carriage to the fuselage and think out how it should be made. Make rough sketches of alternative solutions on a separate sheet of paper and make the final choice. If it is a first original design it is advised to copy these details from existing models; they have given proof of standing up to the work, and, if well made, will not let anyone down. But as soon as he feels he has mastered the art the beginner should break away from current practice and find new ways of doing things.

After all details have been settled the next stage in designing consists of combining the various parts. A careful investigation should be made to find out whether two things do not interfere or one thing could not have been re-designed to perform two functions. Light models of the 4-oz. type are of such simple design that there is very little scope for ingenuity—not half so much as in a large 14-oz. model. It must be remembered, however, that considerable thought and ingenuity have been put into these types by the original designers, and, consequently, there is little scope left for the beginner. Let me say again, do not be tempted to copy full-size design, or produce constructions resembling full-size

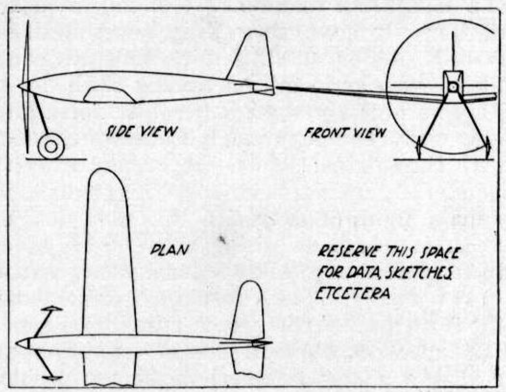


Fig. 107.—Standardised Lay-out of a General Arrangement Drawing.

design. What will work all right in large size is often quite unreliable and certainly far too complicated when "scaled down." During the early light aeroplane competitions at Lympne in 1923 most entries were almost exact replicas of large machines. This seemed quite wrong.

What the model builder should aim at is to make his plane perform what will be asked of it, no more and no less. Beautiful but superfluous construction should be avoided. It may look nice for an exhibition, but not for flying. Therefore, details should be light and simple and great care should be taken to make them neatly and accurately. Finish is very important as it produces a better job, and what is done should be well done.

After sketches have been made and alterations have been carried out to obtain a satisfactory combination of the various parts it is a good policy to make a large working drawing showing all details, not merely an outline. If the model is small, up to 20-in. fuselage, the drawing should certainly be full size. If larger, half full size is best. In any case the drawing should be large enough to allow clear reproduction of small details, such as bolt heads, packing pieces, etc. Such a drawing greatly facilitates construction, and also provides us with a record of all models planned or actually built. Some very useful instructions and hints on drawing will be found in THE MODEL ENGINEER handbook, No. 21, price 10d., post free. But however good a drawing never hesitate to re-design any part, big or small, if this seems advisable.

Make one's drawings in ink on tracing cloth, for then one can have a few blueprints made, or black-on-white prints. This will only cost a shilling or so, but eliminates the necessity to work with the original, which can be put away safely till wanted again. The use of black-on-white prints enables one to readily make notes of alterations in detail design, etc.

Another habit worth acquiring is to make notes on all things which present themselves during the designing and building of the model. They should be preserved with the sketches for reference. Apart from an interesting record they will often be found to contain all sorts of suggestions and ideas, which are all the more valuable because the problems were seen and dealt with from a different angle. It may seem laborious and uninteresting at first, but after some time the accumulated experience laid down on a few hundred sheets and bits of paper will be worth it. Glancing through them on a quiet evening will be like reading a novel dealing with one's own progress on the road of model building. The writer, when home after a few months of work, will never fail to reserve an evening for that particular occupation, and, pipe well aglow, go back to those other evenings and Sundays full of optimism, and, often, failure. One can afford to be enthusiastic about one's early endeavours, as so much time has since passed. Very often a scrap of paper starts a train of thought that may be well worth following again.

Take Nothing for Granted.

A very good thing to do when making the detail drawings is to take some particular detail which has been found rather difficult to design and sit down with paper and pencil to find a better solution. It need not be wanted in the particular model under construction, though, of course, one is little inclined to do this when the actual thing needs attention. It is more suggested as sound training when one has nothing on hand and does not feel like building for a while. Some day it will find its way into a model and prove its worth. There is usually more than one solution to a problem, and those designers who take the trouble to find out which are best or whether there could not be found a still better one will be more successful than others who are content to standardise a detail of the design which has no particular merit. There is nothing worse than adopting a certain type of construction and incorporating it in any subsequent design simply because one has never troubled to investigate the possibilities of an improvement. After experiment has shown that the old type of construction is still superior the latter, of course, is used. But one has then proved his ideas instead of just adopting them.

This leads us to another aspect of model design which is one of the main factors that make a successful designer ; in fact, the successful engineer in all branches of industry. That is adaptability. The engineer, like the scientist, must be ever ready to accept the latest developments and make them his own. The man who, though once first, does not trouble to adjust his ideas gets left behind. What is new to-day may be old to-morrow. One can see this happen in all branches of industry, and the thoughtful student will take it as a lesson to the wise. More particularly in full-size and commercial aviation all over the world there can be found a number of firms who simply refuse to let new ideas disturb the quiet of their minds. Commercial factors and restrictions, also specifications given by buyers may make it financially advisable to go on producing a type of aircraft or model that is hopelessly out of date and should have disappeared a long time ago. But the aeromodellist is not restricted in any way. He can afford to design along unconventional and altogether new lines, because an unusual type of model is no more expensive to make than the more standardised type. But this necessitates keeping up to date and well ahead, not only by beating records, but also by keeping one's ideas to a logical conclusion. Common sense, as in all walks of life, is very often the key to valuable deductions.

The model aeroplane designer must not, however, forget that his work is unlikely to lead him to discoveries unknown to the scientific world. It is not that this is altogether impossible, but it requires a man with the scientist's appreciation of relative values. And only in exceptional cases will the average model builder be able to make sound deductions when he is confronted with a totally new problem, new not only for him, but to the world. Moreover, the model aeroplane is not a very suitable object for observation, as its flying qualities are, to put it mildly, erratic. But the construction and flying of his models, the various improvements in construction and shape, will keep him busy enough and give him lessons in the general behaviour of an aeroplane in the most entertaining and clear form possible. And the thing he should do is to try to conduct his particular work along more or less scientific lines and so acquire a habit of combining facts logically.

CHAPTER XV.

THE "KINGLET" UNGEARED LOW-WING MONOPLANE.

By M. R. Knight, T.M.A.C.

THE descriptions of model aircraft in THE MODEL ENGINEER have included some famous types: Falcon, Resurgam, Pelly-Fry, etc., and a good many successful copies have been built. With the rapid increase in the numbers of model enthusiasts it seems to the writer that a simpler, ungeared design might be welcomed, in which, while appearance and performance are not sacrificed unduly, construction shall be inexpensive and free from complication, and the stability ample to withstand inexpert adjustment and launching. The designer of a record-breaker cannot afford to allow very much in these directions. The novice would do well, therefore, to leave record-breakers for a while till he has acquired enough constructional and handling experience to enable him to obtain from such designs the performance of which they are capable.

The design here given is an attempt to give the novice a model within his scope, and one that will give him encouraging results in the air. As to cost, it may not be possible to buy exactly the quantities required of the various "ingredients," but 15s. will cover everything, including a strong and efficient propeller guaranteed to "deliver the goods," and leave material over for repairs, or the next machine. The following items are required :—

2 lengths $\frac{1}{8}$ in. by $\frac{1}{8}$ in. (3/32nd in. by 3/32nd in. if obtainable) birch (longerons).
2 lengths 3/32nd in. by $\frac{1}{8}$ in. spruce (fuselage cross-struts and stringer).

2 lengths 3/16th in. by $\frac{1}{8}$ in. birch (wing spars and 2 centre ribs).
1 length 3/16th in. by 1/16th in. birch (ribs 1, 3, 8, 10 and sternpost).
1 length 1/16th in. by $\frac{1}{8}$ in. birch (ribs 2, 4, 7, 9).
12 ins. by 6 ins. 1-mm. 3-ply (formers 2-6) and stiffeners).
6 ins. by 6 ins. 1/16th in. 3-ply (No. 1 former).
1 coil 18-gauge wire (front legs of undercarriage, axle, propeller shaft).
1 coil 20-gauge wire (rear legs of undercarriage, snap-fastener, rear hook and tail-skid, wing tips, tail plane, fin, wing attachment fittings, special " dihedral fittings ").
1 coil 26-gauge wire (tail attachment loops, 3 cross-wires in wing).
Thin binding wire.
Packet mixed 3/16th-in. and $\frac{1}{4}$-in. nails.
$1\frac{1}{8}$ ins. by $1\frac{3}{4}$ ins. by $\frac{5}{8}$ in. satin walnut (nose-piece).
1 pair 2-in. aluminium wheels.
1 small tin clear dope (fuselage).
1 small tin aluminium dope (fuselage covering, and wing structure before covering).
1 small tin orange dope (part of deck).
1 small tin black cellulose lacquer (fuselage lining, nose-piece, wheel centres, plane and tail edging and propeller).
1 brass bush for propeller shaft.
$\frac{1}{4}$ yard Jap. silk (fuselage covering).
$\frac{1}{4}$ yard oiled silk (plane, tail and fin covering).
Large cup washers.
Tube of liquid glue.
1 foot of valve tubing.
7 yards $\frac{1}{4}$-in. flat rubber.
1 tin rubber lubricant.

And the propeller. It is better to leave this part of the job to the expert, and propeller carving is an art in itself. The type used on the " Kinglet " is a " Mossturn " of 12 ins. diameter, 12 ins. pitch, and $1\frac{1}{8}$ ins. blade width, turning clockwise as seen from the front.

Construction.

Unless the intending constructor is accustomed to working in a particular way the methods given in this chapter are strongly advised. First of all draw full size a side view of the fuselage and fin, plan view of the planes, plan view of the

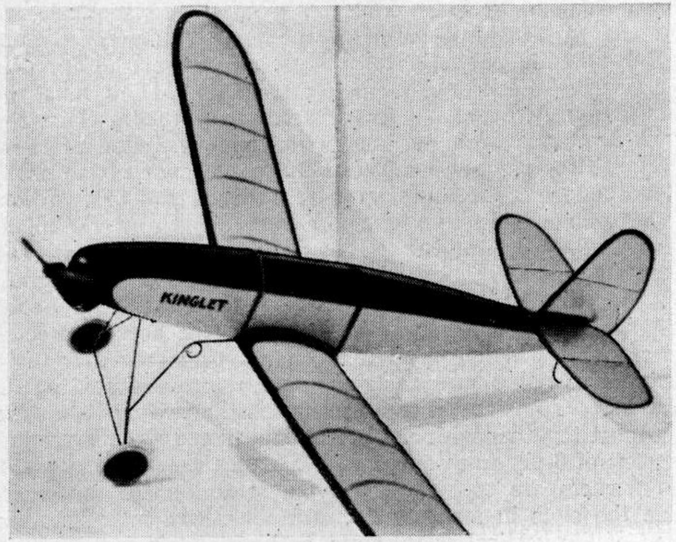


Fig. 108.—The "Kinglet" Ungeared Low-Wing Monoplane.

fuselage and tail-plane. In the plan of the plane increase the chord to $4\frac{1}{4}$ ins. to allow for making up the structure in the flat, the wire tips should be drawn to the correct chord of 4 1/10th ins.

Fuselage.

The longerons are $\frac{1}{8}$-in. square birch. One 4-ft. length will make two longerons. Fasten the full-size drawing to a board free from warps, steam the top and bottom longerons of one side, and fasten on to the plan in correct position, holding in place with pins on either side at frequent intervals. Allow longerons to project beyond the nose and sternpost about 1 in. Note they are only horizontal between formers

3 and 4. At former No. 6 the top longerons rise, to give a negative angle to the tail-plane, which will rest upon them. Glue and tack the spruce cross-struts (3/32nd in. by ⅛ in.) into position as exactly as possible, allowing ½ in. overlap top and bottom (Diagram 2). The sternpost is two pieces of 3/16th in. by 1/16th in. birch, one piece to each fuselage side. Remember, in making the second fuselage side, to put the cross-struts *underneath* the longerons. The 1-mm. 3-ply stiffening pieces in front must be put on the opposite side of the longerons to the cross-struts. They must be very carefully fitted, as when making up the fuselage the front former is brought flush with the front edge of these 3-ply stiffeners. They must, therefore, be put on so as to allow the former to lean forward from the vertical ⅛ in. Allow each fuselage side to set before removing from the plan. Formers 2, 3, 4, 5 and 6 are cut from 1-mm. 3-ply, with the grain running vertically. Their shape is shown in Diagram 10. Measure the width of each from the plan, their depth and position of slot for longerons, from the actual fuselage sides. This will help you to click the parts together more accurately. Glue and tack the lateral cross-struts to the formers. To assemble the fuselage tie the two halves of the sternpost together with a rubber band, likewise the longerons in front of 3-ply front stiffeners. Steam the longerons where the formers are to come, to avoid straining the structure. Glue the slots in formers 2-6, and click each into place, in front of the vertical cross-struts, and with their lateral cross-pieces in front. Glue and tack the formers to the vertical struts, using 3/16th-in. tacks. Former No. 1 is made up of four thicknesses of 1/16th-in. 3-ply, and should measure in front 1 in. wide, 1¼ ins. deep, plus 1/16th in. fairing on top. A piece 4/5th in. deep and 3/5th in. wide should be fretted out, ¼ in. up from the bottom. This piece should be kept to fit on to the rear of the nose-piece. The sides and bottom of this former are carefully sloped as per the plans, and slots cut out for the longerons and top stringer, measuring from your completed fuselage sides. Glue and tack the finished former into place, aligning the front edge flush with the 3-ply stiffeners, for the reason already mentioned. Tack the stiffeners to the sides of the former. Now trim off the ends

of the cross-struts, allowing the sternpost to project ¼ in. below the fuselage. Trim the longerons flush with the front former, and leave ⅛-in. overlap beyond the sternpost. This is to hold the fin steady.

Make up a combined rear rubber hook and tail-skid of 20-gauge wire, as Diagram 12. Glue the inner sides of the two halves of the sternpost, push the completed fitting in between, and bind the whole firmly with thread. Bind also the projecting part below the fuselage. The loop in the skid is made with round-nosed pliers, or by bending around a lead pencil. Be careful to align the two top and two bottom longerons, also the halves of the sternpost, or the fuselage will be out of truth. Glue the slots in the top of the formers and slip in the top stringer (3/32nd in. by ⅛ in. spruce) which finishes just ahead of No. 6 former. Lighten the longerons, struts and stringer with a file, or judicious scraping with a safety-razor blade, reducing to about 3/32nd in. by 3/32nd in. The fuselage should now weigh 1 oz., or slightly over.

Nose-piece.

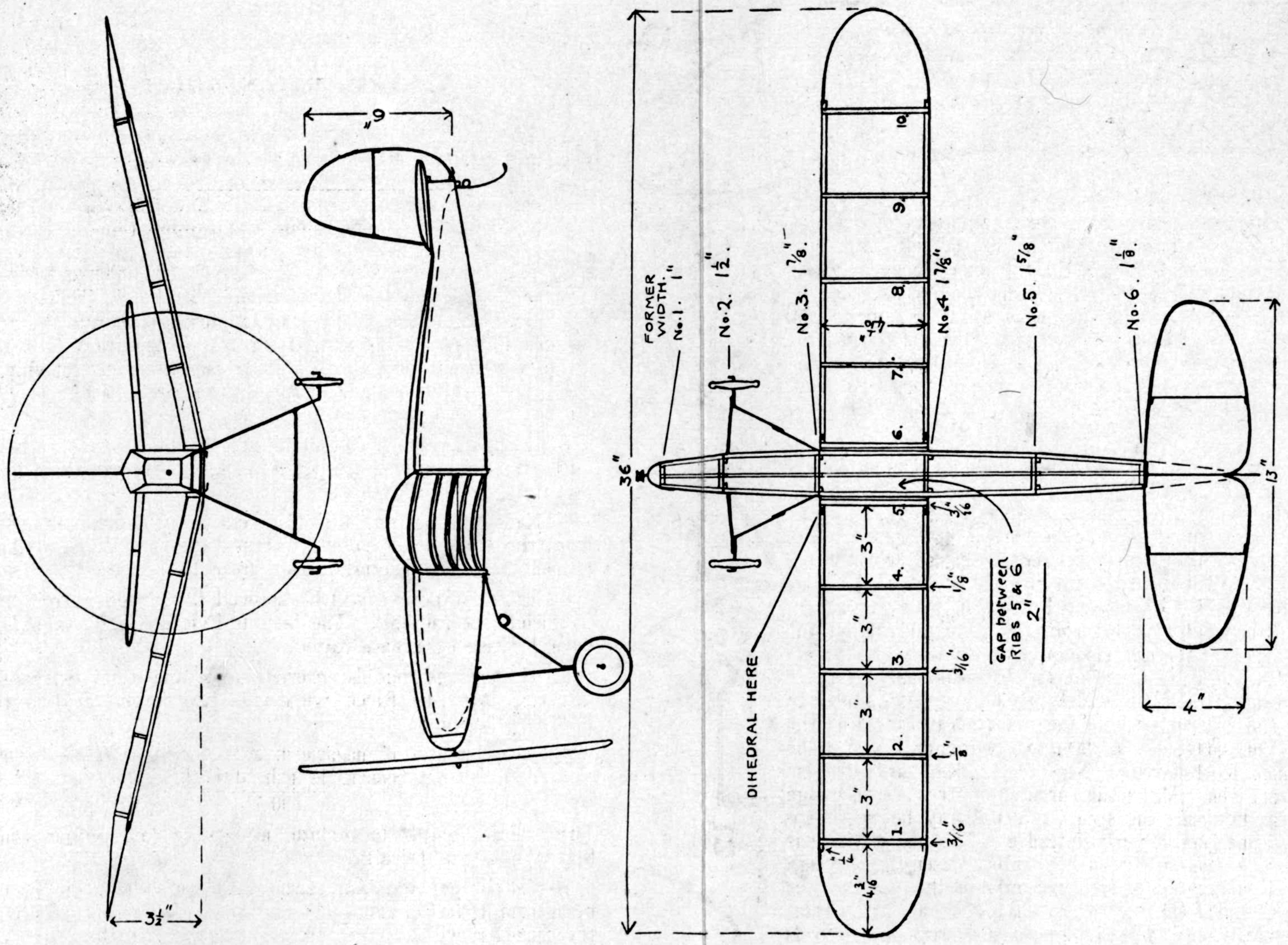
Glue and tack the piece cut from No. 1 former to the piece of satin walnut. Push into place in No. 1 former and mark round to get the shape. Having roughly shaped it, place it in position again, and finish off with razor blade and medium glass-paper, continuing the lines of the fuselage. Bore the hole for the brass bush, ½ in. from the bottom of the nose-piece, and fit the bush, being very careful to keep it vertically and laterally true. It should now weigh slightly under ¼ oz.

Undercarriage.

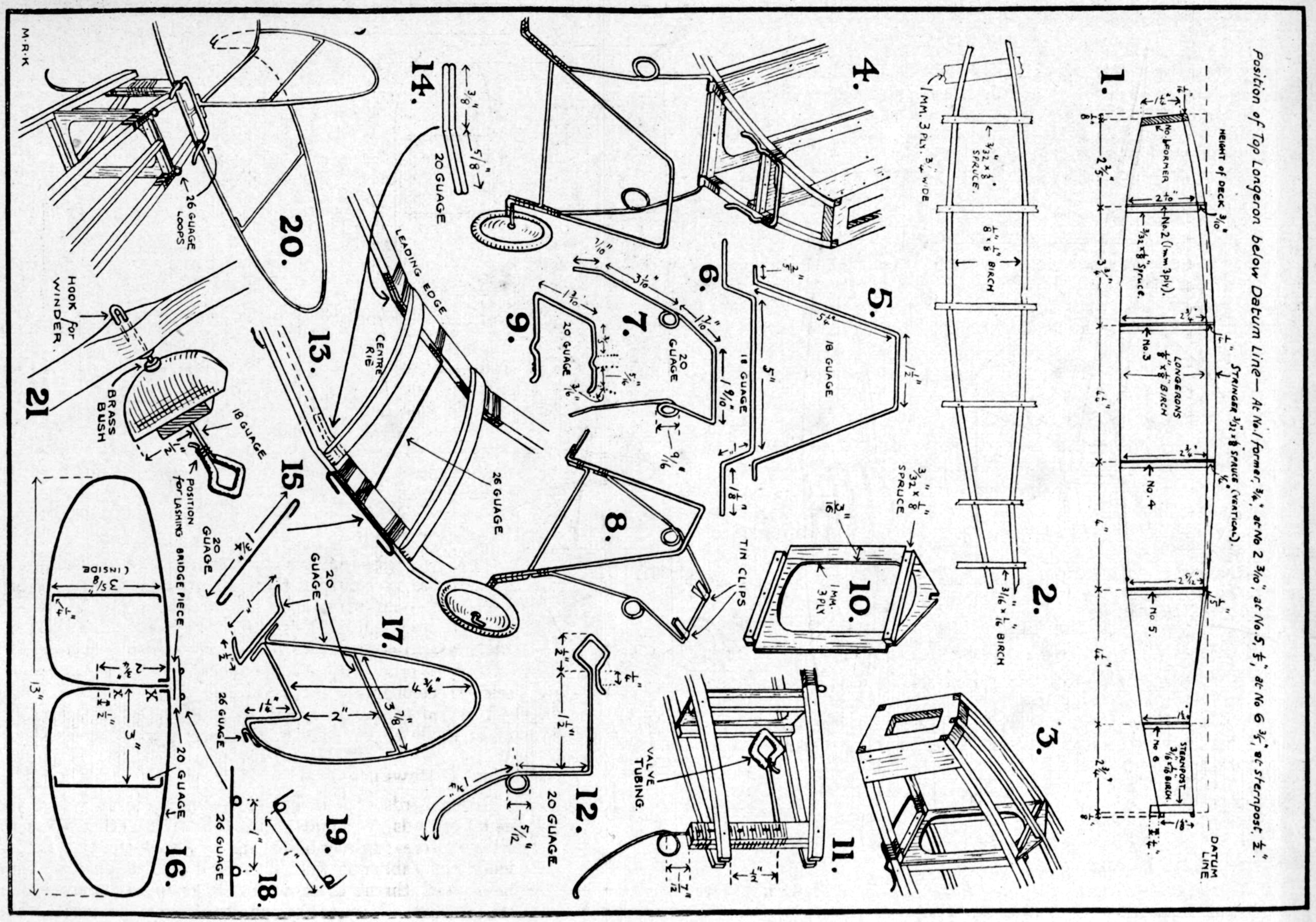
This is made of two pieces of 18-gauge wire and one piece of 20-gauge, and incorporates two shock-absorbing devices. The ordinary shock of landing is taken by the loops in the rear legs. In power landings, or in hitting rising ground, the front legs are free to spring out of the snap-fasteners, allowing the undercarriage to fold back beneath the fuselage. The axle is raised 1 inch to lessen the chances of the model overturning through catching tufts of grass. First make up the front section (Diagram 5). Then make the axle, thread on the wheels, and bend the last ¼ in. at right angles. Bind axle behind the front legs, and solder. The rear legs with wire loops are then made up (Diagram 7). If round-nosed pliers are not available the ordinary domestic poker will be found useful. To ensure that both loops are in line with one another be careful to hold the wire at the same point when starting the loop. Solder the front ends to the front undercarriage legs, tight up to the axle (Diagram 8). The rear legs are held permanently to the lower longerons in front of, but tight up to, No. 3 former by tin strips bent round the wire and lashed with thread to the longerons. The snap-fastener is shown in Diagram 9. It is nicked to hold the 18-gauge front part of the under carriage fairly tightly, and is lashed to the lower longerons in such a position that the nicks rest beneath No. 2 former. Undercarriage and snap-fastener should weigh ¾ oz.

Planes.

Cut two pieces of 3/16th in. by ⅛ in. birch to form the leading and trailing edges. They should be 2 ins. longer than required, and should be fastened down on to the full-size plan as in the case of the fuselage sides. The ribs should be cut to 4¾ ins. and glued and tacked to the main spars before cambering. Note the three different sizes of wood used, 3/16th in. by 1/16th in. birch for ribs 1, 3, 8, 10 ; ⅛ in. by 1/16th in. for ribs 2, 4, 7, 9 ; and 3/16th in. by ⅛ in. for ribs 5 and 6. When set remove from the plan and steam the ribs one by one. The camber should be greatest about one-third from the leading edge, and should reduce the chord of the plane from 4¼ ins. to 4 1/10th ins. Trim off the overlap of the ribs, and cut the ends of the spars ready for fixing the wire tips. The latter are of 20-gauge wire, and should be securely lashed to the spars. Now round the spars off ; also the two centre ribs. Make the three cross-struts of 26-gauge wire and lash between the spars, one midway between ribs 5 and 6, and one beneath ribs 3 and 8. The use of these is to prevent any possibility of the ribs flattening through damp. Next steam the spars just outside the centre ribs and put in the dihedral. Place the wing on a flat surface, weight the centre section of the spars, and prop up the ends of the plane so that at the extremity of the wire tips there is



Front and Side Elevations, and Plan of Ungeared Low-Wing Monoplane



Group of constructional details for building the Low-Wing Monoplane "Kinglet."

3½ ins. of dihedral. Fasten the plane down in this position until it has thoroughly set. Then cut eight pieces of 20-gauge wire, 1 in. long, and bend to the correct dihedral angle. Solder them in pairs, one piece *above* another, as shown in Diagram 14, and lash each completed fitting to the inner edges of front and rear wing spars at the point of dihedral (Diagram 13). These are to strengthen the plane at its weakest points, and help to maintain correct dihedral. Then make the two wing attachment fittings, and lash to the outside edges of the centre section (Diagrams 13 and 15).* The woodwork should now be lightly painted with aluminium dope, which shines through the oiled silk covering and gives the wing a smart metallic appearance. The structure before covering should not exceed 1 oz. The covering of oiled silk is put on in two pieces. A ¼ yard is sufficient for wing and tail unit if divided lengthways, and 19 ins. cut off each piece for left and right planes. Stick each piece to the centre ribs (5 and 6), and allow to set; then pull tightly to the tips, and pin round the wire. Stick along the trailing edge, and when set pull over leading edge, not so tightly as to sag the silk between the ribs but sufficiently to take up any wrinkles or slackness. Finally, sew round the wire tips, removing a pin at a time. Glue the stitches above and below. Lastly, trim off all the overlap.

Tail-plane and Fin.

Cut sufficient 20-gauge wire to go right round the tail-plane and up the centre. Don't straighten out the wire, but bend it double in the centre so that in bending the double thickness to the shape of one-half of the tail you are actually making both halves at once. In commencing make a ¼-in. overlap at right angles. The shape is shown in Diagram 16. Cut away part marked "X" in the same diagram and solder the two halves together as shown. Cut a bridge-piece ¾ in. wide and solder to the front edge, in the centre. Next make and solder into position the two ribs which are not cambered.

* Extensive trials with the "Kinglet" have indicated that the two attachment fittings can be dispensed with, the wing being secured to the fuselage with a length of ¼-in. elastic passed over the fuselage at formers 3 and 4, crossed under the wing, and tied.

Make up the fin of 20-gauge wire, as Diagram 17. Now take some 26-gauge wire and wind round the projecting lugs, making two fittings (Diagrams 18 and 19). No. 18 should be soldered to the leading edge of the tail-plane, and No. 19 to the top longerons. The curved prongs on the fin should slip comfortably through the loops on the tail-plane, then those on the fuselage. The rear of the fin is pulled down between the converging curves of the rear edge of the tail-plane, and should fit fairly tightly, and is then pulled down between the projecting ends of the longerons. A rubber ring is passed round the small hook under the fin, and round the projecting part of the sternpost, several times. This keeps the tail unit quite firmly in place. Take great care to get the tail-plane and fin to fit together and to the fuselage comfortably, shifting the attachment loops if necessary, as a tail that is free to swivel will cause spinning, with possibly " fatal " results. In covering oiled silk is used, as with doped silk it is necessary to use heavier gauge wire to ensure freedom from warping. I suggest pinning the silk into place and sewing and glueing as in the case of the wing-tips. The tail-plane can be covered in two pieces if desired. Care is necessary with the fin to avoid distorting the angle of the cut-away portion.

Covering the Fuselage.

Now the tail-attachment loops are in place, the fuselage is ready for the silk. Cover one side at a time, using separate pieces of jap silk cut the way of the selvedge (if this is unintelligible consult a feminine friend) and allowing a slight overlap—a $\frac{1}{4}$ yard is sufficient if cut into three lengthways. Cut off 22 ins. for top and two sides. The remaining three short lengths can be used for the bottom. Note the last bay of the top is left uncovered to give access to the rubber-hook. In flight this is covered by the tail-plane. Apply the silk as follows: Stick the front end of the side piece and allow it to dry. Damp the silk and stretch to the rear, sticking to the sternpost, and the last inch of top and bottom longerons. Stick along top longeron. When dry damp again and stick to bottom longeron, taking in the slack. This is a job that cannot be hurried. As the glue dries it is possible to tighten the silk slightly, but try to keep the pull

even, so that the threads lie horizontally and vertically even—*i.e.*, not running diagonally anywhere, nor curving all over the place. Trim off the overlap with a razor blade. Proceed similarly with the other three fuselage surfaces. Cut the silk carefully in the region of the undercarriage snap-fastener—needless to say the undercarriage must be unclipped during the process of covering. Two coats of clear dope, applied evenly and thinly the way of the silk grain when the fuselage is completely covered, should tighten and render it airproof without warping. Two coats of aluminium on sides and bottom, and one of orange on top, complete the doping process.

Suggested Colour Scheme.

An orange streak $\frac{3}{4}$ in. wide at the centre and tapering fore and aft is left on top of the fuselage. The remainder is painted with black lacquer, which is continued for $\frac{1}{4}$ in. down the fuselage sides and brought to the nose in a curve, as shown by the dotted line in the side view. The nose-piece, wheel-centres, and a $\frac{1}{4}$-in. edge round planes, tail-plane and fin are also treated with the black. The writer also prefers to give the propeller a coat.

Propeller Shaft.

This is of 18-gauge wire, as Diagram 21. The front end is bent round and pushed back into the propeller boss, leaving sufficient room to attach the hook of a winder. The shaft will be found quite a loose fit in the brass bush. This allows the shaft to continue to function when slightly out of truth, and takes practically all the shock in a heavy landing. It is seldom the propeller suffers damage other than slight chipping. A piece of 18-gauge wire in the pocket enables a replacement to be made on the field in a minute or two.

Motive Power.

Seven yards of $\frac{1}{4}$-in. flat rubber is made up into a skein of eight strands, the ends being lashed together with thread. Front and rear rubber hooks are covered with valve tubing, and when the rubber is well lubricated and in position bind the hooks with thread as shown in Diagram 21 to prevent rubber slipping off. New rubber should be well lubricated the day before it is to be used, and stored in an airtight tin, with room for the rubber to expand. Fit it into the model when actually ready to fly.

Assembling.

The plane should sit tight up to No. 3 former, and be held by two rubber bands from the hooks beneath the centre section round the fuselage. With the model standing on a flat surface measure the height of each wing tip. Both should be equal, any fault in this respect is best remedied by packing the wing spars below the fuselage. Look at the wing from in front to make sure there are no warps and that front and rear spars are in alignment. The tail-plane should be bent to give a slight dihedral. Make sure that each side is equal in this respect, also with regard to negative incidence. Measure from the top of the fin to the end of the tail-plane on each side to ensure that fin is vertical. The top of the fin should then be bent slightly, so that a little of the rear edge is visible on the right, as seen from the front, to allow for propeller torque. (If this proves insufficient slightly increase the incidence of the wing tip on the opposite side.) Where an anti-clockwise propeller is used. the fin must be bent the opposite way, etc. Wind the propeller until the slack of the rubber skein is taken up and secure the propeller with a piece of thread from the front undercarriage leg. The centre of gravity should come 2 ins. back from the front edge of the plane. If the model is nose-heavy bend the rocker arms of the undercarriage to move the whole undercarriage back a little; if tail-heavy weight the nose with, say, a woodscrew in the back of the nose-piece. Try to get the centre of gravity right without moving the plane from its designed position. It is not always realised that the practice of wing sliding is not a sure way of securing trim, as in moving the wing you move weight as well as potential lift, and may upset your side areas.

Flying.

The "Kinglet" will stand a fair amount of wind when the trim is correct, but trim is best obtained when the wind is less boisterous. Give 150 turns, kneel on the ground, and

launch gently into the wind. The model will probably dive slightly. Correct for torque, if necessary, and increase the turns to 200. If O.K. it is now possible to obtain and gradually increase climb by bending the tail-plane to give increased negative incidence. When the limit is reached the model will stall, but thanks to the downward thrust it will be of the gentler variety. The "Kinglet" has been given plenty of stability, but the writer is not such a care-free optimist as to suggest that the constructor has merely to "put it together, wind it to the left, and throw it up." The novice simply must get down to the business of trueing up, and train hand and eye to make careful adjustments. Form a habit of looking the model over before each flight; down- or cross-wind landings, collisions with obstacles, and the efforts of well-meaning helpers make this essential. This trueing up is the secret of success, and anyone who is not determined to master it had better find another hobby before his model's unprovoked assaults bring retribution. It is hoped, however, that builders of the "Kinglet" will do the thing properly, and, having tasted the joys of successful flight, pass on to the construction of more advanced models.

Table of Weights.

Propeller, shaft and nose-piece	$\frac{3}{4}$ ozs.
Fuselage complete and undercarriage	2 ,,
Tail-plane and fin together	$\frac{1}{2}$,,
Plane	$1\frac{1}{4}$,,
Rubber	1 ,,
	$5\frac{1}{2}$ ozs.

B. M. 1/1
Bars 6
One 2
Dac
J. B 1/-

GLOSSARY OF AVIATION TERMS.

AEROFOIL.—Any supporting surface.

AIRSCREW.—Any propeller or tractor screw.

ASPECT RATIO.—The ratio of span to chord.

BIPLANE.—An aeroplane having two aerofoils, one above the other.

CAMBER.—The curvature in a fore and aft direction of an aerofoil.

CENTRE OF GRAVITY.—The point at which the weight of any machine can be considered to act.

CENTRE OF PRESSURE.—The point at which the pressure of the air on the machine can be considered to act.

CENTRE OF RESISTANCE.—The point at which the resistance to forward motion can be considered to act.

CENTRE OF THRUST.—The point at which the aggregate propulsive or tractive power can be considered to act.

CHORD.—The fore and aft dimension of an aerofoil.

DIHEDRAL ANGLE.—The angle which the centre line of each plane makes with the horizontal as seen in front elevation.

DRAG.—The resistance of any body in the line of flight.

ELEVATOR.—An auxiliary plane which may be moved in flight to alter the vertical attitude of the machine.

FAIRING.—Any addition made to reduce resistance.

FLYING BOAT.—An aeroplane in which the fuselage is so placed and constructed as to support the aeroplane on water.

FUSELAGE.—The body of the aeroplane.

GAP.—The vertical distance between the planes of a biplane.

GLIDE.—Flight on a downward path without power.

H.L.—Hand launched.

INCIDENCE.—Angle of. The angle an aerofoil makes with the horizontal.

LOADING.—The weight carried by each unit of area.

LONGERONS.—The fore and aft members of a fuselage.

MONOPLANE.—An aeroplane having a single main plane.

PITCH OF AIRSCREW.—The distance an airscrew would advance in one revolution were there no slip.

PLANE.—The supporting surface of an aeroplane.

PROPELLER.—An airscrew working behind the main plane.

PUSHER.—An aeroplane having its airscrew behind the main plane.

RIB.—Any fore and aft member of a plane which maintains the correct camber of the covering.

R.O.G.—Rising off ground.

R.O.W.—Rising off water.

RUDDER.—An auxiliary plane which directs the movements of an aeroplane to right or left.

SEAPLANE.—An aeroplane provided with floats to support it on the water.

SLIP.—The amount by which an airscrew fails to advance its pitch in one revolution.

SOARING FLIGHT.—Horizontal or rising flight without power.

SPAN.—The distance from tip to tip of an aerofoil.

SPARS.—The main structural members of an aerofoil.

SPAR MACHINE.—A simple model in which the fuselage is replaced by one or more exposed members.

STAGGER.—The horizontal distance between the leading edges of a biplane.

TAIL PLANE.—A horizontal subsidiary plane fixed some distance behind the main plane.

TORQUE.—The couple tending to rotate an aeroplane in a direction opposite to that of the airscrew.

TRACTOR.—An airscrew working in front of the main plane.

UNDERCARRIAGE.—The landing gear.

WASH-IN.—The increase of angle of incidence towards the tip of the plane.

WASH-OUT.—The decrease of angle of incidence towards the tip of the plane.

COMPETITION RULES

A SELECTION of the more important competition rules of the Society of Model Aeronautical Engineers is printed below. As well as giving information necessary to those who wish to enter the Society's competitions they may prove useful to new Clubs and Societies who are framing their own rules.

1. No record flight will be entered in the Society's books unless officially observed by recognised timekeepers.

4. No trial flights may be made during the five minutes preceding the time appointed for the competition to start, or during the competition. Minor repairs and test flights will, however, be allowed during the competition at the discretion of the Judges.

5. Individual flights (rise off ground) of five seconds or under not to count as competition flights, but only two such attempts to be allowed.

7. Each competitor must be ready within two minutes from the time he is called. If not then ready he renders himself liable to disqualification from that round.

8. Each competitor will be allowed three flights, time and conditions permitting. The best individual flight to count, except where otherwise stated.

9. All fuselage models entered for competitions or record-breaking must be fitted with a body complying with the following formula :—

Minimum value of maximum cross-sectional area—

$$\frac{\text{Overall length of body}^2}{100}$$

The overall length to include nose-piece (or spinner when fitted) and tail fairing.

10. In competitions and record-breaking, when flights have been obtained after rising off ground or after rising off water, the duration will be taken from the time when the propellers are released.

SOCIETIES AND CLUBS.

EVERY aero-model maker and flier should become a member of a club, where he will meet other people with similar interests to his own. Flying meetings and competitions are arranged throughout the Summer, while papers are read and discussions held during the Winter, keeping members in friendly and intimate touch throughout the year. In this country the Society of Model Aeronautical Engineers, by agreement with the Royal Aero Club, governs the sport of model flying. Members of affiliated clubs may enter all competitions and attend lectures arranged by the S.M.A.E. The Society will put anyone interested in model flying in touch with local clubs already formed, or with other members in the same district and help them to form their own clubs.

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Printed by LOXLEY BROTHERS LIMITED, 50, Southwark Bridge Road, London.