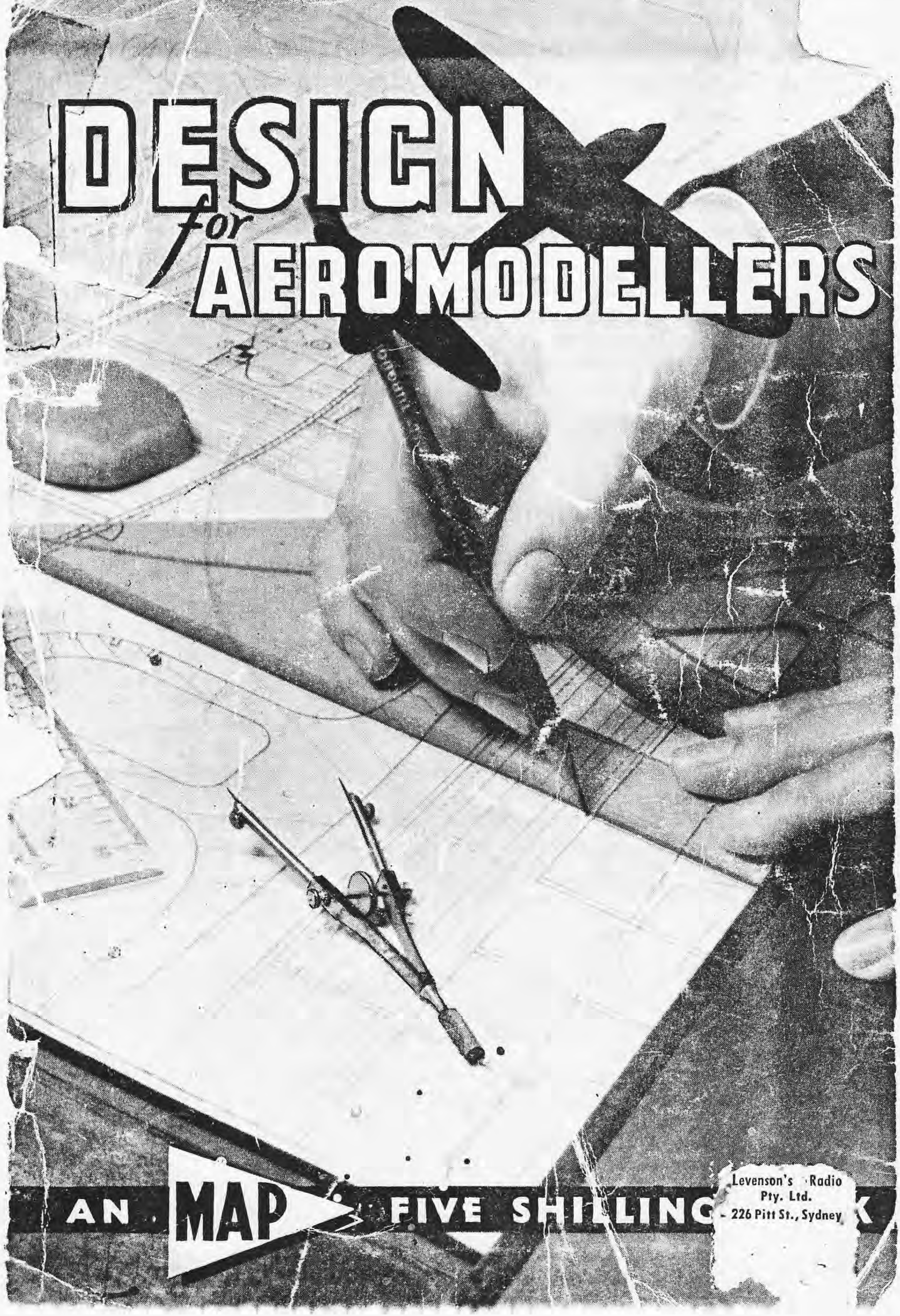
DESIGN for AEROMODELLERS



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DESIGN FOR AEROMODELLERS

A Treatise on the design of all types of model aircraft, covered in a practical way without the use of formulae, and with notes on suitable sizes of materials, based on Ron Warring's series of articles in AEROMODELLER "It's Designed for You."

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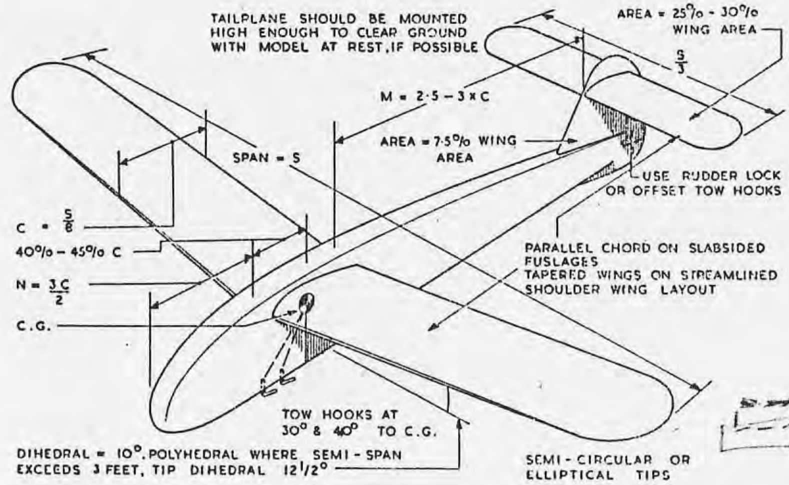
FOREWORD

IT is very many years since any model publication attempted to cover the whole range of aeromodelling design in a single book. So much development has taken place in the hobby during the post-war years that any such attempt must necessarily deal only briefly with each type of model, indeed, some of the more complex types merit a whole book devoted to them alone.

Within these limitations, however, we feel that DESIGN FOR AEROMODELLERS does provide in easily readable style the basic facts behind the design of all types of models. With its aid the comparative novice can move easily from the first phase of building other people's designs into that infinitely satisfying second phase of designing his own. Possibly these early "own designs" will not equal the contest winning efforts of the experts that he has formerly copied, but at least he will be able to say "all my own work!"

But the tyro designer is urged to persevere. If he can follow the basic principles set out in this book, and bring reasonable manual skill to his aid, so that he really does fly what is laid out on his drawing board, then we are confident he will not have to wait long for success in whatever branches he may be attempting.

C. S. RUSHBROOKE,
EDITOR OF *AEROMODELLER*.



CHAPTER ONE . . . . GLIDERS

GLIDER design is comparatively straightforward, for flight stability problems are minimised. Almost any combination of wings, tailplane and fuselage can be made to glide, even if some of the components are badly proportioned. As a typical example, let us take fin area. A fin of only three or four per cent. of the wing area is adequate for stability on the glide with orthodox rigging and layout, but such a fin will be found far too small for *towline stability* in conditions other than a flat calm.

Basically, it would appear from numerous practical tests, that any model which is stable under tow can be made *unstable* by moving the centre of gravity back, even though the free flight trim may be adjusted to give excellent results with this new C.G. position. Conversely, some models which have proved *unstable* under tow have been made stable by re-trimming with the C.G. farther forward. With a fixed (pre-determined) C.G. position the practical solution to this problem is an adjustable tow hook position.

Instability of any sort is aggravated by speeding up the model. Thus, a model which has only marginal towline stability, may prove quite satisfactory in still air conditions, where the actual airspeed during the launch can be kept low. The same model, however, in gusty or windy conditions can become quite unstable on the line, since, as soon as the airspeed is allowed to build up for any reason, instability sets in and is usually progressive.

Obviously, then, it is no good having a glider which is only stable on tow under calm conditions. Nor is it safe to assume that any model *is* stable under tow until it has been tested under rough weather conditions.

Directional instability due to offset rudder (or other free flight turn trim) can be countered by mechanical means, and there are two basic ways of doing this. The first, and simplest, is to offset the tow hooks to one side of the fuselage, so that the pull on the line tends to turn the model in one direction. This is counteracted, for a straight tow, by offset rudder, which, once the model is released, gives circling glide in free flight which is highly desirable—Fig. 1.

Any degree of rudder offset will act against the turn under tow, induced by the offset hooks. Control is then entirely in the hands of the launcher, who adjusts the towing speed to suit the conditions prevailing and thus maintain a straight tow up.

The second method utilises a mechanical

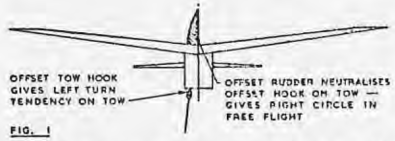


FIG. 1

form of rudder adjustment which holds the rudder central for a straight tow and then, as soon as the model is off the line, allows the rudder to move over a predetermined amount for a circling glide. In other words, the aerodynamic set up is such that, with straight trim the model has adequate towline stability and the onus for a successful launch lies in the design of the model, rather than in the skill of the launcher.

Auto-Rudders

The original auto-rudder method, worked off a pivoted tow hook. With the line in position the tow hook is pulled forward, moving the rudder straight. Once the line is released, the tow hook is spring loaded to move back, releasing the rudder which then moves over to give circling gliding flight. Schemes essentially similar to this are in wide use to-day, or the alternative rudder-lock device.

The rudder-lock scheme is sketched in Fig. 2. Rudder movement is controlled by a pivoted arm called the "trigger" which is normally tensioned to rest against a forward stop; this corresponds to offset rudder for free flight conditions. For tow launching, a wedge of balsa is tied to the line and inserted in the fuselage between the trigger and its stop, moving the trigger to a new position. This allows the rudder to move over against its centre stop, giving straight rudder for the tow launch. When the line falls free it pulls out the wedge and the rudder snaps over for circling flight at once. An alternative, somewhat simplified hook-up is also shown.

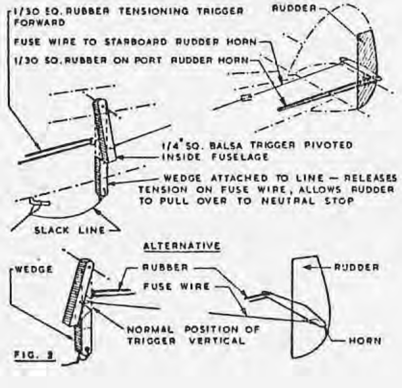


FIG. 2

The great advantage of this system is that it is absolutely positive from the time the wedge is inserted to the time the towline drops off the model. In other words, varying line tension, which may cause trouble on the original auto-rudder system, has no effect at all. Nor is any failure likely, due to the wedge jamming in position, provided that the line joining it to the towline is, at least, as strong as the towline.

The other form of towline instability is also aerodynamic in origin, and can therefore be discussed very briefly, before going on to deal with specific design layouts for gliders of all types. This is "hunting," where the model swings from side to side under tow, each swing generally getting worse than the one before it, until the model may even turn right round and become completely uncontrollable. This, in fact, is the dangerous form of towline instability which is often extremely hard to cure. Small fin areas, excessive dihedral and aft C.G. positions are three possible causes. Tow hook position, also, has an effect, for the farther aft the point of line attachment the greater the tendency for the glider to "wander" on the line, but this should not be considered as a major factor. To get maximum height under tow it is necessary to get the tow hook reasonably far aft. Instability under tow should be cured *in the design itself* rather than by using a forward tow hook position. This will only be effective in mild cases of instability (if originally within the accepted limits), and will in any case result in loss of initial height during the launch. It is no good, for example, using a forward hook position to get a reasonably stable tow, and then find that it is only possible to get about 100 feet of initial height from 164 feet of line with that hook position. It is quite common to find that models like this, of F.A.I. or heavier loading, just cannot be towed up during calm conditions. Quite

a heavy model however, which has a generous reserve of towline stability, can use a tow hook position well aft under such conditions, and be towed up to the full height of the line without the launcher having to run unduly fast.

Basic glider types

Six basic glider types are shown in Fig. 3. The simple parasol arrangement is much favoured, with slabsided or box fuselage, probably on the principle that the parasol wing layout is generally the most stable for almost any type of model. But although excellent results can, and have been achieved with parasol wing gliders, it is the one type on which the inexperienced are most likely to go wrong.

Parasol models are almost invariably rigged with the tail-plane lifting and contributing a part of the total lift. That is, the centre of gravity is rigged behind the centre of lift of the wings. An aft C.G. position can lead to towline instability and therefore *the whole design becomes more critical.* Unless the layout is such that a generous reserve of towline stability is present, the set-up may become unstable in anything but relatively calm conditions. Unfortunately, it is not possible to boil down the design requirements for towline stability to a few simple proportions.

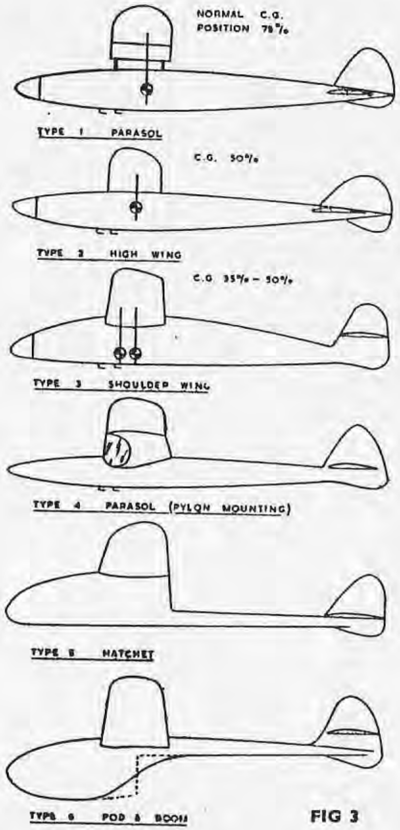


FIG 3

Where a simple, orthodox, functional design is required, the normal high wing layout is probably better, for this is easier to trim with a forward C.G. position, if found necessary. A more "refined" design is the shoulder wing model, where the wing remains at roughly the same position as on the high wing layout. The fuselage deck line is humped so that the wings actually plug into the fuselage sides, in the shoulder position. This gives a neat and effective combination for a streamlined fuselage, but has also been adopted on many of the large and very large models with a slabsided fuselage. Once the span of the model exceeds about four to five feet, the wings have to be made in two (or more) pieces, in any case. It is then probably simpler, and quite as effective, to plug each wing half into the fuselage with a shoulder wing layout, rather than plug them together and then lash them on top of the fuselage.

Some very successful designs, in these orthodox forms, have used a lengthened nose with good effect on towline stability. Briefly, the effect is that a forward mounted fin (in these cases increased forward fuselage side area) has proved particularly effective in giving good towline stability. Consequently, a narrow, rather deep fuselage with a fairly generous nose length is, generally, better in this respect than a slim fuselage design with little or no nose area.

This may account, in part at least, for the undoubted success of parasol models of type (iv), where the wing is carried on a cabin-type superstructure which is, in effect, a forward fin. The remainder of the fuselage is then very slim, usually diamond.

section, or fully streamlined, reducing wetted area to a minimum.

Further, more unorthodox layouts also incorporate "forward fin" effect, e.g., the "hatchet" type and "pod-and-boom" fuselages. These have proved particularly effective in the small and medium class range.

Probably the size of the finished model has more influence on the design layout than many people appear to realise. Where the model is intended for regular flying, such as contest work, the larger the actual size of the model the more the tendency to adopt a simplified layout. In the very largest class of gliders, of around eleven to twelve feet span, we find that box fuselages are almost the universal rule. From aerodynamic considerations however, one would expect that, to utilise the increased aerodynamic efficiency of the larger models to the fullest advantage, full streamlining would be applied to the fuselage.

There is little doubt that, all other things being equal, the larger model will beat the smaller model under almost all conditions. Therefore, for contest work in particular, the larger the model you can afford to build (both in material, cost and time) the better.

Actually the significance of the wing loading rule tends to disappear as size increases. Above about 300-500 sq. in. wing area, a glider of F.A.I. loading will generally out-perform a more lightly loaded model of the same size, mainly because it has better penetration. The lightly loaded glider makes little or no headway and tends to sink straight down in any slight breeze and, in fact, about the only time that it does show a possible advantage is in absolute dead air conditions

The effect of size

For contest work, any glider of below about 400 sq. in. wing area is now considered too small. At the other end of the scale, a figure of nearly 1,600 sq. in. has been reached and, on an overall average basis, models with wing area exceeding 1,000 sq. in. have placed consistently in major glider contests during the past two or three years. The exception still crops up, where the smaller glider has a lucky break and makes three excellent thermal flights to top the list, but the trend is for more and more of the competition places to go to the larger models.

The new "Nordic" class comes at the lower end of the contest scale, as regards size. With conventional tailplane area this specification corresponds to a wing area of about 400-450 sq. in. A handy size for building and carrying about, this is at the same time, large enough to prove a good contest model when competing with models of larger size in "open" events.

The Nordic class represents about the upper limit of size where all the forms of fuselage layout detailed in Fig. 3 are still practicable. With larger models, the pod-and-boom and hatchet types tend to become structurally weak, being particularly vulnerable where the relatively thin boom joins the main fuselage nacelle. One could summarise the useful application of these various designs under class sizes as under:—

Up to 300 *sq. in. wing area.* Relatively useless for serious competition work. All types practicable, but the smaller models (150-200 sq. in. area) should have slab-sided fuselages for minimum structural weight.

300-400 *sq. in. wing area.* All types practicable, but preference should be given to the more streamlined layouts, either by using streamlined section fuselages or reducing fuselage wetted area.

400-750 *sq. in.* High, shoulder-wing, or cabin-pylon types are all well suited to this range, preferably with the fuselage streamlined as far as possible.

1,000 *sq. in. and over.* Here, complex fuselage construction is generally abandoned and simple, slabsided types are general with either high or shoulder-wing mounting.

As a general rule, less tailplane area is needed on a glider than on any other type of free flight model, to give adequate longitudinal stability. The larger the wing area, the less the proportion of tailplane area required. The smaller models, 300 sq. in. and under, can well use a 33 per cent. tailplane area as, on account of their size, they are more apt to be displaced and thrown about in rough weather. They need, therefore the greatest reserve of stability to recover their normal glide path quickly. Above this size, tailplane area can be proportionately decreased, until at 1,000 sq. in. wing area and over, a 10 per cent. tailplane is adequate. There is no particular rule on the subject, and the proportion is far from critical. If in any doubt it is better to err on the generous side, but there is seldom any need to exceed 25-30 per cent.

TABLE I. AERODYNAMIC DATA

Size	Area	Span	Chord	Aspect Ratio	TAILPLANE			FUSELAGE			Weight
					Span	Chord	Area	N	M	LOA	
Non-Contest ...	200	40	5	8.0	14½	4½	65	7½	15	32½	Light as possible
Small	300	50	6	8.3	18	5	90	10	18	40	10¾
Nordic	392	56	7	8.0	22	5½	121	12½	22	48	14¼
Medium	576	72	8	9.0	24	6	144	13½	25	54	19⅝
Large	1440	120	12	10.0	45	8	360	15	35	72	49½ oz.

Other design features

Unless the model is to be a fully streamlined design, there is very little reason for departing from a rectangular wing planform with elliptic or rounded tips. From the purely practical point of view, it is infinitely simpler to cut a large number of ribs of identical size, than to plot or carve a set of ribs all different lengths for a tapered wing. However, with a shoulder wing *streamliner*, it is more pleasing and better aerodynamically, to have a tapered wing. The taper is restricted so that the tip cord is generally not less than two-thirds of the root chord, and never less than one-half.

Aspect ratio for a rectangular wing should be between 8 and 10, as these figures give the best compromise between low drag and optimum structural weight. Structural weight is not as important with gliders as with most other models, but it is always an advantage to make the wings as light as practicable. Heavy wings can set up towline instablity on their own, due to their inertiia when displaced. It is best practice, in fact, to produce the whole airframe of the model to the lightest weight consistent with the required strength, and then load up with ballast to conform to F.A.I. rules, *by adding weight in the fuselage around the C.G. position.* This is where a shoulder wing design scores to a certain extent, for the actual wing fixing can be made extremely tough and robust, the extra weight added at this point being desirable rather than a handicap.

The most popular type of fixing, in such cases, is the tongue and box, but it should be noted that, for all wings of 300 sq. in. area or more, the tongue should be located in the fuselage and the boxes in the wing halves. Using plywood tongues this scheme works extremely well, even right up to the very largest size of models.

Straight dihedral is adequate for all types of glider; "Fancy" dihedral forms should be avoided in any case, as adding weight and structural difficulties and as possible sources of warps. Polyhedral, or more usually a straight centre section with dihedralled tips, is often used where the semi-span exceeds the standard wood length of three feet. To avoid splicing all the mainspars necessary to get a straight wing panel, each half wing is built in two sections. These are joined together at a dihedral break which comes somewhere about mid-way out along the semi-span.

The wing section is rather important, particularly as the size, and thus the chord, of the wing increases. As a general rule, thin sections are not desirable since, although they generally have an excellent lift-drag ratio, they have to fly quite fast to develop the necessary lift. Although the lift/drag ratio, and resultant gliding angle are flattering, both drag *and* lift are *low*, and therefore, to get lift, the wing has to operate at a reasonably high airspeed. There is still insufficient evidence to point to any one particular section being superior. Some of the laminar flow and turbulent flow sections have been tried quite successfully, but conventional sections like Gottingen 532, Eiffel 400, RAF 32 and so on, appear equally good in practice. The choice is extremely open offering an interesting field for practical research.

On theoretical grounds there would appear to be a strong argument in favour of using the largest possible wing *chord*, i.e., reducing the aspect ratio, to get a higher operative Reynolds Number and thus greater aerodynamic efficiency. This is particularly applicable where the wing area is restricted, as in the "Nordic" class, and models of this type have appeared, where the aspect ratio has been reduced to 6, or thereabouts. Since lowering the aspect ratio increases the induced drag of the wing, it is still a matter of doubt as to whether any specific advantage is gained by this method. On the basis of past results, the original aspect ratio figures quoted appear best. In the case of shoulder wing models, the tendency is to go even higher, about 12 : 1 being the top value, even with rectangular wings.

Structurally, a wide variety of methods are available to the designer, for there is no reason for economy of space *inside* the fuselage. For the smaller and medium sized models, therefore, with a streamlined fuselage, crutch construction is probably the ideal method. This applies to fuselage lengths up to about four feet (even if the crutch members have to be spliced to obtain these wood lengths), but above this the figure tends to be a little on the heavy side, owing to the generous section required.

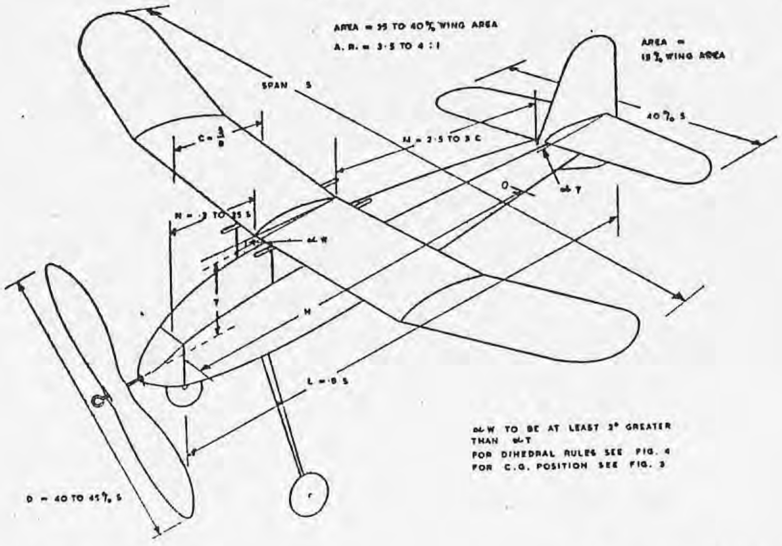
The simple slabsided box construction holds throughout the range. Adequate diagonal bracing and/or sheet covering must be used in the larger sizes, but fuselages of six feet length or more have still proved satisfactory with only ¼ sq. balsa longerons. The pod and boom and hatchet types need careful boom construction, and preferably, these components should be true monocoque, rolled from balsa sheet or even thin ply. Metal booms, incidentally, have seldom proved satisfactory; when small enough to be of economic weight they have a tendency to whip or twist, and fail by buckling or bending in a hard landing. Once bent they are difficult to straighten successfully.

Many successful streamlined fuselages have been built by the half-shell method, using a vertical keel of sheet balsa on which the side elevation of the fuselage is traced and cut out.

Formers and stringers are added to each side of this keel to complete the structure. The best guide in attempting unorthodox construction is to study the plans of a previous successful model of similar size and type and use similar wood proportions.

TABLE II.

TYPE	WINGS					FUSELAGE				TAILPLANE		TOW HOOKS
	TYPE	L.E.	SPAR(S)	T.E.	COVERING	TYPE	MEMBERS (MAIN)	STRINGERS	COVERING	TYPE	SPAR(S)	
NON-CONTEST	SPARLESS	3/8" SQ.	—	3/4" X 3/16"	TISSUE	BOX	1/8" SQ.	1/8" X 1/16" OR 3/32" SQ.	TISSUE	SPARLESS	—	18 S.W.G.
	MONOSPAR	3/16" SQ.	1/4" X 1/8"	1/2" X 1/8"	TISSUE	BOX	1/8" SQ.	—	TISSUE	MONOSPAR	1/4" X 1/16"	18 S.W.G.
SMALL	MONOSPAR	1/4" SQ.	3/8" X 3/16"	3/4" X 1/8"	TISSUE OR	BOX	3/32" SQ.	—	TISSUE	SPARLESS	—	16 S.W.G.
			OR 2 1/8" SQ.	OR 3/4" X 3/16"	SHEET L.E.	STREAM-LINED	1/8" X 1/2" CRUTCH	3/32" SQ.	TISSUE	MONOSPAR	[illegible] X 3/32"	16 S.W.G.
	TWO-SPAR	1/4" SQ.	1/4" X 1/8" & 3/32"	1/2" X 1/8"	"	POD & BOOM	HOLLOW LOG	1 MM PLY OR 1/16" BALSA	BALSA	MULTISPAR	3/32" SQ.	16 S.W.G.
NORDIC	MONOSPAR	3/16" SQ.	1/2" X 1/8"	3/4" X 3/16"	TISSUE OR	BOX	3/16" SQ.	—	SHT. NOSE	MONOSPAR	3/8" X 1/8"	16 S.W.G.
	TWO-SPAR	3/16" OR 1/4" SQ.	1/4" & 1/4" X 1/8"	5/8" X 5/32"	SHEET L.E.	STREAM-LINED	1/8" X 1/2" CRUTCH	3/32" OR 1/8" SQ.	TISSUE	TWO-SPAR	1/4" X 3/32"	16 S.W.G.
MEDIUM	MONOSPAR	3/8" SQ.	2 X 3/16" SQ.	1 X 1/4"	SHEET L.E.	BOX	1/4" SQ.	—	SHT NOSE	MONOSPAR	1/2" X 1/8"	14 S.W.G.
	TWO-SPAR	3/8" SQ.	1/2" X 1/4" & 3/8" X 3/16"	3/4" X 3/16"	"	STREAM-LINED	KEEL	3/16" X 1/8"	RAG TISSUE	TWO-SPAR OR MULTI	1/4" X 1/8"	14 S.W.G.
LARGE	TWO-SPAR	3/8" OR 1/2" SQ.	1 X 1/4"	1 X 1/4"	"	BOX	3/8" X 1/4"	—	SHEET	"	1/2" X 1/4"	14 S.W.G.



CHAPTER TWO . . . . RUBBER MODELS

RUBBER models are, in the long run, the cheapest form of "power" flying. Many modellers, in fact, openly state that they get far more enjoyment out of a two to three minute flight with a rubber model than a comparable duration with any other type, so that it is a pity, indeed, that the rubber model has become relatively neglected with the rise in popularity of the free flight power machines.

However, let us get right down to the problems associated with rubber model design for optimum performance.

Stability is probably the greatest single factor affecting design, for it is better to have a stable, but relatively inefficient model to work on than a very efficient model from the aerodynamic (performance) standpoint which is *unstable*. You just cannot obtain consistent results with an unstable model.

Complete automatic stability must be achieved in three directions, *longitudinally* (or "up and down"); *laterally* and *directionally* (i.e., so that the model flies on a true course, whether straight or circular,

TABLE II AERODYNAMIC DATA

(Basic design figures selected to convenient simple dimensions)

Approx. wing area sq. in.	Span S in.	Chord in.	Section	Tailplane		Section	L in.	N in.	M in.	Fin area sq. in.	Prop dia. D in.
				Span in.	Chord in.						
100	28	3½	Clark Y	11	3	Flat Plate	22½	7	9	15	12
150	34	4½	Marquardt Thin Davis etc.	13½	4	Flat Plate	28	8	11½	23	14
200	40	5	Joukowski R.A.F. 32 etc.	15½	4½	60% Clark Y	33	9	14½	30	17
300	48	6	Joukowski NACA 6912 etc.	20	5	60% Clark Y	38½	11	16½	43	20

without sideslipping or yawing); and *spirally* (where the model flies in circles without spinning or stalling, or otherwise becoming unstable). It is not enough to ensure that the model trims out and flies smoothly under ideal conditions, i.e., still air, for there must be sufficient reserve of stability to ensure that if it is displaced, by a gust of wind for example, it will return to its true flight path. It is possible to have a model which will be quite stable until it is upset by some outside force, when it becomes unstable. This means that it has not sufficient reserve of stability or, in technical language, whilst it is *statically* stable, it is *dynamically* unstable.

Longitudinal stability is largely taken care of by a tailplane of adequate area. A wing in itself is unstable (unless specially designed as in the case of tailless models) and so needs coupling up to another aerofoil surface—the tailplane—to give a stable combination. American terminology for tailplane is, in fact, *stabiliser.*

Tailplane size

A tailplane area of about one-quarter of the wing area is really the smallest satisfactory size, and it is generally better to make it considerably larger than this. Much will depend upon the dimension "T"—the height of the wing above the thrust line, and the moment arm, "M." In practice there is less variation in the latter.

As a general rule the distance between the trailing edge of the wing and the leading edge of the tailplane ("M") should never be less than twice the chord, and preferably greater. There is a logical limit to the greater value, for as "M" is increased, so the weight of the rear fuselage is increased and the tailplane weight moved farther back. This means either a longer nose to balance (resulting in an over-long fuselage), or moving the rear rubber anchorage forward to get the motor weight forward. This latter practice is adopted on most models of the parasol-lightweight layout, but should not be overdone. Overall fuselage length is the final deciding factor, as this should normally not be greater than the span. A long fuselage means more weight, greater area and consequently more drag.

An average figure for "M" is, therefore, 2.5 to 3.0 C (where C is the wing chord). In the case of tapered wings, "C" may be taken as the root chord, when the corresponding value for "M" can be reduced to $2 \times C$ as a *minimum* figure (never less).

The greater the value of "T," the greater the tailplane area required for an adequate margin of stability. Thus for shoulder wing models a tailplane area of one-third of the wing area is quite adequate. For high wing models the same figure will apply, although an increase to 35 per cent. will be beneficial. For parasol models (i.e., greater "T"), 35 per cent. is about the minimum figure for best results and it is not uncommon to boost this area to 40 or 45 per cent. of the wing area.

That is not to say that models outside these rules will not perform satisfactorily with smaller tailplanes; they will. In the Wakefield class, for example, very long fuselage models have given exceptionally good results. They are not, however, the sort of design to adopt for "general-purpose" flying.

Now the final *balance* for longitudinal trim is obtained by adjusting the wing and tailplane incidences, together with the centre of gravity position. It is possible to trim a model to fly with the centre of gravity at almost any position from the leading edge of the wing to the trailing edge, or even farther aft. If the C.G. comes in front of the centre of pressure (or point of application of the lift) of the wings (Fig. 1) then obviously the tailplane will have to be rigged so as to have a download applied during flight. That is, it will be set at some considerable *negative* incidence. Similarly (Fig. 2), if the C.G. comes aft of the centre of pressure of the wing, the tailplane will have to carry an upload to balance, which means that it will be rigged at some *positive* angle of incidence. The farther aft the C.G., the more lift the tailplane must supply to balance.

Of course, the centre of pressure of the wing itself is not a fixed point, it varies with the attitude of the wing (*i.e.*, the actual flight attitude or angle of attack, which must not be confused with rigging incidence. *Rigging incidence* is the angle at which the wing or tailplane is rigged relative to some datum line, usually the centre line of the fuselage). There is no

need, however, to complicate the issue for, when a rubber model is flying at its best trim, the corresponding angle of attack of the wings is around 5 to 6 degrees and the centre of pressure of most conventional aerofoils under these conditions is about 30 per cent. of the chord back from the leading edge.

Arriving at the best solution for longitudinal stability and *longitudinal trim* for a rubber model is far more complex than with any other type, for we have to contend with a varying thrust output. It is comparatively easy to work out a solution for *stability alone*, such as generous use of downthrust, but to use the power *efficiently* often requires a considerable degree of skill in trimming.

Thus, whilst theoretically it is possible to rig a model to fly with almost any C.G. position within the wing chord, there are many other factors to consider as well. C.G. *forward* gives the greatest margin of stability, but is inefficient from the point of view that, whilst the wings are lifting upwards, the tailplane is actually "lifting" downwards and counteracting part of the wing lift, virtually equivalent to a reduction in wing area.

Also, the fact that the tailplane has to be rigged at some appreciable *negative* angle makes thrust adjustment awkward. With the tail at a negative angle to the thrust line, a marked stalling tendency will be present under power, calling for considerable downthrust to counteract. In fact, it is a characteristic of rubber models with a forward C.G. position that a large amount of downthrust is usually necessary.

This, in itself, is not wasteful of power, contrary to popular belief, but does not make for easy rise-off-ground flights.

When the model is released, there is a tendency for the downward inclined thrust to tip the model right forward, before it has picked up sufficient airspeed for the tailplane to become effective and correct the nosing-over tendency. In actual practice, the tailplane comes right up, forcing the wings into a very small or even negative angle of attack, whence they have low drag, but very little lift, so that the model gathers speed quickly, but takes off flat, rather than leaps off the ground into its normal climbing attitude.

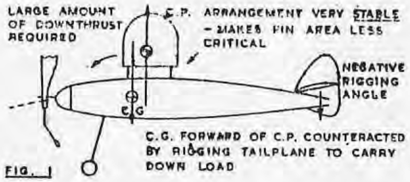


FIG. 1

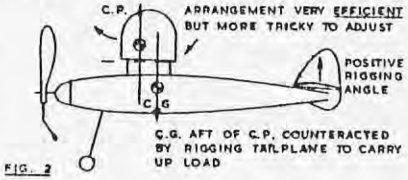


FIG. 2

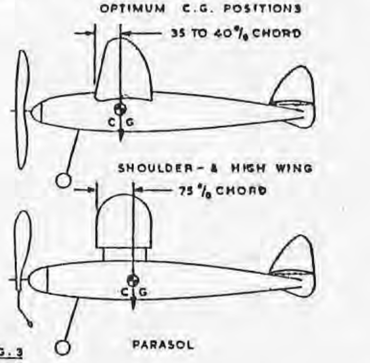


FIG. 3

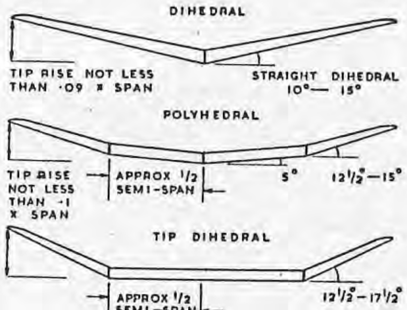


FIG. 4

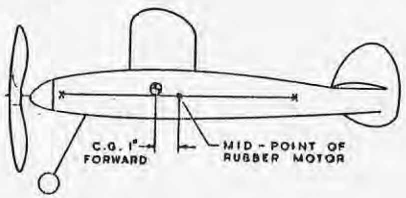


FIG. 5

On the other hand, the danger of a rearward C.G. position is this: to achieve balance the tailplane must contribute a good proportion of lift, which means that it must be at a positive angle. In extreme cases, this positive angle may be as much as the angle of incidence of the wings themselves. This may give satisfactory *static* balance, but is liable to be *dynamically unstable*, for both wing and tailplane stall at the same attitude. In other words, the correcting or stabilising feature of the tailplane has been destroyed and there may be no recovery from a stall, should this occur, or the tailplane may take charge and override the wing lift, forcing the nose of the model down and holding it down in an ever-steepening dive.

To guard against just this, there must be a certain angular difference between the wing and tailplane rigging incidences. Strictly speaking, it is only necessary to have an angular difference between the operating angles of attack. This can be achieved with identical rigging incidences, since the airflow over the wings is deflected downwards and artificially introduces a different angle of attack. The danger here is, however, that under certain conditions, downwash over the wings may disappear so that the combination (wing and tailplane) is left with no angular difference and hence no stability to recover.

Three degrees is the accepted figure for angular difference between wings and tailplane incidence, which only corresponds to a C.G. position of about 35 to 40 per cent. of the wing chord. This combination is the best for all shoulder- and high-wing designs. For parasol models, however, a C.G. position farther aft is desirable—75 per cent of the chord from the leading edge being an average figure. To still retain some angular difference in wing and tailplane setting, we can see, at once, how a larger tailplane area is beneficial.

TABLE II PROP. BLOCK DIMENSIONS

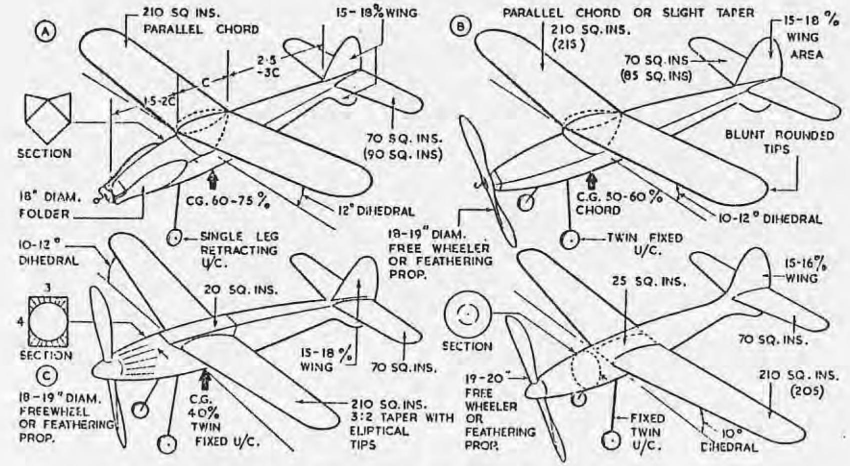
		Dia.	Width	Depth
(1)	Lightw't	12	1⅜	1¼
	Heavyw't	12	1⅝	1⅜
(2)	Lightw't	14	2	1½
	Heavyw't	14	1¾	1⅝
(3)	Lightw't	17	2¼	1⅝
	Heavyw't	17	2	1¾
(4)	Lightw't	20	2½	1⅝
	Heavyw't	20	2¼	1¾

The propeller will have a very considerable effect on the efficiency of the power flight, and, here again, we have many problems to face. Obviously, from any given amount of rubber we can only get so much energy. That is to say, if we have a motor weighing 3 ounces we shall, broadly speaking, get the same amount of energy out of that motor if we use a large number of strands of a short, powerful thrust, as with a smaller number of strands and a longer, moderate thrust.

Actually, of course, this is not quite true, otherwise the obvious solution would be to use any given motor *weight* in the minimum number of strands so as to get increased overall flight duration by increasing the power-on duration. The danger in working at the lower end of the power output range (i.e., minimum number of strands), is that the power available is marginal. The slightest difference (tiring rubber, or poor weather conditions) may kill the climb completely. And there is also the fact that the fast revving propeller is working at a different figure of efficiency to its slow revving counterpart.

Broadly speaking, the more rubber we can use, the better the performance, although there are practical limits again. Adding more rubber means adding more weight, so the result may be better climb but faster glide and possible *decreased* overall performance. A figure of about 60 per cent. of the total weight for (rubber) motor weight is about the maximum possible and it is usual to work to a lower figure.

Now, with this proportion of rubber, experience has shown us that the propeller diameter should be roughly 40 to 45 per cent. of the wing span, and nothing much less will give *consistent* "duration" results up to modern contest standard. The greater the proportion of rubber, the greater the required propeller diameter; so that a 50 per cent. motor weight could well handle a 50 per cent. span propeller, this, surprisingly enough, holds true.



Suggested Design Layouts for Wakefield Type Models.
N.B.—Total area must be adjusted to 294.5 sq. ins. maximum

The remaining leading propeller factor, the pitch, is closely allied to the rest of the design. Large diameter propellers are a source of considerable drag, once the power has run out, even when made to freewheel, and so it is common practice on duration rubber models to use a folding prop. This, properly done, must benefit the glide and so there is a natural tendency to emphasise this point. To take advantage of good glide characteristics, maximum altitude is aimed at by using a powerful motor and relatively fine propeller pitch.

Selection of pitch for this type of flying generally lies between 1.2 and 1.5 times the diameter. Also most successful models of this type utilise parasol wing mounting. This layout seems better suited to handling the C.G. shift when the propeller does fold, so that the model can be trimmed initially for a very good glide and still retain an efficient trim under power. If trimmed first with the prop. unfolded (i.e., on the power run) the C.G. will have moved forward, slightly making the model nose heavy, and it is a noticeable characteristic of some models of this type that they tend to nose down slightly towards the end of the power run until the prop. does fold and restore proper glide trim.

Those modellers who still prefer the free-wheeling type of propeller can claim advantages for this system in that it is less critical and does give greater efficiency on the climb. But it is most necessary to start with a relatively high pitch, for anything less than 1.3 times the diameter will have a very considerable braking effect when freewheeling and ruin the glide. Average pitch figures run from 1.5 × diameter, up to 2.0 × diameter, with 1.75 × diameter as a good design average.

This modifies the type of climb and gives most efficient results with moderate power extended over a much longer time than the other system. Properly adjusted, although the initial rate of climb may be lower, it should be possible to reach a greater height, eventually, under power, with the advantage of added power duration.

Aspect ratio is not a critical factor on rubber models. What may be gained by higher aspect ratios is more than lost through the reduced aerodynamic efficiency of smaller chords, and the reduced strength weight factor. A high aspect ratio wing is either weaker for the same weight, or heavier for the same strength, as a lower aspect ratio wing of the same area. A figure of 8 : 1 is a very satisfactory choice, although some of the smaller lightweight models go down to 6 : 1. A higher figure of 10 : 1 is generally associated with shoulder wing models where the fuselage "artificially" increases the span. Tailplane aspect ratio is lower again, mainly for reasons of structural economy, with 3.5 to 4 a very good compromise.

As regards plan form, there is virtually no need to depart from a rectangular wing, except on shoulder wing models. In the latter case, quite apart from appearance, a moderately tapered wing can give the benefits of increased aspect ratio without the drawbacks noted above.

Dihedral is another factor which is not too critical. In fact, the general rule here is, *use whatever form of dihedral you prefer as long as you have enough of it.* It is far better to have too much rather than too little.

For straight dihedralled wings, the minimum figure for adequate stability is 10 degrees, and you can increase this to 15 degrees with no appreciable effect on the efficiency of the wings again, contrary to popular belief.

When handling designs intended for more powerful motors, i.e., fast climbing types, polyhedral is preferable—this in two breaks in each wing half rather than a straight centre section with tip dihedral, Fig. 4. These breaks should occur, roughly, half way along the semi-span.

The fin is still, unfortunately, a subject which is indeterminate, yet the whole spiral characteristics of the model hinge on its area and location. Unlike power duration models, it is better to have too big a fin than too small a fin and a minimum figure of 15 per cent. of the wing area is suggested. It should be disposed about the fuselage centre line with, at least, one-third of its area below and its uppermost point should not come above the tip of the wings.

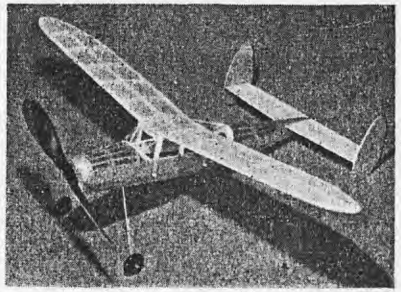
Centre of gravity position, the other major factor not covered in the specification and analysis, is shown in the form of a simple solution in Fig. 5. Whilst most models are designed to have a certain amount of fore-and-aft movement of the wings, for final adjustment, it is always necessary to estimate the final C.G. position, if only to determine the wing mount position. In the case of a fixed shoulder-wing design, of course, it is necessary to be reasonably sure of the wing position, otherwise one may have to add unwanted weight, in the form of ballast, to trim the model.

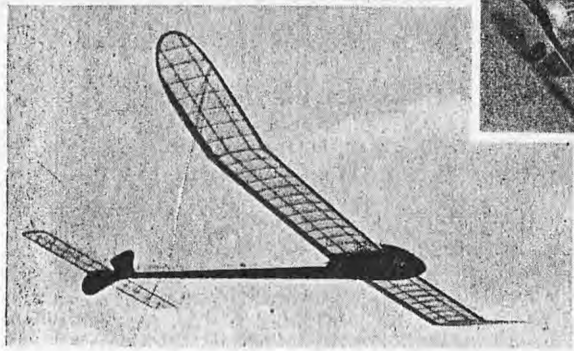
The rubber motor is the greatest single factor affecting the final C.G. position. This accounts for up to 50 per cent. of the total weight and is strung throughout the length of the fuselage and it is found, as a general rule, that on models of Wakefield proportions the final C.G. comes out about one inch in front of the *centre of the rubber motor*. This means that you can adjust "N" and "H" as necessary to get the wings in the right place, once having settled on the C.G. position required. Other models of different specifications to the Wakefield can be adjusted proportionally, according to size, although the proportions given in the general specification and tables will be found to hold true in the majority of cases. This C.G. check is a final step which can be applied after the design has been laid out and before building it.

TABLE III. CONSTRUCTIONAL DATA

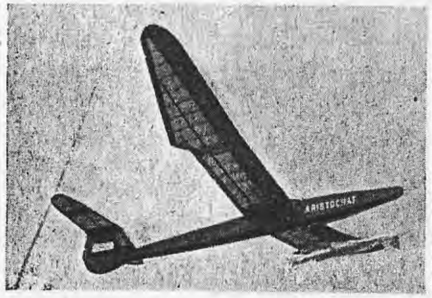
Model	WINGS					FUSELAGE		TAILPLANE	
	Type	L.E.	Spars	T.E.	Ribs	Longerons	Spacers	Type	Spar(s)
100 sq. in.	Sparless	1/8 × 1/4	—	3/8 × 3/32	1/32	1/16 sq.	1/16 sq.	Sparless	—
	Monospar	3/32 sq.	1/4 × 1/16	1/4 × 1/16					
150 sq. in.	Sparless	1/8 × 3/8	—	3/8 × 3/16	1/32	3/32 sq.	3/32 sq. or 3/32 × 1/16	Spar-less	—
	Monospar	3/16 sq.	3/8 × 3/32	1/2 × 1/8				Monospar	1/4 × 1/16
	Multi-spar	1/8 sq.	1/16 sq.	1/4 × 3/32					
200 sq. in.	Monospar	3/16 sq.	1/2 × 3/32	1/2 × 1/8	1/32 or 1/24	1/8 sq.	1/8 sq. or 1/8 × 3/32	Monospar	3/8 × 1/16
	Two-spar	1/8 sq.	1/2 × 1/16	1/2 × 1/8				Multi-spar	1/16 sq.
	Multi-spar	1/8 sq.	1/16 sq.	3/8 × 1/8					
300 sq. in.	Monospar	3/16 sq.	1/2 × 1/8	3/4 × 3/16	1/24	3/32 sq. or 3/16 sq.	3/32 sq. or 3/16 × 1/8	Monospar	1/2 × 3/32
	Two-spar	3/16 sq.	1/2 × 1/8, 3/8 × 3/32	3/8 × 3/16				Multi-spar	1/16 sq.

Ultimate development of the pre-1954 Wakefield was the extra long fuselage version, here exemplified by P. H. Gilder from Luton. (Ed. Stoffel photo). Below, is the pert little Aeromodeller Cabin Duration,—specially designed by Bill Dean for A.P.S.

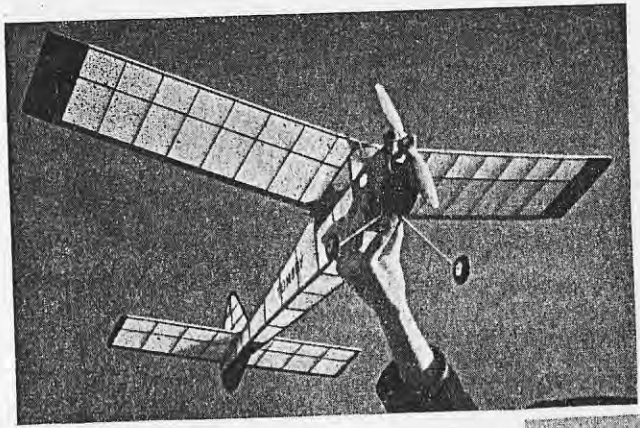




Successful in '53, and promising leadership in the future, is the long tail, short nose type of A/2 glider, shown in comparison with the older design form, below. Upper model is Don Butler's Seraph, an A.P.S. plan.

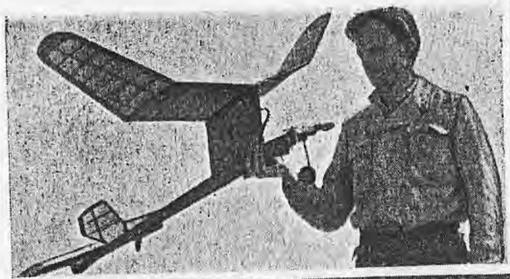


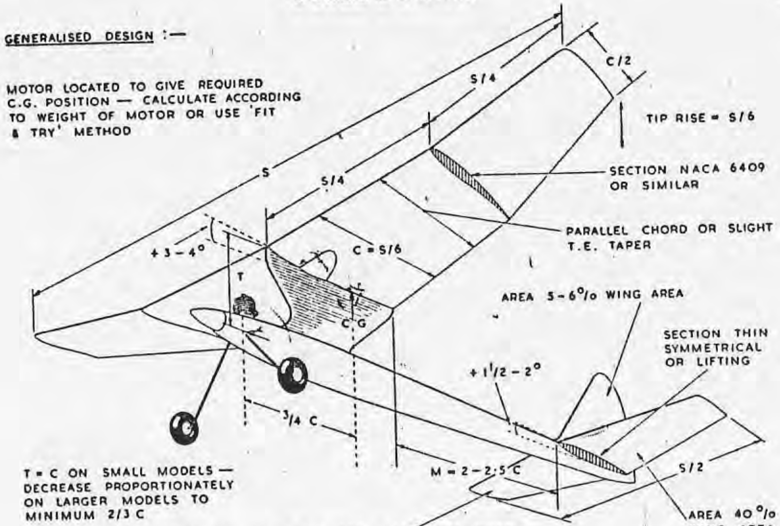
Medium length fuselage with shallow pylon wing mount and rocket climb, was Norman Marcus's approach to the Wakefield class. (Upper right). Note that the undercarriage has already retracted in this take-off shot by Ed. Stoffel. Bottom, an older design by Bernard of France, showing high wing mounting and folding single bladed prop.



Most popular of all sport designs for 1 c.c. diesels is the A.P.S. Tomboy, a Vic Smeed design. Simple lines make it the ideal beginners subject, whilst the aerodynamic layout assures every constructor of pleasing performance. Below, in contrast, Jim Lewis's super streamlined entry in the Queen's Cup contest. A high powered pylon model with elliptical surfaces.

Below: From Yugoslavia, Joze Prhavc displays an extra high pylon on his relatively simple power contest model. Twin skids under the tailplane provide three-point take-off contact in conjunction with the single forward wheel. Bottom, Mercury IV, an elegant beauty for large engines, and very suitable for radio control. Span is 96 in., and full size plans are available through A.P.S. Designed by Mick Smith, now resident in Rhodesia, Mercury represents the elite of sport power models.





CHAPTER THREE . . . . POWER DURATION

POWER Duration models undoubtedly have the highest mortality rate of any type of free flight model aircraft. On the face of it they should be simpler to make stable and trim than a rubber powered model: for in the first case we have a constant thrust, and the second a varying thrust, so that power-on conditions are constant with a power model, but continually changing with a rubber job.

The main reason why so many power models exhibit instability and often come to a sticky, and abrupt, end is simply a matter of the *degree* of power applied. Whereas in a rubber driven model even a really fast climb to, say, two or three hundred feet, is seldom accomplished in anything under thirty or forty seconds, a good power duration model, properly trimmed, can reach a similar altitude in ten seconds or less.

As soon as you speed up a model, stability problems become magnified and what might be a perfectly stable layout at lower speeds can become hopelessly unstable. Even with the best of designs, the margin of stability is reduced, so even the slightest error in trimming may lead to instability in an otherwise stable machine.

Bearing in mind, then, that most power duration models are *overpowered*, and therefore require an extreme reserve of stability, we can appreciate the popularity of the pylon design, for this does definitely give the most stable layout under such conditions.

TABLE I. AERODYNAMIC DATA

Model Size	Motors	Span	Root Chord	Dihedral Tip Rise	C.G. from L.E.	T	M	Tailplane Area	Tailplane Span	Fin area
250	1 c.c.	42	7	6	5	5	16	100	20	12.5
350	2 c.c.	50	8	7	6	6½	18	140	24	17.5
500	3.5 c.c.	60	10	9	7½	7	22	200	30	25
800	5–7.5 c.c.	75	12	10	9	8	28	300	36	40
1200	10 c.c.	92	15	12	12	9	30	400	44	70

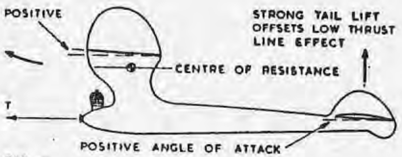


FIG. 1

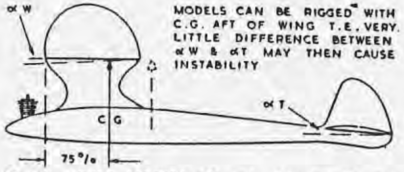


FIG. 2

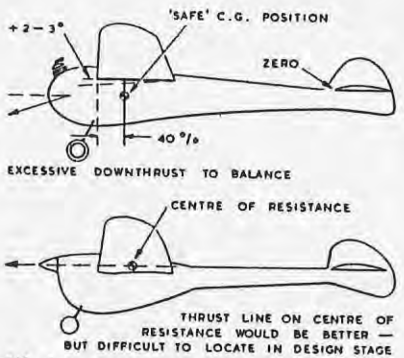


FIG. 3

Glide stability is relatively unimportant; any model layout with conventional proportions can be trimmed for a stable glide, and the pylon type is certainly no exception here.

With power on, however, the pylon set-up would not appear particularly good at first sight—Fig. 1. The high mounted wing positioned well above the line of thrust, gives a strong looping tendency. But this is readily combated by tail lift, rigging the tailplane at some positive incidence (and also ensuring a positive angle of attack during flight), so that this cancels out the nose-up moment of the thrust—and the faster the model flies the more pronounced is this effect.

With positive tailplane incidence, an aft C.G. position is also necessary for balance, which turns the design into a tandem wing machine with both wings and tailplane contributing lift. Generally the tailplane is lifting strongly, which means that there is very little difference between wing incidence and tailplane incidence when properly trimmed. The danger is in getting this difference too small, when the tailplane may take over completely and force the model down into an ever-steepening dive. The farther aft the C.G. (which virtually means the less the difference in incidence between wings and tailplane) the more critical the layout becomes to adjust, although flying with the C.G. on the trailing edge of the wing, or even behind it is still quite practicable, with careful trimming—Fig. 2.

The tailplane, then, is one of the major stabilising factors in the pylon layout and, provided it is not misused, is extremely efficient as such. Hence, it is not difficult to appreciate the modern tendency to use larger and larger tailplane areas on power duration designs; 40%, 45%, and even 50% of the wing area being used more and more.

Lowering the centre of resistance with a shoulder wing design, or raising the thrust line to near the wing position does not necessarily provide a better answer. In fact, practice has shown to date that such models are even more tricky to adjust as they must still balance with the C.G. well aft for adequate longitudinal stability, and the whole layout is then more critical than the comparable pylon design. A shoulder wing design, for example, is very difficult to trim for climb without looping, or spiralling in if made to turn. Adjustment can be made a little less critical by moving the C.G. forward and re-adjusting the tailplane incidence, but then an excessive downthrust angle is generally necessary—Fig. 3.

Without going into any more detail, we would state simply that at the present state of knowledge and development the pylon layout is undoubtedly the most satisfactory where sheer duration is the aim.

Before this, however, let us first consider the model's size. American influence has given British designers a rather unfortunate lead in that the first British power duration models were almost all based on

current American trends. These, at the time, were all built down to specific wing and power loadings, so that in the British field the relatively heavily loaded power duration model became the "standard" when the rules called only for F.A.I. loading, which is very light indeed. These first designs, with their subsequent influence on later British competition models, have rather tended to produce the over-powered model—or rather the *under-sized* model for the capacity of motor used—with all its exaggerated stability problems. The trend now is towards larger models for the same size of motor which, while possibly losing out as regards rate of climb, should be far less critical (and therefore more consistent), and definitely score on the glide. There is no doubt that the larger the model the better its aerodynamic efficiency as reflected in glide performance.

Current contest specifications are based on F.A.I. wing and power loading rules (7.06 oz. per c.c. and 2.73 oz. per 100 sq. in total area). F.A.I. rules also permit a maximum of 30 seconds for the power run, whilst most British contests are run with a limit of twenty seconds, fifteen seconds, or even ten seconds. Obviously the length of power run permitted for contest work affects the design of the model, and should therefore be standardised for all contests. A model designed for duration from a ten second power run, for example, would have a very rapid climb (calling for a smaller *size* of model). If flown in a contest where a 30 second power run was permitted its rate of climb would be unnecessarily high. For the thirty seconds power run a larger model with a more moderate climb would be better, with its greater consistency, and still be capable of putting up limit flights on account of its better glide.

However, for the moment at least, this question must remain unanswered and we must compromise by assuming that 20 seconds is about the maximum power run likely to be permitted in most contests, with 15 seconds as a likely minimum, both of which still justify a relatively large model.

The smaller the model the more noticeable the effect of a higher wing loading, due to the decreasing aerodynamic efficiency. Thus, for models of around 200 sq. in. and less, maximum wing loading should be around 3 ounces per 100 sq. in. and certainly never more than 4 ounces per 100 sq. in. But, before we go any further let us reduce F.A.I. loading rules to more convenient figures and see how our limits fit in.

Converting the F.A.I. loading figures of 2.73 oz. per 100 sq. in. *total* area into wing loading for different tailplane proportions, we have:

Tailplane % wing	35%	40%	45%	50%
Ozs./100 sq. in. wing	3.69	3.82	3.96	4.1

It will be seen, then, that with a tailplane of 45% area the 4 oz. per 100 sq. in. maximum figure suggested for the smallest class of model still conforms. In fact, small models of this type are capable of really excellent durations and can be as useful for contest work as the largest size.

As the size of the model goes up, the possible wing loading can increase, with no apparent ill effect. In fact, it is *desirable* to increase the structure weight to get a more robust aeroplane and one less "lively" to trim. There is no particular rule as to how maximum loading varies with area, but higher loadings tend to produce a model which has a sinking speed too high to take full advantage of thermal lift on every possible occasion, and is, therefore, not really suitable for consistent contest work. Models with quite high wing loading *will* still soar in strong thermals, but it is the ability to prolong the glide in weak thermals which counts where consistent top performance is the aim.

The next thing we have to decide is the total wing area, which is not quite so easy as might first appear. Logically, wing area should be related to motor capacity—so many sq. in. per c.c.—but motors of near or identical capacity frequently have

TABLE II. COMPONENT WEIGHTS

Component	Wings	Fuselage	Tail	U/C	Motor
% Total	27.5	32.5	10	12.5	17.5

different power outputs. What might be right for one motor may be far too much area for another in the same class. However, short of listing every available motor and calculating at length the best probable wing area, after finding the power output of that motor, relating wing area to motor capacity in a general manner is probably the only solution. Further practical experience with any particular motor may indicate that its power output is really equivalent to that of an average motor of larger capacity, and choice can be adjusted accordingly, initial selection being based on the design sizes specified in Table I.

All the major design layout factors are summarised in the heading drawing, so there should be no need to elaborate on the various points. As regards the shape of the individual components, this is largely non-critical. Straight-tapered wings with raked or rounded tips appear equally as efficient as elliptic wings. As a general rule we would say that the centre portion should be of parallel chord, or with slight taper, and tip panels tapered down to roughly one-half of the root chord, or made of blunt elliptic plan form.

Tailplane planform should preferably be tapered, if only to reduce the possibility of warping. A properly designed (structurally) elliptic planform is nice, but straight taper on both leading and trailing edges with squared tips is equally effective. Section can then either be thin "lifting" (i.e., flat undersurface), or symmetrical. Either are equally effective as regards lift and drag developed at small angles of attack. The main thing is to keep the tailplane section reasonably thin—certainly never as thick as the section of the wing.

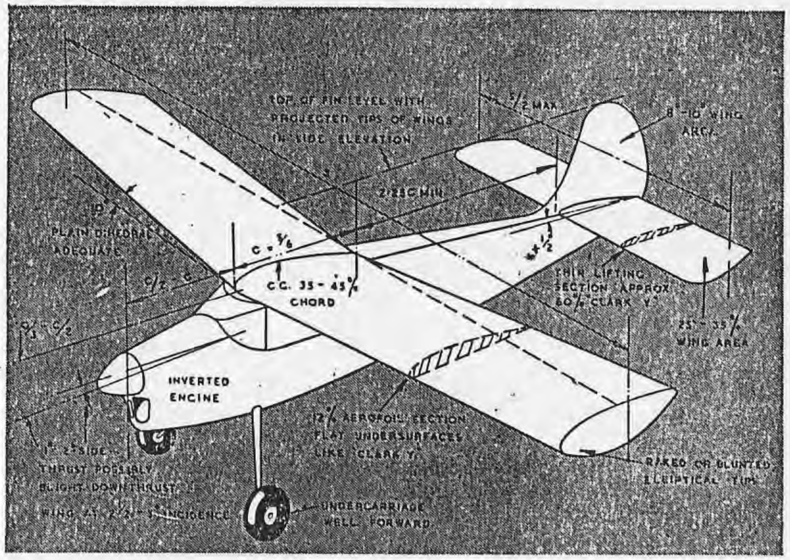
For the wing, generously cambered sections of the NACA 6409 type have proved about the best for medium and light loadings, possibly using a slightly thicker section with similar camber characteristics, such as NACA 6412, on heavier loadings. The section does not need to be thicker than this (12 per cent.) in any case, nor should it ever be much thinner than 9 per cent. Where a good glide is required, avoid, too, thin sections with a flat undersurface. Sections of this type can give an extremely rapid climb, but gliding speed is generally high, and consequently the sinking speed suffers.

Some experts do, however, favour aerofoil sections with a flat undersurface as giving better control, or stability, on the climb. Experience has shown that it is easier to trim out a fast-climbing model with a flat undersurface aerofoil than an undercambered aerofoil. The danger lies in using too thin a "flat" section which can result in too fast a glide.

Probably a better way to approach the problem of controlling the power run, when using an exceptionally powerful engine, is by increasing the wing *area*. It is, in fact, possible to find a "best" or "optimum" wing area for any particular engine-propeller combination, although this can only be done on the basis of considerable test flying. Here, too, the individual's style of flying will also affect the issue, reflected in his skill at fine trimming.

TABLE III. STRUCTURAL DATA

	WINGS					FUSELAGE			TAIL	UNDERCART	
Model Size	Type	L.E.	Spar(s)	T.E.	Ribs	Type	Basic	Stringers	Type	Wire	Wheel dia.
250	Mono-spar	1/4 sq.	1/2×1/8	5/8×3/32	1/16	Box	3/16 sq.	—	Mono-spar	14 swg.	2
350	,,	1/2×3/8	3/4×3/16	3/4×3/16	3/32	Box	1/4 sq.	—	,,	3/32	2 1/4
500	two-spar	3/8 sq.	3/4×3/16	1/2×1/8	3/32	Crutch	1/2×1/4	—	two-spar	3/32	2 1/2
800	,,	3/8 sq.	1×1/4	1/2×1/8	1/8	Crutch	1/2×1/4	1/4×1/8	,,	3/32	2 1/2
1200	,,	1/2 sq.	1 to 3/4×1/4	1 1/4×1/4	1/8	Crutch	3/4×3/8	3/8×1/8	,,	1/8	3 1/2



CHAPTER FOUR . . . . CABIN POWER

ON the face of it there may not appear to be a very great deal of difference between the design of a power duration model of the pylon layout and one with a cabin. Some cabin models, in fact, maintain the same high wing position, only instead of a pylon pure and simple the forebody of the fuselage is so shaped as to incorporate a cabin front and a certain semi-scale appearance. These, however, are not true cabin models. They are still pylon models on account of their wing positioning and are designed and laid out on similar lines.

The true cabin model is not a duration type as such, although some may have a comparable performance. As a general rule, however, they use less powerful motors for the same size of model and wing loading may also be greater.

The type of cabin model chosen is intended for sport flying rather than contest work. Stability remains the first and most important feature, but appearance can be considered on an equal basis with performance. In duration design, appearance is generally a secondary consideration.

Power loading

Now in the design article covering power duration we emphasised the fact that such models are generally overpowered and it was this excessive power which led to so much difficulty in trimming. Some people will, quite justly, claim that power duration models are the most difficult type to trim on this score, although that is not the true state of affairs. It is not trimming that is so difficult as much as the original *design* being at fault.

We should be able to avoid many of these difficulties with the sports type of cabin model, for there is not the call for an extremely rapid rate of climb and the excessively powerful motor. As an example —a 1 c.c. motor will fly a 4 ft. span, 350 to 400 sq. in., cabin model quite well, if only a moderate climb is required, whereas motors of 5 c.c. or more have been used in the same size of model for duration work. The **Zipper**, pioneer model of the pylon type with 488 sq. in wing area, used a motor of anything between 5 and 10 c.c.

There is, of course, the danger of going to the other extreme and producing an underpowered model. Under certain conditions underpowering can be as harmful as overpowering. The latter may introduce stability troubles, but the former can be almost as disastrous in being insufficient to keep the model under control in gusts as might be experienced in windy weather. The true sports model must be just as capable of flying in winds when that little extra power is so helpful.

Our choice, then, is for the moderately powered cabin model which will have quite a good climb, but not approaching the usual duration standards. If the design proves stable enough it could, of course, be "hotted up" by using a more powerful motor, but the bulk of evidence is against the true cabin type as a contest model. The cabin contest model is usually the "cabin-pylon."

Wing design

Proportions of the model can be laid out with reference to the selected size (*see table*) as detailed in the heading drawing. Wing span is a good criterion for the proportioning and layout of the rest of the components on almost every type of model and the cabin design is no exception. However, for a given wing area we must decide the aspect ratio before we can arrive at the span, for

$$\text{Aspect ratio} = \frac{\text{span}}{\text{average chord.}}$$

Broadly speaking, increasing the aspect ratio of a wing of given area increases its efficiency, but since the sports model is not basically concerned with efficiency, choice of aspect ratio should be considered on the basis of structural design and appearance. As regards the former, a figure of between six and eight generally gives the most economic structure, i.e., the greatest strength/weight ratio, whilst the latter is largely a matter of taste.

A plain rectangular wing with an aspect ratio of six, therefore, is a very good standard which, with blunt elliptic tips, has quite a good appearance. A more squared tip form with very simple sheet construction is an alternative which is now finding favour, and again is quite satisfactory. If a taper wing is decided on then the aspect ratio can be increased to around eight. The taper ratio should be kept low, to avoid both the undesirable (unstable) effect of a small tip chord and keep the root chord to a reasonable figure. The taper should be proportioned equally on both leading and trailing edge or one-third of the leading edge and two-thirds on the trailing edge. Aerodynamically there is little to choose between the two.

Tail area

Tailplane size can be directly related to wing area. It will not be necessary to use the large tailplane sizes common with the modern power duration model, but the proportion required for adequate stability will vary with the size of the model. Small models will need a proportionately larger tailplane than the larger ones. At the lower end of the scale, for example, it is considered unwise to use a tailplane area of much less than one-third of the wing area. When the wing area approaches 1,000 sq. in. or more a tailplane of only 20 per cent. can be adequate, although few designers work right down to this limit.

There is no point in making the tailplane too small. A smaller tailplane may result in a certain reduction in overall drag, but at the expense of decreasing longitudinal stability. Far better to err on the side of having a tailplane larger than strictly necessary.

Against this, of course, is the fact that a large tailplane detracts from the semi-scale appearance of the model and so figures within the limits suggested represent a satisfactory compromise. Little harm will result from varying these a small amount either way.

The two remaining factors determining longitudinal stability are, then, centre of gravity position and tailplane moment arm. Both are important, but we can fix a minimum for the latter of about 2.25 times the root chord of the wing when, with the tailplane proportion already arrived at, tailplane power will be quite adequate. Too long a tail moment will spoil the appearance of the completed model, and so a maximum of three times the root wing chord is suggested.

C.G. position

Selection of the best centre of gravity position must take into account a number of other factors. The wing is considerably lower, relative to the thrust line, than that of the pylon model and less power is being used. There is little point in using an aft centre of gravity position and possibly reintroducing stability troubles. In other words, the tailplane should be considered as a *stabilising* component whence, by so doing, we make its adjustment less critical.

At the same time, bringing the centre of gravity right forward so that the tailplane is normally operating as a stabiliser pure and simple (i.e., all the lift coming from the wings) does not necessarily produce the best set-up of forces. Generally to control such an arrangement under power a fair downthrust angle is required, since the stalling tendency is aggravated the moment the model noses up, with a straight thrust line. Downthrust may provide a safe way of flying a model so rigged, but the use of an excessive downthrust angle again tends to spoil the appearance.

In practice, best results appear to be obtained when the C.G. is moved back again to somewhere between 35 and 45 per cent. of the chord, when the tailplane is normally called upon to carry a small proportion of the total life. The need for any downthrust is then eliminated, or at least reduced to a degree or so.

The actual balance will, of course, depend also on the height of the wing above the thrust line—chosen as the simplest determining factor. The greater this is, the more desirable it is to use the aft or 45 per cent. C.G. position. Normally, however, this figure should be kept within one third and not more than one half of the root chord.

Motor mounting

One result of this latter recommendation is that the thrust line should preferably be high, even coming above the centre of gravity of the whole model, if possible. It may in many cases be necessary to bring it above the centre of gravity ultimately—with downthrust. To achieve this thrust line position, and still enclose the motor to preserve semi-scale appearance an inverted motor installation is practically essential. If mounted upright the top of the cylinder will almost certainly come somewhere on a level with the top of the cabin and prove impossible to cowl in properly. Here appearance again must be the deciding factor. If the ready accessibility and easy operation of an upright motor is to be retained, appearance is likely to suffer as a consequence. Otherwise with an inverted, cowled-in motor, access to the controls and tank must be provided either by hinging the cowling or providing suitable cut-outs. In any case, with an inverted motor, ready access must be given to the open end of the induction tube for choking—either a hole in the side of the cowling or an extension tube on the induction pipe coming to the outside of the fuselage or cowling Sidewinder mounting is another possibility calling for dummy cowling on one side.

With wing and tailplane proportions decided, together with the tail moment arm, the centre of gravity position and the distance of the wing above the thrust line, other details of the outline design can be sketched around this skeleton. The vertical position of the tailplane does not appear to be critical. The usual place is on, or somewhere near, the thrust line. The length of the nose, which will depend largely on the motor weight, is a variable which can be adjusted to achieve the correct centre of gravity position of the completed model. General figures are given in the heading drawing, these varying with the size of the model. A shorter nose is required to balance on a small model, mainly because the motor weight in such cases is proportionately larger than in the bigger models.

If in doubt, it is best to complete the whole model, less motor assembly, leaving just the motor bearers protruding. These should be longer than necessary. The motor can then be rested on these and the correct mounting position established for the final balance of the whole model.

Structurally, the cabin type sports model offers considerable scope for ingenuity. Extreme light weight is not so necessary and a robust, rigid frame should be the aim. At the same time there is no point in increasing total weight unduly. The more the model weighs the greater the landing shocks and the increased possibility of damage.

The undercarriage

In the smaller models employing motors of up to about 1.5 c.c. a simple tricycle gear is generally excellent and more trouble-free than the conventional gear. The larger (and heavier) the model, the more difficult it becomes to produce a front leg unit which is capable of withstanding the landing loads.

Many people fail to understand why a tricycle undercart model does not tip over immediately the front leg touches the ground. The answer is quite simple. All the time the model is moving forwards, the wings are still generating lift and it is the wing lift which keeps the model level. By the time the wing lift has dropped off, all three wheels are rolling along the ground and the model stops on a level keel. It is surprising just how stable a properly designed tricycle undercarriage can be on sports models.

Structure

For the wing frame design of all sports models we would strongly recommend a modern spar arrangement which gives exceptional rigidity and freedom from warps at a reasonable light weight. This is a two-spar wing, and thus suited to almost every size of sports model, where built-up beam spars are used. The basis of this arrangement is that the two top and bottom spars—virtually strips of sheet—are strongly resistant to bending. The top spar is in compression under bending load and the bottom one in tension. If left unsupported they would buckle, hence the space between them is filled with a spar web. Main job of this web is to stop the upper and lower spar members from bending and buckling and each web itself is not highly stressed.

In the smallest sizes of models ordinary monospar construction may be considered adequate, but when it is remembered that this two-spar system has been adopted for Wakefield tailplanes to give rigidity at no increase in weight over a normal monospar system, the advantage of the built-up spar system is seen.

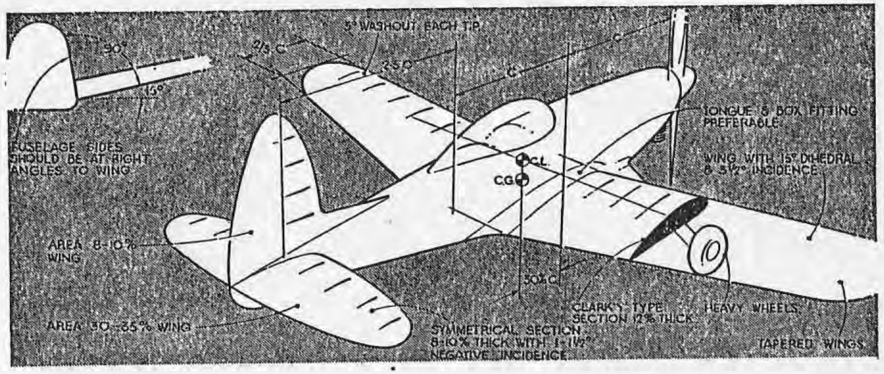
For the fuselage, box-type construction is still the simplest and lightest. It should also be strong enough for any size of sports model if generous longeron sizes are selected. Appearance can, of course, be improved by adding fairings top and/or bottom, if desired. Crutch construction is excellent for rounded fuselages, or a cross between ordinary "box" construction with sheet sides and orthodox crutch construction lends itself to the production of pleasing fuselage lines.

Finally a word about covering. For all but the smallest models we cannot speak too highly of nylon as a covering material for sports models (and other large power models). Nylon is easy to apply if used damp, takes dope well and is extremely tough and durable. Tissue has the one basic defect, that it is readily punctured or torn and, if too many coats of dope are applied, it becomes brittle and splits on impact.

DESIGN DATA

	WING			TAILPLANE			Moment Arm (in.)	L.O.A. (in.)	Motor
	Area (sq. in.)	Span (in.)	Chord (in.)	Area (sq. in.)	Span (in.)	Chord (in.)			
A	260	40	6½	90	20	4½	15	30	.5*–.75 c.c.*
B	340	45	7½	110	22	5	17	34	1*–1.5 c.c.*†
C	442	52	8½	144	24	6	20	40	1.5*–2 c.c.*†
D	600	60	10	180	30	6	24	46	3.5 c.c.†*
E	770	70	11	208	32	6½	26	52	5 c.c. *†‡
F	1040	80	13	245	35	7	30	60	7.5–10 c.c.†‡

* Diesel. † Glowplug. ‡ Spark ignition.



CHAPTER FIVE . . . . LOW WING POWER

AERODYNAMICALLY, the low wing machine may be somewhat inferior to other layouts. This is even more marked in the case of low wing *models*, where stability requirements may emphasise some of the least desirable aerodynamic features of the layout. Structurally the model designer has little to appreciate in the low wing layout, for such a wing position is more difficult to arrange than the simple one-piece tie-on high or parasol wing.

On these grounds, then, there is little justification for building a low wing contest model. To whatever specification a low wing contest model is built it seems fairly certain that a similar high-wing machine should have a superior performance, although this difference may not be so marked as many people may imagine.

However, for "sport" flying there is no reason at all why a low wing project should not give excellent results—no reason, that is, except for the fact that there has been little or no published data on low wing proportions.

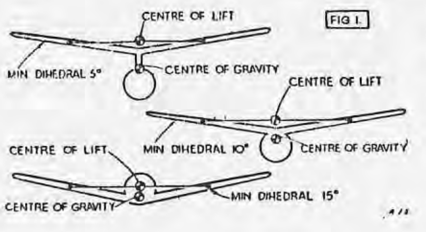
Logically the proportions of wing and tailplane area and tail moment arm suitable for satisfactory longitudinal stability on a high wing model should also apply to the low wing layout. A moderate moment arm, with a tailplane area of between 30 and 35 per cent. of the wing area should be quite satisfactory. A *minimum* moment arm would appear to be 2.5 times the root chord of the wing (or three times the average wing chord, whichever is the smaller).

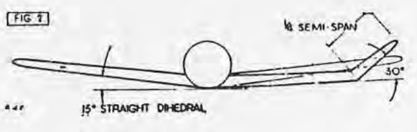
Stability requirements

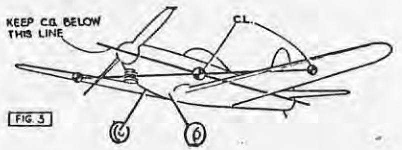
Satisfactory stability about the other two axes is, however, more difficult to achieve. It is a well-established fact, for example, that the greater the height of the wing above the centre of gravity the smaller is the dihedral needed on that wing for the same *degree* of lateral stability (Fig. 1). This height should be measured relative to the mean or average chord of the wing.

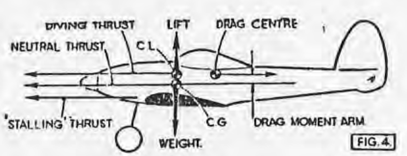
Depending on the type of model, certain figures have been established for satisfactory stability in terms of minimum dihedral angles on high wing layouts. For a conventional high wing this is about 10 degrees, and may be more if high power is being used. For example, a parasol wing, which normally needs a minimum of about 5 degrees dihedral may require twice that figure to handle high power satisfactorily.

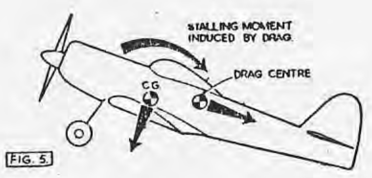
On this basis we are faced with the conclusion that we shall need a *minimum* of about 15 degrees dihedral on a low wing layout in any case. We can partially negotiate this problem of excessive dihedral requirement by using polyhedral with a sharply upswept tip, but since the chief appeal of the low wing layout is for a semi-scale sports design we want, as far as possible, to retain a fair "full size" appearance. Full size aircraft frequently do employ tip dihedral, but often barely

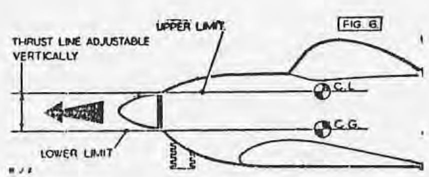












recognisable. The type of tip dihedral required on a model, to be effective, is only too apparent (Fig. 2).

The C. G. effect

If we examine Fig. 1 again we can see that we can improve the arrangement somewhat by lowering the centre of gravity. If the centre of gravity is *above* the mean wing chord, in fact, the model may turn out extremely tricky to handle and so it would seem worth while to plot out a head-on view of the projected design to find the limiting height of the final centre of gravity, as a check (Fig. 3). A fair proportion of the total weight of the model will, in any case, be concentrated in the wings and so there should be no especial difficulty in arranging that the final C.G. does come out low enough. Designers with low wing model experience sometimes advise the use of heavy wheels to lower the final C.G.

We can now consider the flight forces acting in side elevation (Fig. 4). In all other model layouts the thrust line is invariably below the mean chord of the wing, requiring either a small downthrust angle to compensate, or tail "lift," accomplished by locating the C.G. behind the centre of lift of the wings and balancing by lift from the tailplane.

With the low wing layout of Fig. 4 we can see that we can quite easily get the thrust line above both the centre of lift of the wings and the centre of gravity of the whole model. The high thrust line would have a stabilising effect under power.

However, this would depend to a large extent on the fore and aft location of the C.G., relative to the centre of lift of the wings. Broadly speaking, on the low wing layout it would seem best to use the tailplane purely as a stabiliser, and not as a means of lift, so that at normal flight attitudes the tailplane has zero lift and only develops "lift" ("up" or "down") when the model is displaced to correct that displacement.

The thrust line

It is important to note that the C.G. would not necessarily come exactly under the centre of lift, for the centre of resistance of the whole model may be located distant from the C.G. and thus have its own upsetting moment (Fig. 5). As drawn, this is a small stalling moment, which would be balanced out by locating the C.G. very slightly in front of the centre of lift.

The ideal solution, i.e., to pass the thrust line through the C.G., is, however, rather more difficult to put into practice. For one thing, the vertical position of the C.G. is very much a guesstimated item and cannot finally be resolved until the model is completed, It could be calculated, provided components weights were estimated correctly, but this is tedious. A simpler solution would, it appears, be to complete the model with an adjustable thrust line position (in the vertical direction) and find, by test flying, which is the best position for it (Fig. 6). The same effect could be achieved by using down thrust or upthrust to "direct" the thrust line as required relative to the C.G., but this has the disadvantage that the slipstream is now inclined at an angle to the datum line of the model. The tailplane being rigged "non-lifting" in normal trim may now experience an up or down load due to slipstream effect and cause a considerable difference in trim between power on and glide (Fig. 7). This, in fact, is a characteristic of many low wing models trimmed by adjusting the thrust line in this manner—a good power flight may be followed by a stalling or (more usually) diving glide.

Normally, any power model flies faster under power than on the glide. Expressed in terms of the *flight attitude* of the model this means that under power the wings are operating at a lower angle of attack than on the glide. Correspondingly, there are two "centre of lift" positions, for the centre of pressure of the wings will vary with the angle of attack.

Trim requirements

Trimming first for glide, then, for relatively slow flight, corresponding to a fairly high angle of attack on the wings, the centre of lift will be in its forward position and the C.G. located to trim out the model at this attitude (Fig. 8).

The trimming attitude required under power is with the wings operating at a lower angle of attack. Consequently, the centre of pressure has moved back (Fig. 9), and the model is actually under-elevated under this condition. Adding a thrust component *above* the centre of gravity will only aggravate the under-elevation, which is somewhat disturbing. Either we have got to get the thrust line to pass below the centre of gravity, or use the tail in some way to trim out this difference.

There appear to be two distinct methods of solving this problem. Either the model is trimmed with the difference between power-on flight and glide flight attitude kept as small as possible (and a low thrust line position used with tailplane rigged "non-lifting"); or the model is deliberately balanced out slightly nose-heavy and balanced with a small down-load on the tailplane, i.e., the tailplane at a negative angle of attack.

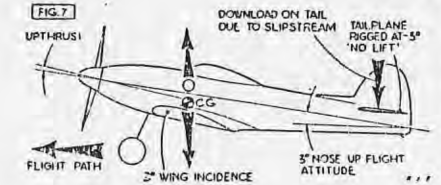
It would seem advisable on all low wing designs to mount the tailplane on the top deck line of the fuselage, i.e., well above the wing root. Rigged at a small negative angle of attack, and coupled with a wing balanced out with the C.G. at some 30 per cent. chord, would appear to be the skeleton outline of the successful low wing model (Fig. 10).

Spiral stability problems are acute in model design. There is no reason why a low wing model should be any more unstable in turning than any other properly proportioned design and satisfactory results appear to have been achieved with a fin mounted on top of the fuselage with a height not less than its base width (Fig. 11).

A frequent cause of instability with low wing models is tip stalling, due either to a badly proportioned wing plan-form, or excessive wing weights, or both. Assuming that the wing halves are separate, each half wing should balance roughly one third from the root (Fig. 12) to reduce tip weight and possible inertia forces building up in turns.

Tapered wings are, unfortunately, prone to stall first at the tips and to reduce this characteristic to a minimum only a moderate degree of taper should be used. The tip chord should never be less

FIG. 7



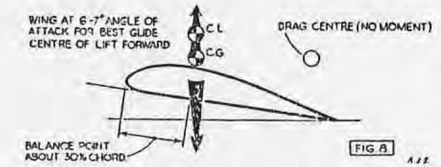


FIG. 8

FIG. 9

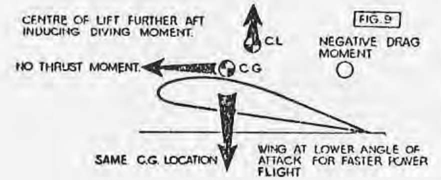


FIG. 10

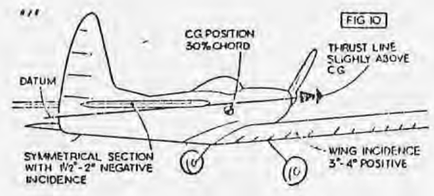
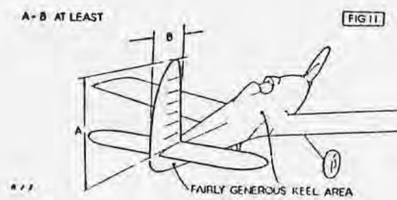


FIG. 11



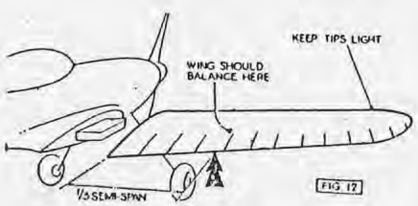


FIG. 17

than 66 per cent. root chord. Another valuable feature would be to incorporate some three degrees or so of washout in each wing, as a further safeguard against tip stalling.

Structurally, of course, there are additional problems. Either the wings have to be built in halves plugged into the fuselage sides, or in one piece strapped into a cut-out in the fuselage underside. The latter is simpler, but untidy. For small and medium size models, at least, plug-in wings with tongue and box fitting would appear to be the best solution (Fig. 13). A satisfactory fairing may be difficult to achieve with tongue-and-box fitting without resorting to a fixed stub centre section, as in Fig. 14, the wing box itself being built into the lower part of the crutch, in the case illustrated. An alternative solution is to extend the stub centre section outwards slightly, and then add the dihedralled outer panels (Fig. 15).

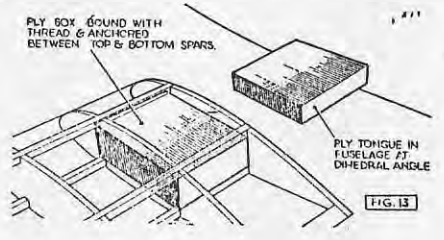


FIG. 13

FIG. 14

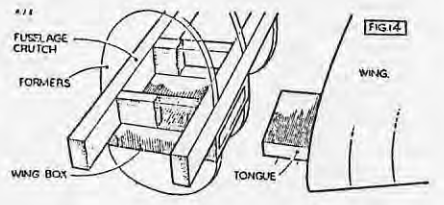
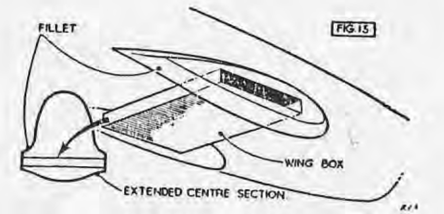
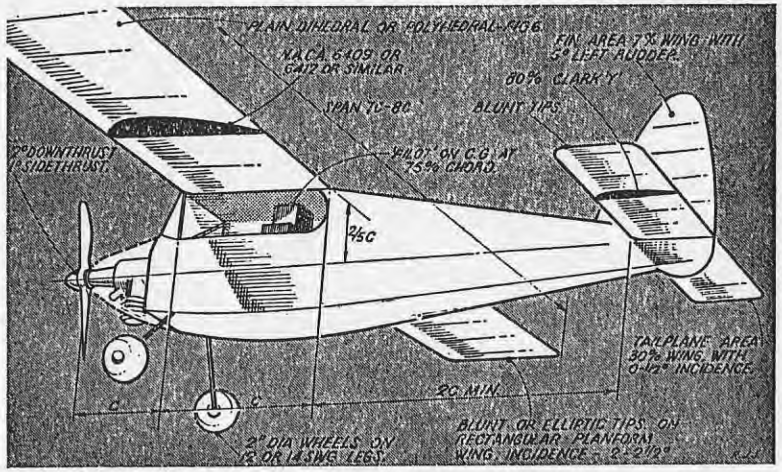


FIG. 15





CHAPTER SIX . . . . PAA - LOAD

THE first major point to decide in roughing out a new PAA-load design is the size of the model. Without doubt models of this type come into the heavily loaded class and a good "duration" climb comes only from using the motor wide open and with the rest of the model proportioned correctly with regard to the power available. First we can consider the effect of overall weight.

With all duration models, minimum weight is accepted as a most desirable feature. Where loading rules exist, designers like to work right down to the lower limits permitted, which is only logical. For a given size of model, less weight means greater height under power and a slower sinking speed on the glide, all other things being equal. In the PAA-load specification we are not restricted to size of model, but only to minimum weight and maximum size of motor. In effect this latter factor does introduce its own limits as to model size.

Let us take weight first. The rules call for a minimum weight of 6 ounces per c.c. motor size, plus the 8-ounce payload. The *minimum* weight of a PAA-load model must, therefore, be:—

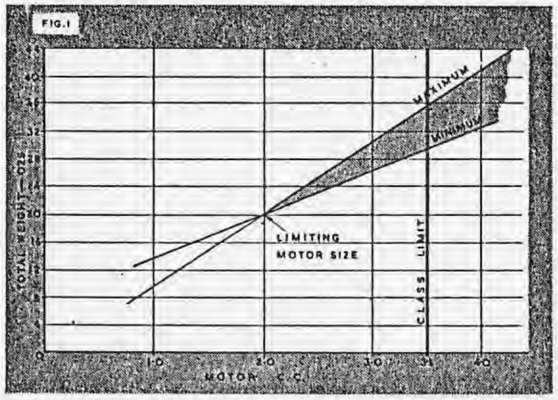
6 × motor c.c. plus 8 ounces.

If, now, we can establish a similar simple formula for *maximum* (desirable) weight, we shall have two useful limits which will be of considerable use in design.

To find a figure for *maximum* weight we continued to load up a successful PAA-load model until a definite falling off in performance was noticed. It is interesting to find that moderate weight increases over the *minimum* (as given by the rules) had little appreciable effect, but once the overall weight exceeded 10 ounces per c.c. climb most definitely began to taper off and the glide was appreciably faster.

If these two limits are plotted in the form of a graph, as in Fig. 1, a very interesting fact emerges. The two lines cross and on the left-hand side of where they cross the *minimum* weight required is *greater* than what is taken as the absolute *maximum* for good duration performance.

In other words, the PAA-load model with a motor of under 2 c.c. is not likely to be as successful as one proportioned for a larger motor. In fact, within the limit of 3.5 c.c. maximum motor size, the larger the motor the greater the tolerance between the minimum weight called for by the rules and the upper limit governing performance. It will be an advantage therefore, to use as large a motor as possible, although above 2 c.c. capacity



all models built down to the minimum weight should have a similar performance (ignoring scale effect, which will show an advantage to the larger *size* of model, called for by a larger *motor size*).

Obviously the motor used is going to be governed by availability and contest specifications. Standard "British" sizes are 1.5, 2 c.c., 2.5 c.c. and a more limited range in the 3.5 c.c. size. The 2 c.c. motor would appear to be on the marginal size, as determined by the loading graph, and the other sizes would appear to be preferable. The 2.5 c.c. motor will probably be preferable. The 2.5 c.c. motor will probably be the popular choice for "up to 3.5 c.c." PAA-load, although the 3.5 c.c. motors are probably the more powerful, size for size, and would probably produce the best duration performance. The models, in such cases, would be larger.

Motor size, determined by availability or personal preference, will govern the total weight and this in turn will govern he overall size of the model. Once these wo factors have been fixed the overall design can be analysed. Probably the most efficient way of determining the model size is by reference to wing loading.

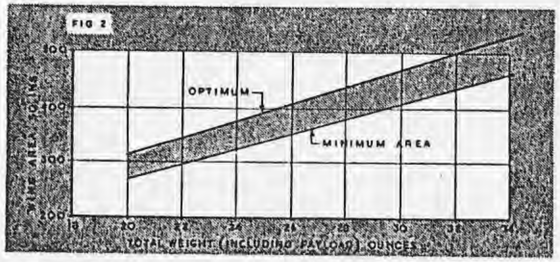
Wing loading effect

The lower the wing loading, the better the glide. At the same time, if we go on pushing up wing *area* to reduce wing *loading* we increase the overall structural weight (with the larger wing) and the drag. Both will detract from climb performance.

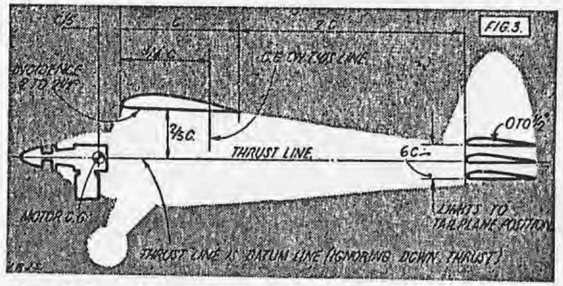
For simple analysis we can adopt a figure of 100 square inches wing area per 6.5 ounces total weight as the minimum limit which will give a good climb without excessive wing area to spoil the climb; and 100 square inches per 7.5 ounces as the maximum wing loading above which glide begins to suffer. Our model size, proportioned according to estimated overall weight (in turn related to motor size) can then be determined between the limits on Fig. 2.

The C.G. position

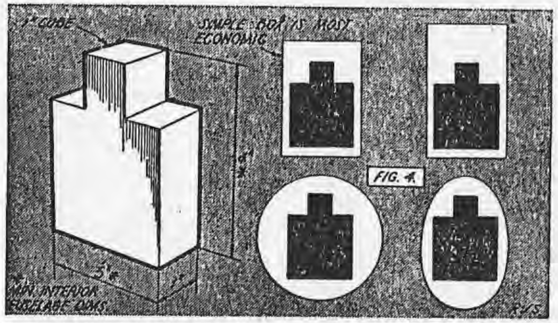
For stability reasons a semi-pylon wing position is desirable, with the wing mounted approximately 40 per cent. of the chord above the thrust line (horizontal component). There is no point in having a shallow fuselage, anyway, for interior height must be at least four inches to accommodate the payload. Used with an incidence of 2–2½ degrees on the wing (employing a duration type section lik NACA 6409 or 6412) and a zero or slightly positive thin lifting section tail plane one-third of the wing area, and tail moment arm 2 × wing chord, the balance point will come at approximately 75 per cent. of the chord. Slight downthrust may be necessary to trim out the power flight. With



orthodox construction this centre of gravity position should be realised by locating the centre of gravity of the motor approximately one-fifth of the wing chord in front of the leading edge of the wing. The eight-ounce payload can then be located approximately under the C.G. position, making provision for slight fore and aft movement for fine trimming. Once the required position has been found for the payload it is imperative that it be located strongly.



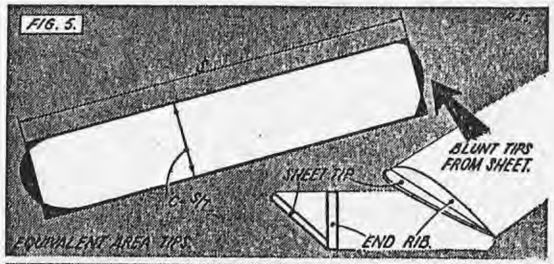
An important feature of the fuselage design is the size of the payload itself—Fig. 2. Overall width of the dummy pilot is three inches, which means that the minimum inside fuselage width is also three inches—wider than current duration practice. This calls for a rather more box-like fuselage than usual, for it would be difficult to accommodate the pilot in a rounded or thin rectangular fuselage without an exaggerated fuselage cross section, at least at that point.

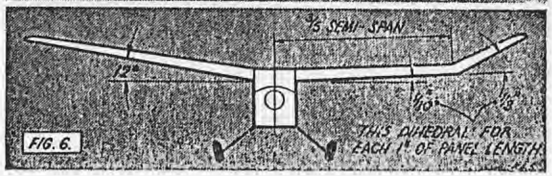


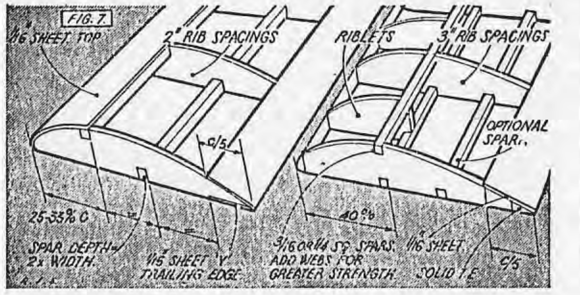
With the disposition of Fig. 3 satisfactorily for stability we can effect a small saving in overall size by increasing the aspect ratio. Fig. 3 applies to wing aspect ratios of from 6 to 8. Structurally the higher aspect ratio is not to be recommended and so an aspect ratio figure of 7 appears to suggest itself as a good compromise, when the whole wing can be proportioned around a rectangular plan-form for convenience—Fig. 5.

Wing design

Despite the fact that modern practice is to use very blunt wing tip shapes, aerodynamically and aesthetically we still prefer rounded or blunt elliptic tips, although these are undoubtedly harder to make. A simple sheet tip butted onto the end rib suffices for the "modern" tip and does not appear to introduce much extra drag, whereas theory would



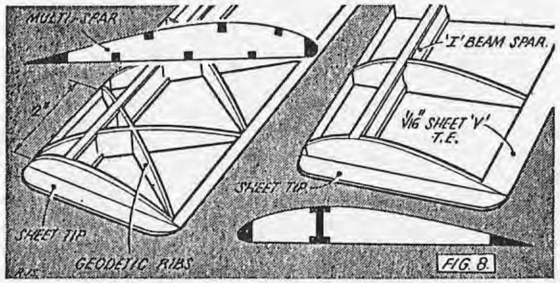


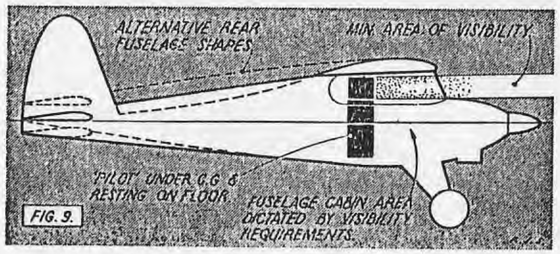


indicate that such blunt tips require washout over the outer wing panel to reduce tip drag to a comparable level.

As regards dihedral, there does not appear any reason why straight dihedral should not be adequate. The PAA-load model is not grossly overpowered and straight dihedral is generally quite adequate in such cases. Polyhedral is undoubtedly more effective for duration flying but will, of course, detract from semi-scale appearance—Fig. 6.

Other details should then fall naturally into line. Possible wing and tail construction methods are summarised in Figs. 7 and 8. Fuselage construction is more difficult to fit into generalisations owing to the variety of side elevation shapes.





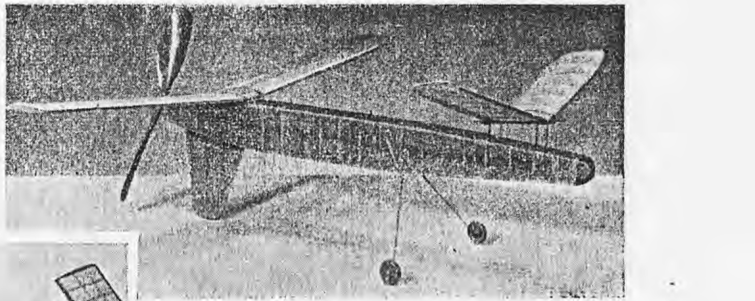
Normal slabsider construction would appear the easiest approach with any refinements added in the form of rounded top and bottom, given by formers and stringers. Rounded decking would, it appears, best be confined to the top of the fuselage since the bulk of the rectangular cross section will, in any case, be filled by the "pilot." Windscreen area will be governed by the position of the "pilot" who has to have the degree of visibility outlined in Fig. 9.

An interesting class

PAA-load promises to be a very interesting specification. Being forced to carry a dead weight of eight ounces, which may be as much as one-third of the total weight of the whole model, PAA-load models do not behave in the same manner as the much lighter, over-powered duration models. The original weight specification appears to have been selected with expert care and just that bit of luck to ensure that the edge is knocked off the pure duration element. Yet the PAA-load model is still definitely a duration machine and must be designed with that end in view.

A final point as regards trimming. With the layout suggested a turn to the right should be safe under power, a turn to the left possibly dangerous. It is recommended, therefore, that right side-thrust be used for a right-hand climbing turn, together with a small amount of downthrust. Slight left rudder offset should be used to hold the nose up in the climb and give a left-hand glide circle.

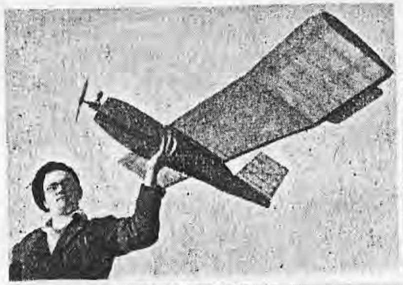
The rubber driven Canard is not necessarily inferior to its conventional counterpart. This example in "Pegasus" by George Harrison is only a 34 in. model, yet its average flight is over 1 m. 30 secs.



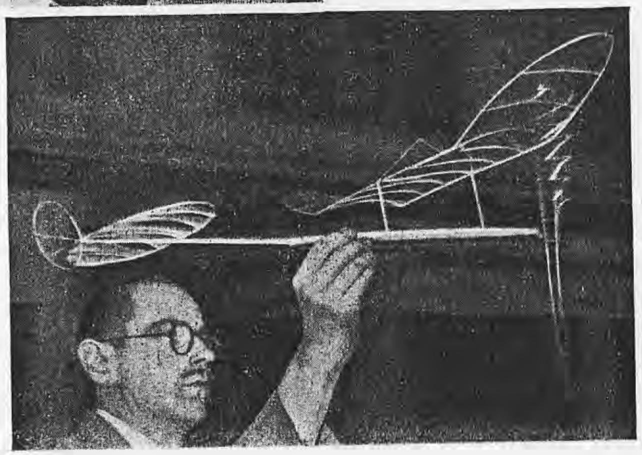
Using an engine facing forwards in the normal way, P. Snodin's powered Canard has a distinctly unique appearance. For trim, the power egg could be moved along the fuselage. This model has an E.D. Bee diesel, has quite simple structure, and is well within the capabilities of any ambitious modeller.

The rubber driven Helicopter bears very little resemblance to the full-size machine. As seen in Vic King's (Left) and Ian Dowsett's (Above) models, they are no more than contra-rotating airscrews separated by the long stick fuselage. Ascent to over 300 ft. is possible with this type of model, and in still air, they frequently descend to the point of take-off.

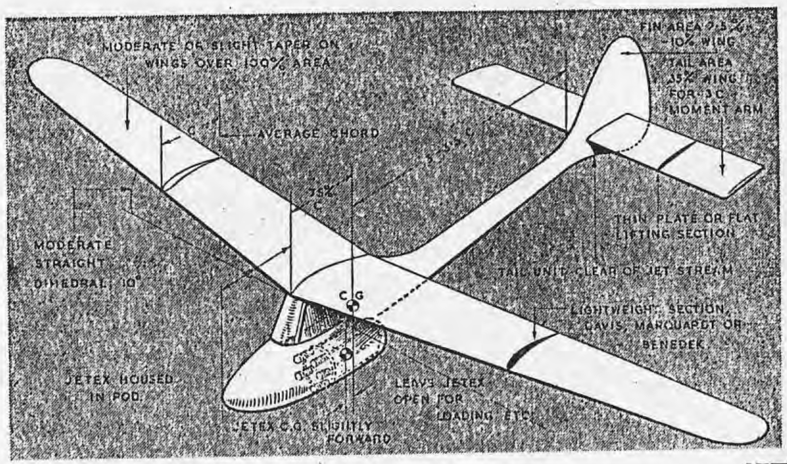
Extra large tailless sailplane by Mr. Allen of St. Georges Heights club is not far short of full-size! It contrasts with the "Flying Plank" type of powered tailless below, by T. Hargreaves and J. Toode. (Bill Dean Photo).



John Gorham flew his 1954 Wakefield on floats at Radlett, and as seen above, take off run was no more than a "jump" of a few inches. At left, G. Perkins shows his single float arrangement, two smaller support floats being fitted to the tailplane.



The indoor model is the lightest type of model constructed and is usually covered with microfilm. This one by Ted Muxlow is free-flight and even has a built up propeller, also micro-film covered. Total weight of such models seldom exceeds three-quarters of an ounce, and durations are only limited by the indoor space available.



CHAPTER SEVEN . . . . JETEX

JETEX is a most interesting form of power unit, available as it is in seven distinct "motor" sizes suitable for powering models of between 10 and 45 ins. span. The Jetex motor has the singular advantage of being a completely self-contained power unit which is located by a simple clip. A single motor, in other words, can be used in a number of different models. Servicing is reduced to a minimum since about the only attention the Jetex needs is a regular cleaning and occasional replacement of the sealing washers and gauzes. There are no moving parts, and hence there is no wear. The power unit, too, is virtually indestructible.

Thrust is produced directly by the expanding gases of the burning charge and is almost a pure *straight* thrust, as well as being appreciably constant over the bulk of the power run. There is no torque as there would be with thrust developed by a propeller.

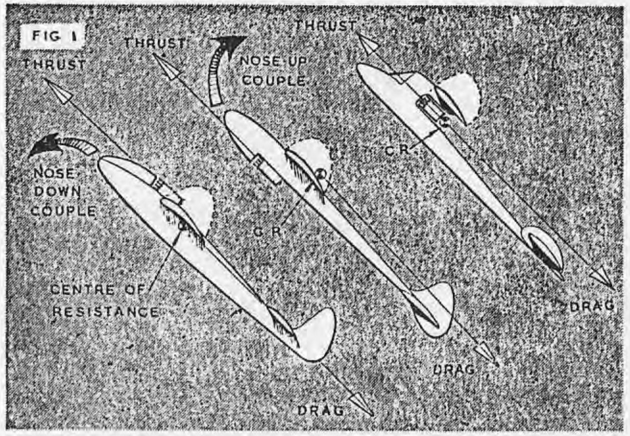
Thrust output

When a Jetex unit is fired, the thrust builds up slowly at first, reaching a peak value in a reasonably short time. It remains roughly at this peak value until the end of the burning time, when it tapers off. Although all the charges are prepared to the same close specification there is, in practice, some variation in the actual thrust output from individual charges in the same motor. Thrust output may also be modified by such physical conditions as the cleanliness of the jet hole in the motor, the state of the interior gauze, and so on. All things considered, however, it is reasonable to assume that the power output of the motor will remain substantially the same, flight by flight, without adjustment.

The number of the Jetex motor is actually a designation of the thrust output it is intended to give. Thus the Jetex "50" gives a thrust of approximately 0.5 ounce; a Jetex "100" 1.0 ounce, and so on. These figures are a useful guide in the proportioning of suitable models for maximum performance. The leading physical characteristics of the various sizes of Jetex units are summarised in the table.

The Jetex-powered model designed for duration work is in a similar category to the power duration model. Power run is limited, in this case by the time of burning of the charge, and so the main object of design is to produce a model which will have a good flight ratio (total duration: duration of power run) which means, in effect, a fast climb to a good height, followed by the best possible glide at minimum sinking speed.

In this respect the Jetex motor is very well suited to duration work, for the weight of the complete motor is less than



the sustained thrust it is capable of developing. It is not in the same category as some internal combustion engines, however, where the thrust developed is so high, for the size and weight of the motor, that it is possible to produce a complete model with a total weight less than the thrust developed by the motor. Such a model, of course, could climb vertically under propeller thrust alone, although this would not necessarily be achieving the fastest rate of climb possible with that particular model, quite apart from the problem of stablising such a climb.

The Jetex may be regarded as a more "moderate" power unit where the resulting model climbs largely by wing lift. This is an important factor in determining the best *size* of model for a particular Jetex unit.

Model sizes

Experience has dictated a range of wing area sizes which appear best suited to the various Jetex units. These are summarised in the table. The inference is that size is likely to be less critical using the larger Jetex motors than the smallest ones in the present range. The wing area sizes indicated appear to be the optimum for a good rate of climb, whilst still enabling low wing loading figures to be achieved for a satisfactory glide performance. The main disadvantages of using a model smaller than that indicated for a particular unit is first that it may be rather difficult to trim under power, and secondly that the smaller area may result in too high a wing loading for optimum glide performance, particularly in the smaller sizes.

A suggested maximum all-up weight for a "200" is 2½ ounces (with unit empty), and for a "350" is 4 ounces (unit empty). No amount of streamlining will compensate for the performance losses which will be suffered if the model is overweight.

It. s usual to work to empty weights for design purposes since we are mainly concerned with weight as affecting glide performance, and on the glide the charge has been consumed.

Thrust-line and trim

As to the layout of the design, here the Jetex power unit opens up a range of possibilities. Being such a compact power unit it will fit almost anywhere into a conventional or unorthodox outline. It would appear an almost ideal layout for flying wings, for example. If we are primarily concerned with duration, however, we are more concerned with finding the most efficient, or what is apparently the best layout.

Both high and low thrust-line positions have been used successfully, and as a matter of fact the I.C.I. Challenge Trophy has been won by each.

Many designers prefer the high thrust-line layout since such a model has less tendency to loop under high power, and does not waste power in down-thrust. A typical high thrust-line layout may in fact be rigged (taking the tailplane as the datum line) with wings at +3° and thrust at +3° also, so making the most of its available power.

However, both layouts have their supporters and neither can be condemned. A compromise design solution, with a centrally-located thrust line is now also finding favour—Fig. 1. All these points are inseparable from considerations of wing mounting, and lightness and simplicity may again prove the decisive factors.

Recommended practice is normally to fly Jetex models straight or nearly straight under power.

A tight spiral climb is a good thing; but the ideal is a straight climb and a circling glide, which can be achieved with careful trimming.

First mount the jet unit with built-in side-thrust. This is most effective, if the unit is mounted *ahead* of the model's C.G. However, since this distance is not great, one or two degrees of sidethrust would have little effect. As much as 10° sidethrust must be used. Rudder is offset against side-thrust.

When the glide is a satisfactory circle, begin powered flights with small amounts of fuel, i.e., one charge halved. Increase to one full charge and so arrive gradually at full power, making small adjustments to side-thrust, as necessary, flight by flight.

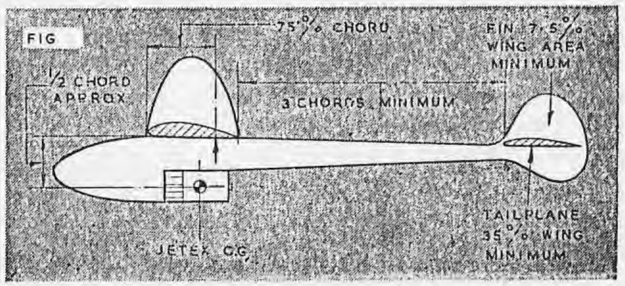
Alternative to rudder offset, wing warping may be used to produce a turn. One wing is given wash-in and the other wash-out. On the glide, where the wing is operating at a high angle of attack, the wing with greater incidence drags more and turns the model in that direction. Speed the model up, as under power, and this wing with greater incidence now tends to lift more and roll the model into a turn in the opposite direction.

We can complete our summary of the basic layout requirements by reference to Fig. 2, which summarises the main requirements of what should be a good duration design. The Jetex motor itself should be located with its centre of gravity slightly forward of the design C.G. of the completed model to add a slight stabilising nose-down or under-elevated effect when loaded, i.e., under power. This will assist in promoting the acceleration into fast climbing flight as the thrust builds up, for in this flight attitude the wing angle of attack will have to decrease.

After this, the remainder of the design layout is fairly non-critical. The one really important factor is the size and disposition of the fin or vertical tail surface(s), but this is just the one point on which no empirical rules can be given! A fin area of around 7.5 per cent. of the wing area should be more than adequate (up to 10 per cent. total fin area on a twin-fin design) and would appear best with at least two-thirds of this area placed above the tailplane, assuming that the tailplane is roughly in line with the wings.

In the main it is best to design the wing and tailplane basically on structural considerations. Small wing chords should be avoided, as these will introduce inefficiency. Accepting a figure of 3 ins. as the minimum wing chord to be used, this immediately fixes the maximum aspect ratio of a Jetex "50" wing as 6. Lower aspect ratios are not desirable in any case, and so 6 : 1 will serve as a good *minimum* figure for all the other model sizes. Above an aspect ratio of about 8 : 1 the normal parallel wing chord ceases to be a good proposition, and if higher aspect ratios are to be used, tapered wings are called for.

The balance of the design data required can be drawn from the heading illustration. Construction is normal lightweight practice, as exemplified by current rubber



model and glider practice. It is an advantage as far as possible to reduce the nose length as this will have a beneficial effect on stability during turning flight. This calls for light rear fuselage and tail unit construction, when it should be possible to reduce the nose length to one chord and still require little or no ballast to trim.

Contest designs

The figures for model weight given in the table represent *maximum* weights for the respective sizes of *Jetex* motors. For duration contest work, obviously, a light overall weight should be aimed at. For example, expert opinion is that the ideal airframe weight for a contest model powered with a *Jetex 350* is about 1½ ounces.

Actually it is difficult to give set weights for a contest design. Whilst the lightest possible airframe weight is the obvious ideal, the model must still be strong enough to resist warping or distortion during flight and be capable of withstanding normal landing shocks, handling, etc. The model *size*, at the same time, remains substantially the same—so ultra-lightweight construction of adequate strength becomes largely a matter of individual skill in construction and the selection of suitable grades of wood, allied to an overall strength factor which the particular individual is prepared to accept as reasonable.

Augmenter tubes

Augmenter tubes are available for use with certain *Jetex* units—notably the 35 (using a 50 augmenter), the 50, the *Jetmaster* and *Scorpion*. With the *Jetmaster* in particular, a very definite gain in thrust is experienced with the use of an augmenter tube. With the others there is still a gain, although rather less marked.

The principle use of an augmenter tube is to enable a *Jetex* unit to be "buried" in the fuselage of a scale or near-scale single-jet model, exhausting the jet efflux from a tailpipe at the extreme rear of the fuselage. The fuselage must be ducted to allow a flow of air to the mouth of the augmenter.

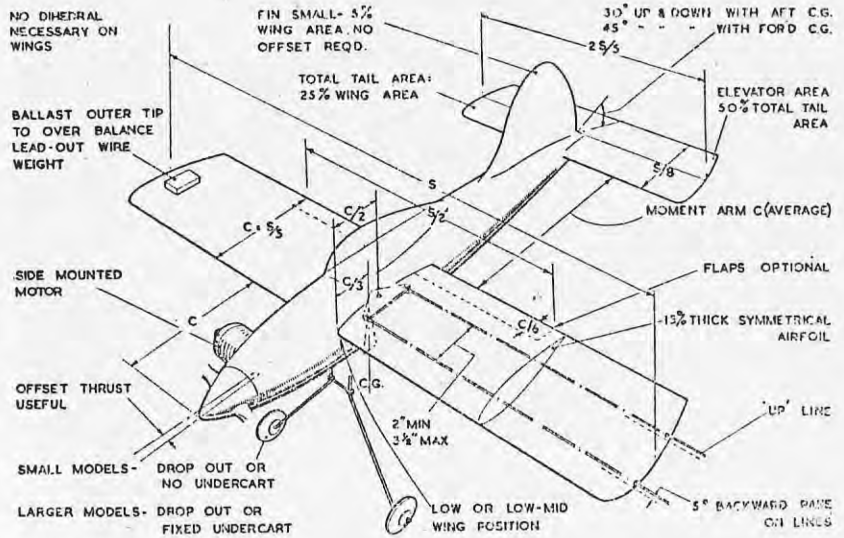
With duration designs the *Jetex* unit is invariably mounted on an external fixing, or virtually so. The addition of an augmenter tube, therefore, poses certain problems as regards fixing. Another major point to consider in such cases is that although an appreciable thrust increase may be realised whilst the *Jetex* is giving power, on the glide the augmenter tube may be very likely to produce a quite high drag, nullifying the beneficial effect of the extra height gained by the increased thrust on the power run.

Care of Jetex charges

A certain cause of loss of thrust, or even failure to fire, is an excessively damp charge. Charges should never be left around to get damp. Warm with gentle heat, such as on a radiator, just before use, if possible. If not, keep in a closed tin box carried in your pocket when on the flying field. Never lay charges down on damp grass or expose to a damp atmosphere for any length of time, when they might absorb moisture.

Jetex	Nominal Thrust (ozs.)	Empty Weight (ozs.)	Weight Charge (ozs.)	MODEL SPECIFICATION			
				Area (sq. in.)	Chord (in.)	Span (in.)	Weight† (ozs.)
35	0.4	5/32	3/32	25-30	2½	10-12	½–¾
50	0.5	¼	⅛	50	3	18	¾–1
100	1.0	⅝	¼	100–170	4	30	1–1¼
Jetmaster	1.5	¾	¼	120–150	4½	32–34	1½–2
200	2.0	1⅛	5/16*	140–160	4½	34–36	2–3
350	3.5	2¼	13/32*	180–240	5	40–44	4–5
Scorpion	5.0	1⅝	⅜	180-260	5½	32-48	14

* Single Charge. † Including Jetex Motor



CHAPTER EIGHT . . . . CONTROL LINE STUNT

A STUNT model nowadays must be capable of performing "everything in the book" in the hands of a capable pilot. Otherwise it simply is not a stunt design. The original Millsbomb, for example, which Mike Booth flew at the 1948 Nationals at Northampton, was then an outstanding stunt model. It was one of the first aerobatic models utilising such low power as a 1.3 c.c. capacity diesel motor. Yet this model could only perform single loops. It would stall or mush at the end of the first loop if consecutive loops were attempted. Yet the difference between this model and the Millsbomb II which will perform consecutive loops is relatively small.

Pete Cock first convincingly demonstrated that the smaller capacity diesel motors could be used for a complete aerobatic range with a small size model. As most enthusiasts will remember, he won the stunt event at the same Nationals with an E.D. II powered Kan-Doo profile-type model, quite contrary to the popular belief that one of the West Essex 10 c.c. powered lightweight "boxcars" was the "cert" winner.

Den Allen's original "Boxcar" was typical of the early trend of fully aerobatic stunt models in this country, with fairly low wing area (336 sq. ins.), but extremely light weight (27 ounces) for the size of motor employed—10 c.c. Wing loading was only 8 ounces per 100 sq. ins. wing area and, equally significant, power loading was as low as 2.7 ounces per c.c.

Light wing and power loadings subsequently formed the basis of almost all the successful stunt models later produced in the smaller sizes, and these, as everyone knows, have been outstandingly successful.

With this development, too, designs have tended to become much more refined. The purely functional layout of many of the earlier successful stunt models has given way to a more attractive appearance. Quite a number of modern stunt designs, in fact, truly fall into the category of semi-scale machines, provided some allowance is made for the fact that certain features, such as large wing area, are a necessity. The functional design, of course, still remains, but it has been proved that reasonably good lines are no handicap as regards performance.

FIG 1

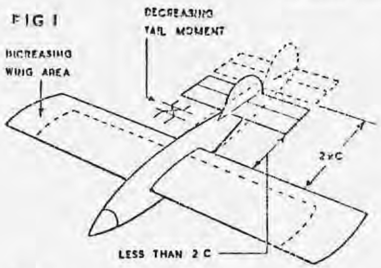


FIG 2

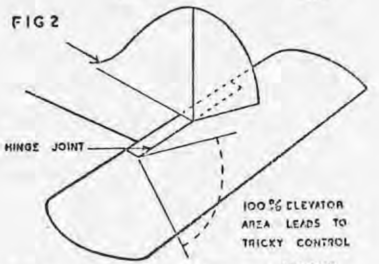


FIG 3

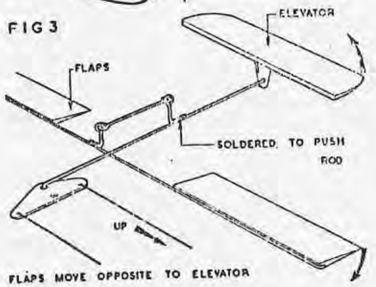
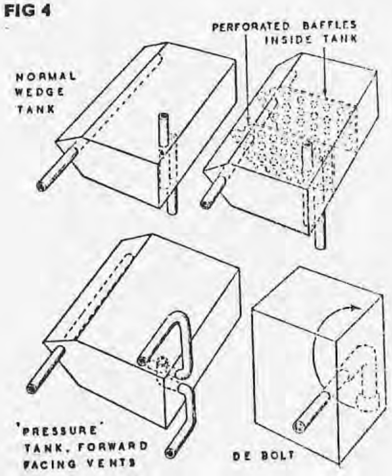


FIG 4



Probably one of the most marked trends in the design layout of stunt models has been the shortening of the moment arm. The moment arm is, strictly speaking, the distance between the centre of gravity of the model and the centre of pressure of the tailplane, but for all practical purposes the standard of measurement adopted is to measure moment arm as the distance between the trailing edge of the wing and the leading edge of the tailplane. This, in many of the early models, was frequently twice the wing chord, but it was soon found that decreasing this moment gave a model with a much smaller looping radius. This started a design trend, through which the moment arm has virtually disappeared and the tailplane starts some very small distance behind the wing—Fig. 1.

Parallel with this development, too, wing areas increased proportionately, so that the short-coupled stunt model, which has become so popular today virtually compromised between a flying wing and a more orthodox layout.

Manoeuvrability

Most of the original design development work was directed towards making the model more manoeuvrable, and, in particular, reducing the looping radius. Shortening the moment arm and using large elevator areas and large movement certainly did this, but at the same time did not produce an entirely satisfactory state of affairs. Although models might now loop in a very small radius, there was a definite tendency for them to stall or mush at the bottom of a loop, or even on a sharp pull out from a dive, and consecutive manoeuvres often required considerable skill in *flying* the model round all the time. In other words, it was readily possible to *overcontrol* the model and get it into a stalled condition where, with both wings and propeller stalled, the model just hung in the air and there was a very definite danger of losing control altogether. This was well illustrated by some of the designs which appeared with *all* the horizontal tail surface area movable, i.e., a 100 per cent. elevator area. There was no doubt that such models responded rapidly to control movement, but the response was often so rapid that they were extremely difficult, or even impossible, to keep under control at all. Mushing or stalling on a pull out from almost any manoeuvre was common and few models now attempt to get rapid control response by exaggerated elevator area and angular movement.

However, a very effective way of combating "mushing" has been found—the use of small wing flaps coupled to the control system and working with the opposite angular movement as that of the elevators. In other words, when elevators move "up" the flaps move "down." Combined flap and elevator control of this nature has proved particularly effective and although their aerodynamic action is not fully understood, they can vastly improve the performance of an otherwise "tricky" stunt model.

Details of a typical method of linking up the controls are shown in Fig. 3. A flap area of about two-thirds of the *elevator* area appears to give the best results, the flaps themselves being of narrow chord. Full span (narrow chord) flaps have been tried on some designs with positive results.

Stability and design

At the same time, stable design layouts have often proved equally as ineffective as overcontrolled designs, although for just the opposite reason! A number of flying wing designs, for example, were based on a stable, swept-back planform when it was found that with the forward C.G. position considered safe for maintaining line tension, they were just too stable for small radius manoeuvres. In other words, they resisted displacement and automatically tended to open up any loop induced by elevators or equivalent controlling surfaces. About the only satisfactory way to make such models perform as stunt designs was to reduce their margin of longitudinal stability *by moving the C.G. aft.*

This has proved a particularly significant point. As we know now, line stability obtained by using a forward C.G. position *opposes* manoeuvrability and "playing safe" in this respect automatically opens up the looping radius of the model, however powerful the controls. A forward C.G. position, in other words, tends to act against the controls.

Thus provided the loading figures for the design are reasonable, i.e., sufficient wing area per c.c. motor capacity, with low wing and power loadings, designs with a reasonable moment arm can be made very manoeuvrable, *with proper location of the control plate and C.G. position.* Furthermore, such models will then require less elevator power for manoeuvrability and there will consequently be much less risk of stalling or mushing on sharp pull-outs.

As far as generalisations can go, these desirable conditions are realised with the pivot point at about 50 per cent. of the wing chord with the C.G. then as far aft as possible without running into the trouble of lines slackening off. With the C.G. too far aft the model will tend to come in on the lines all the time. If too far forward, manoeuvrability will be reduced. Similarly, line stability will be lost if the pivot point is placed too far aft.

Designs of this type generally employ a moment arm of about one and a half wing chords, or slightly less, and can be made particularly smooth in response to control handle movement, since no more than about 30 degrees elevator movement should be necessary and, consequently, a large control plate and long elevator control horn can be used.

Fuel feed troubles

The same remarks regarding C.G. position apply also to the short-coupled designs, although undoubtedly this arrangement, generally using a 50 per cent. elevator area and generous movement (45 degrees up and down), is easier to displace and consequently makes it easier for the less experienced pilot to fly out a fairly advanced flight pattern. The less experienced in stunt work the pilot is, the more he would be advised to tackle a short-coupled stunter if he is after quick results. He will probably have to pay for manoeuvrability either in a certain tendency to mush at the bottom of sharp radius manoeuvres, which is still present to a certain degree on many of the best short-coupled stunters, or fuel feed troubles induced by the violence of the manoeuvres.

The latter has become particularly noticeable with the increasing use of glow plug motors for stunt work, especially in the larger sizes. Violent manoeuvres often momentarily upset the fuel feed, causing the motor to starve or run rich. It is difficult to generalise on this particular subject, since the individual characteristics of different glow motors can vary so considerably, and even motors of the same make behave differently in different models with, to all intents and purposes, similar tank systems. But for best results with glow motors it pays to give particular attention to tank design and layout.

A tank with a swivelling feed pipe, such as the De Bolt or EmDee type—Fig. 4—has proved satisfactory in many cases, but troubles do not appear to be so much a case of the fuel being thrown away from the feed pipe as of the fuel being aerated within the tank. Tanks with baffles have been used in America for some considerable time with glow motors, but the modern tendency is to use *pressure tanks*, either of the form where pressure is induced via two forward facing vents or a collapsible tank sandwiched between two plates. The simplest form of pressure tank is, of course, the balloon tank, introduced in the early days of control line flying, and still regarded as very efficient. Other systems which have been tried are the fitting of a compensator between the tank and the motor.

Design layout

Regarding the design layout of the stunt model itself, the heading drawing again summarises the salient features. The type illustrated is based on a moderate moment arm which should give ample manoeuvrability with the correct power available.

Correct size of model is rather important. It is generally better to err on the side of making the model too large (in wing area) rather than too small. It is then generally possible to get good manoeuvrability without thrust power becoming critical, i.e., the model will generally be stuntable on a range of propellers instead of on one particular diameter and pitch matched to the motor. The smaller the size of the motor, the larger the wing area required, in proportion.

For the smaller sizes about 100 to 125 sq. inches of wing area is required per c.c. of motor capacity. Thus a Mills-powered stunt model would have an area of about 125 to 150 sq. in. Use of fairly generous wing area should enable the wing loading to be kept to a low figure, about 6 ounces per 100 sq. in. wing area being the figure to aim at.

Roughly the same wing area and loading figures can be maintained up to 3.5 c.c. motor capacity. Exceptionally large wings present increasingly difficult structural problems to preserve the same degree of robustness, and for a 5 c.c. motor a wing area of 400 sq. in. can be considered quite adequate. Smaller areas can be used—50 sq. in. per c.c. being about the minimum for motors of from 5 to 10 c.c. 80 sq. in. per c.c. represents about the top limit for 5 c.c., decreasing to 60 sq. in. for 10 c.c.

As far as possible, power loading should remain roughly the same throughout. The best figure appears to be between 4.5 and 5 ounces per c.c. Six ounces per c.c. is about the top limit, but it is easier to get away with this higher loading in the smaller sizes of model than in the larger sizes.

TABLE I. AERODYNAMIC DESIGN

Motor c.c.	Wing Area (sq. in.)	Span	Chord	Moment Arm	Tail Span	Tail Chord	Tail Area	Elevator Area
1	125	25	5	4½	10	3	30	15
1.5	180	30	6	4½	12	4	48	24
2.5	300	40	7½	6½	16	5	80	40
3.5	360	43	8	7	18	5	90	45
5	400	45	9	8	18	5	90	45
10	600	57	10½	10	24	6	144	70

From these generalisations, then, it is possible to draw up a rough specification for a design to suit any size of motor. Designing for a 5 c.c. motor, for example, total weight of the model should not be more than 22.5 to 25 ounces. Subtracting the weight of motor from this gives the amount of weight available for the air-frame unit complete. Wing area should be at least $5 \times 50 = 250$ sq. in., up to $5 \times 80 = 400$ sq. in. Corresponding calculated weights for these two limits of areas based on a loading of 5 ounces per 100 sq. in. are: 12½ ounces and 20 ounces.

It will be difficult, or even impossible, to build down to the lower limit of area and weight and so the upper figure would appear to fit the bill well—400 sq. in. area at a required weight of 20 ounces.

Shapes and sizes

Shapes and other sizes are not particularly critical. Certain generalisations hold true, such as the use of a symmetrical aerofoil section for the wings and a thin, flat-plate aerofoil for the tailplane and elevators. Since the drag of an aerofoil increases only slightly with increasing aerofoil thickness up to a thickness of 15 per cent. of the chord, and the thicker symmetrical section has definite aerodynamic and structural advantages, thin wing sections should be avoided. A 15 per cent. thick symmetrical section, in fact, is generally accepted as about the best for stunt work, and sometimes an even thicker section such as NACA 0018 (18 per cent. thick) is used.

For the wing planform a purely rectangular shape is quite adequate with blunt, raked or rounded tips. The latter are best constructed of sheet. Since the model will normally be operating at quite low angles of attack a blunt tip shape will not be inefficient, nor will appearance suffer greatly.

The fuselage is a purely functional unit in that it holds and locates the wings and tail unit in their correct positions, houses the control link-up and carries the power unit. A low or mid-wing layout is generally accepted as best practice, with the tail-plane then mounted on the top line of the fuselage, slightly above the wing position. Tailplane position does not appear to be at all critical.

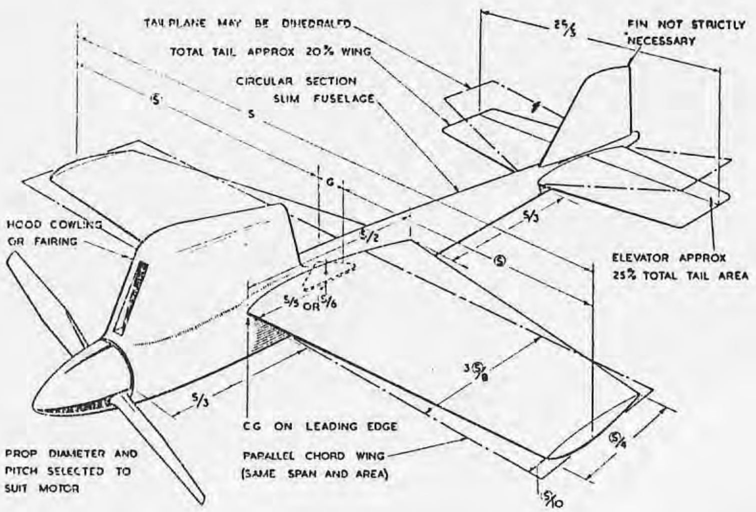
Side-mounting of the motor is used in most commercial designs. Stunt flying calls for inverted flying, and if the motor cuts in the inverted position the only solution is to land the model in the inverted position, a side-mounted motor will be far less liable to damage than an upright or inverted motor.

Most designers, however, prefer to mount their motors with the cylinder pointing outwards, i.e., away from the centre of the flight circle, irrespective of whether the motor itself originally runs best in the upright or inverted position. A motor recommended for inverted running should point outwards when side-mounted. Centrifugal force then replaces gravity under flight conditions.

Some form of stunt tank is absolutely essential. For most models the normal wedge-type tank is adequate, but glow motors may need special attention, as noted previously. The whole success—and life—of a stunt model may depend upon having an efficient tank hook up, so it pays to experiment here for best results.

TABLE II. STRUCTURAL DESIGN

SIZE (Wing Area)	WINGS			FUSELAGE			TAIL-PLANE
	L.E.	Spars	T.E.	Sides	Fairings	Motor Mount	
125	3/16 sq.	—	1×1/4	1/8 sq.	—	Ply	3/32 Balsa
180	1/4 sq.	1/8×1/4	1×1/4	3/16 sq.	1/4×1/16	3/8 sq.	1/8 ,,
300	5/32 sq.	3/8×1/4	1×1/16 'V'	1/8 Sheet	Block	1/2×3/16	1/8 ,,
360	3/8 sq.	3/8×1/4 & 1/8×1/4	1¼×1/16 'V'	,,	,,	1/2×1/4	3/16 ,,
400	3/8 sq.	7/8×1/4 & 3/8×1/4	1¼×1/16 'V'	,,	,,	3/8×3/8	1/8 ,,
600	1/2 sq.	1 & 3/8×1/4	1½×1/16 'V'	3/16 Sheet	1/4×1/8	3/8×1/2	3/8 ,,



CHAPTER NINE . . . . CONTROL LINE SPEED

WITH regard to design layout, most models now conform to the conventional layout of slim, conical fuselage with hood-type cowling, straight tapered wings and tailplane with squared tips, mid- or shoulder-wing positioning and dolly or drop-out undercarriage. Generalised proportions are summarised in the heading illustration. Considerable variation in tailplane proportion is permissible without running into trouble, although it is better to err on the large size rather than cut down this area to a minimum. The saving in drag resulting from reduced tail area is very small and if the resultant area is *too* small, the model will have marginal longitudinal stability. In other words, it will tend to "hunt" or wander up and down on the line and may prove difficult, or even impossible, to keep under control.

Overall size of the model is determined by the motor to be used. It is usual to match model size to a specific motor, rather than to a specific *size* of motor, although, again, this does not appear at all critical.

Choice of motor resolves itself simply into choosing the most powerful motor available in any particular class. The chief criterion in this respect is motor size for, given two motors of similar efficiency, the one with greater capacity will have the greater power. In other words, for speed work, select a racing motor with the maximum possible capacity within the permitted class range.

The racing motor

Now what decides which is a racing motor? Broadly, speaking, it is a motor which is capable of developing very high r.p.m., and this is about the most useful practical guide to selection. In the larger capacities, 5 c.c. and up,almost all motors of this type are characterised by ring-type pistons, short stroke and large port areas, with crankcase (rotary valve) induction a "must." This last generalisation holds true in all sizes. The motor with rotary valve induction (as opposed to sideport induction) is invariably faster than its sideport counterpart.

With these larger racing motors, methanol fuels are standard and spark and glow ignition give comparable results. Maximum r.p.m. is usually obtained with glow ignition, but spark ignition tends to be more reliable. Against spark ignition, of course, is the additional weight of the ignition equipment. A point against glow ignition is that if the model strikes the ground with the motor running, shearing off the propeller blades, the motor will usually continue to run, unbalanced and at very high speed, with the consequent risk of serious damage.

The modern tendency, however, is to use glow ignition almost exclusively and concentrate on finding the best possible fuel for the motor. Fuel requirements can, and do, vary with atmospheric conditions and so considerable attention must be given to this point if *consistent* high speeds are the aim.

Model sizes

In the lower range of motor sizes, ignition weight (and space requirements) generally rule out spark ignition, and so glow ignition is used right down to the smallest sizes. At the lower end of the range (2.5 c.c. and under) the diesel proves a comparable, and better, power plant.

Once having decided the class of model, size must be proportioned accordingly. The generalised diagram shows two simplified alternatives, one with a normal straight tapered wing, and the other a parallel chord wing of the same area but higher aspect ratio. Although there is very little theoretical justification for using high aspect ratio wings for speed work such types have proved popular and given excellent results, with aspect ratios even higher than that shown.

Gross wing area of this layout is $\circledS\left(\frac{G}{2}+\frac{3\circledS}{4}\right)$ where "$\circledS$" is the actual semi-span of the wing itself, but it is usual to work to *nett* or actual wing area when this is $\frac{3\circledS^2}{4}$. The solution for semi-span (wing only) is thus :—

$$\circledS = \sqrt{\frac{4 \times \text{wing area}}{3}} = 2\sqrt{\frac{\text{wing area}}{3}}$$

Since wing area is not all that critical, calculated figures can be rounded off to a convenient number for ease of working.

Now in order to determine the best wing area for any particular class of model, we must first appreciate how wing area affects performance. Briefly, the problem is this; the greater the weight of the model, the greater the lift required to support it. This lift can be achieved either with a small wing (high wing loading) operating at a relatively high angle of attack, or a large wing (low wing loading) operating at a small angle of attack. Low wing loading conditions are desirable, since wing drag is lower under these conditions. But achieving this with a large wing leads to a vicious circle. The larger the wing, the greater its weight, and so on.

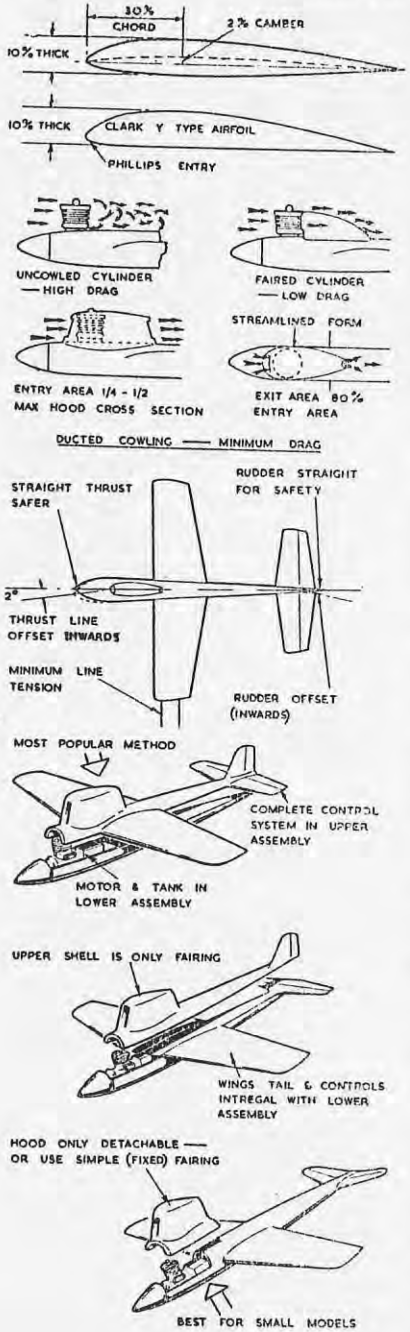
The solution is to work within a range of permissible wing area sizes and keep the total weight of the model down as much as possible, consistent with the necessary strength. The lighter you think you can make the model, the more nearly can you approach the lower wing area limit. Over-optimism in this respect will mean that your model will ultimately have to fly nose-up at higher drag, to achieve the necessary lift. Suggested wing area limits are listed in Table I.

To finalise the design layout, there are a number of details to be taken into consideration. First, the aerofoil sections. The tailplane can be dismissed quite simply; with its very small area a simple flat plate section will suffice, when this unit can be made out of thin ply to give

TABLE I. BRITISH C/L SPEED CLASSES

Class	I	II	III	IV	V	VI	VII
Motor Size	0-1.50 c.c.	1.51-2.50 c.c.	2.51-3.50 c.c.	3.51-5.00 c.c.	5.01-8.50 c.c.	8.51-15.00 c.c.	Rocket or Jet
Optimum Wing Area sq. in.	20–30	25–40	30–45	35–50	50–80	80–110	90–130

F.A.I. Speed Classes: I 0–2.50 c.c.; II 0–5.00 c.c.; III 0–10.00 c.c.



adequate strength. The wing section, however, demands more careful treatment. Two drag-producing factors in aerofoil section design are camber and thickness Drag increases as these increase. As far as thickness is concerned, drag increase with anything greater than a 15 per cent. thickness factor is prohibitive and, preferably, the section thickness should be somewhat less. A section thickness of about 10 per cent. of the chord is about the usual minimum. Thinning the section right down below this figure will not produce correspondingly better performance, for lift will taper off rapidly, leading to the same bad effects as high wing loading. In fact, it is probably better to err on the side of a slightly thicker section than an unduly thin one.

To get a reasonable amount of lift at a low operative angle of attack, some moderate degree of camber is desirable—somewhere in the region of 2 per cent. Thus, a good speed section will have a thickness of about 10 per cent. of the chord and a camber of about 2 per cent. Position of maximum camber is not likely to have a great effect.

A section fulfilling these requirements would be NACA 2310, although almost any conventional aerofoil form proportioned on similar lines could be expected to give similar results—Fig. 1. Such sections, it will be noted, are of the bi-convex type.

Chord sizes on control line model wings are so small that efficiencies are problematical, so a more practical section with a flat undersurface is likely to give almost identical performance. Such a section, of course, has the great advantage that the wing can be built flat over the plan. For ordinates, a normal Clark Y section thinned to 10 per cent. will be as good as any. It is, in fact, probably more important to build the wings true and free from any twist than attempt some slight refinement of section.

Regarding the very thin section sometimes used, these, as we have seen, will probably have to operate at a rather high angle of attack and in such cases high aspect ratio will be effective in reducing induced drag. But this does not appear to be the best solution to the problem, although it has the practical advantage that a light weight, thin section, high aspect ratio wing can be made direct from solid balsa.

Spinner shape is another mis-understood detail. The present trend is towards long, pointed spinners of the super-sonic type, presumably on the basis that high-speed models need "high-speed" spinner shapes. However, from the aerodynamic point of view, the top speed on control line models is in the lower speed range of full size aerodynamics, where best streamline shapes are somewhat bluntish in appearance. A properly shaped blunt spinner on a speed model may, in fact, have lower drag than that given by the more pointed entry.

Cowlings

But the most abused subject of all is cowling design. At model speeds—say above about 75 m.p.h.—the drag of a bare cylinder projecting from the fuselage outline is appreciable—Fig. 2—and some form of fairing is necessary. The object of such a fairing or cowling should be to smooth out and control the airstream immediately in the wake of the cylinder, which can be done by the fairing form shown in the second illustration. Enclosing the cylinder in a hood-type cowling does not automatically guarantee a drag saving over the first condition, and may have a very much higher drag than the simple fairing, unless properly ducted. The common error is to cut only a very small entry slot in the hood cowling so that turbulence is virtually built up around this area. Without the hood, turbulence would start farther aft at the cylinder itself.

To be properly effective, a hood cowling must have correctly proportioned entry and exit openings. Also, the inside of the cowling should be smooth and properly shaped, so that the airstream is not forced to change direction, but flows smoothly past the cylinder and out through the exit slot. The normal turbulence behind the cylinder is then smoothed out.

Cowlings are sometimes made asymmetric to impart a sidethrust on the nose of the model, to prevent the nose yawing, in, or out, as the case may be. Normally the designer avoids the problems of offset rigging, using straight thrust and fin settings. However, for maximum performance, reducing line tension by rigging the model to fly in a "natural" circle is commonly adopted. Fig. 3. The usual method is to offset the thrust line inwards. If overdone, and about 2 degrees sidethrust is the limit, the model will not maintain line tension, control will be lost and the model will roll inwards into the ground. Even if rigged to trim out with adequate control at top speed, at lower speeds, i.e., after take off and accelerating up to top speed, the model may still roll inwards. Striking the right compromise is difficult, and best left to the experts.

Straight rigging generally gives good results with comparative safety. No offset rudder should be needed, in fact, no vertical tail surfaces are really necessary at all. It is now common to dispense with the fin and give the tailplane a dihedral angle which, although the aerodynamic effects may be negligible, does keep this unit clear of the ground during landing and thus minimise the risk of damage.

TABLE II. AERODYNAMIC DATA

Class	Span	Root Chord	Tip Chord	Net Area	LOA Excluding Spinner	Moment Arm Wing TE to Tail LE	Tail Span	Area	Elevator Area
I	13	2½	1½	24	12	4½	5	6	1½
II	14½	2¾	1½	30	13	5	5½	8	2
III	16	3	2	38	15	5½	6	10	2½
IV	17½	3½	2	44	16	6	7	10	2½
V	20	4¼	2	60	19	7	8½	14	3
VI	20	6	4	92	20	8	9	18	5

The undercarriage

A drop-off undercarriage of some form is essential for rise off ground flights. The drag of a fixed unit is much too high. Opinion appears to be equally divided between the merits of the three-or-four wheeled dolly and the two-or three wheel drop out unit. Both have their respective advantages and disadvantages. The drop-out type is probably simpler to operate.

Construction

The fuselages of most speed models are carved from solid block; balsa in the case of the smaller models, and turned from pine or similar hardwood and hollowed out in the larger sizes. Motor mounts are of hardwood or sometimes metal (dural). Sometimes the mounts are extended aft for the length of the fuselage to form a crutch carrying the upper and lower shells.

Fig. 4 shows the three main methods of construction of the complete model. The most popular method is to split the model into two major components, held together by suitable locating screws (e.g., cut down bicycle spokes). The upper shell then simply becomes a fairing, or, more usually, the motor unit is housed in the lower shell, and the wings, tail unit and control system complete in the upper component. Both these methods are particularly suited to the larger sizes of model.

The smaller models are generally built as one integral unit, with the hood portion detachable, or cut away, for access to the motor controls. The very small size of fuselage involved does not readily permit of splitting it into two halves.

Solid wings are popular in the smaller sizes, with or without a hardwood strengthening piece inset across the centre section. A similar, but lighter, form of construction is to use large solid leading and trailing edges and sheet ribs, then $\frac{1}{16}$ sheet balsa covering top and bottom.

Built-up wings are generally employed on the larger models, these being almost invariably of the monospar type. The spar can be made of hardwood. Sheet covering is used throughout, a skin of at least $\frac{1}{16}$ in. thickness being necessary, otherwise it will not be possible to sand down smooth without working the skin down unduly thin over the rib positions.

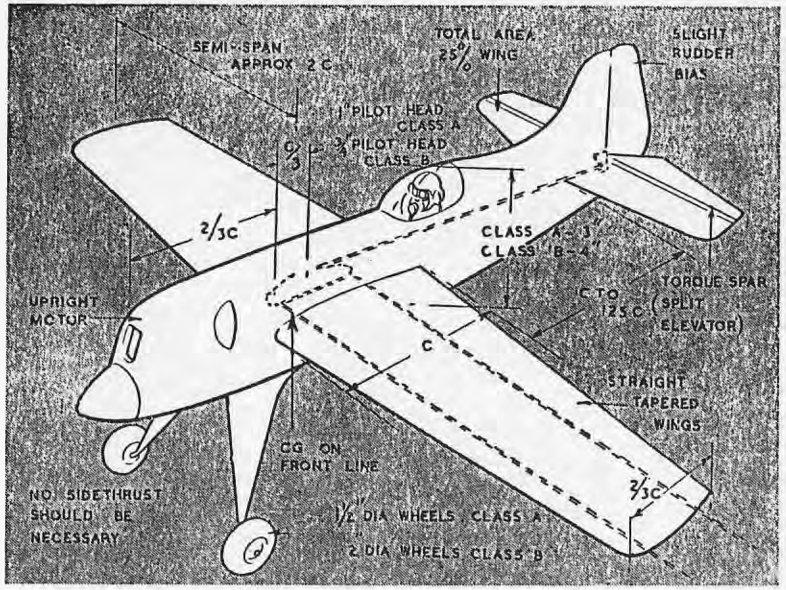
Metal construction has been applied to speed control line models with considerable success. Metal fuselages are beyond the scope of the average model builder, but metal wings are not so difficult. Metal wings and a wooden fuselage make an effective combination.

Basis of the wing structure is then a hardwood spar. .015 sheet aluminium or Alclad is then used for the metal wing skins, bent round and folded back over itself to form a conventional aerofoil section and then riveted along the trailing edge. The wing panels are then mounted on the hardwood spar and secured with countersunk wood screws. Tips can be of balsa or hardwood plugged in place and sanded down to a suitable section. Locating stub spars will be necessary to make a stable wing-fuselage joint; one at the leading edge, at least, and possibly another at, or near, the trailing edge.

Such wings compare very well, weight for weight, with built up wood wings and can be finished to a very smooth durable, surface.

TABLE III. CONSTRUCTION DATA

Class	WINGS	FUSELAGE	Motor Mount	TAIL UNIT Material	TAIL UNIT Hinge	Undercart	Notes
I, II	Solid or Sparless	Hollow Log	Hardwood	$\frac{3}{32}$ Balsa or $\frac{3}{64}$ ply	Tape	Drop-out	Integral Construction (I–III)
III	Sparless	Hollow Log	Hardwood	$\frac{1}{16}$ ply	Tape	Drop-out	
IV, V, VI	Sparless Monospar or metal	Hollow Log or Crutch	Hardwood or metal	$\frac{5}{64}$ or $\frac{3}{32}$ ply	Wire & Tube	Drop-out or Dolly	Two-shell Assembly



CHAPTER TEN . . . . TEAM RACERS

TEAM RACERS—latest addition to the competition classes and, incidentally, just about the best type of sports control-liner—offer considerable scope for ingenuity in design. The field is still very open. No one has yet established the best compromise between speed and range. The actual competition course itself may be anything from five to ten miles. Five miles is usually chosen for the eliminating rounds; ten miles for the finals. The basic problem is one of matching speed against fuel consumption. Whether to go fast by using the most powerful motor available—and in gaining speed, sacrifice range, which means one, two, three or more stops for re-fuelling in the course of a ten mile run. Or whether to aim for maximum range by using a smaller motor and cruising at a lower flying speed and possibly cover the whole course without re-fuelling. There is no simple answer to this.

The two official Team Racer specifications are summarised below.

In addition models must be scale or semi-scale in appearance, with a cockpit or cabin, the foremost point of which must not be lower than the top of the engine cowling. The cockpit must contain a dummy pilot with the required depth between chin and crown. It must have a completely cowled engine, except for access to spark plug, glow plug and compression adjustment. Wheels must be of the correct minimum diameter and the undercarriage must be fixed or retractable —if the latter, it must be lowered for each landing.

Good design means a high aerodynamic

CLASS A

Minimum wing area : 70 sq. in.
Engine capacity : 0–2.5 cc.
Maximum tank capacity : 15 cc.
Line length (C/L handle to C/L model) : 42 ft.
Fuselage depth at cockpit : 3 in.
Pilot head : ¾ in. deep.
Wheel diameter : 1½ in.

CLASS B

Minimum wing area : 125 sq. in.
Engine capacity : 2.51–5.0 cc.
Maximum tank capacity : 30 cc.
Line length (C/L handle to C/L model) : 52 ft. 6 in.
Fuselage depth at cockpit : 4 in.
Pilot head : 1 in. deep.
Wheel diameter : 2 in.

efficiency. The higher this efficiency, the faster the model can be flown on the same power; or the farther it can be flown at the same speed. The power plant is a separate, although closely related, problem. Selection of motor and best propeller combination must obviously depend to a very considerable extent on the design of the model. But there are additional problems associated with the power plant, such as the provision of a foolproof fuel feed system which runs out the full 30 c.c. (or 15 c.c.) capacity of the tank as far as possible, and also keeps the fuel feed reasonably constant, so that the motor is running properly all the time.

Operation of the model under flying conditions involves both the piloting of the machine and the "ground crew" efficiency. Obviously, if a number of re-fuelling stops have to be made, the quicker the model can be refuelled, started and taken off again the better. It is surprising just how much any stop can reduce a high average flying speed to a quite mediocre *overall average* speed. The model has to be designed for quick ground handling. The ground crew have to practice and attain the quickest "turn around" possible.

The power unit

Let us examine the two team racer classes separately. First, the smaller class: Here motor capacity is limited to 2.5 c.c. maximum. Since line length is restricted to 42 ft. and wing area 70 sq. in. minimum, almost any motor of from 1 c.c. upwards can be expected to give satisfactory flight performance with this size of model. The smaller motors will have less power and thus fly the 70 sq. in. (minimum area) model more slowly. Against this they will gain in duration or distance covered without refuelling.

Some comparative figures are available for speed and distance performance of typical motors in Class A,—Table I.

Of these it will be seen that the Mills II and E.D. Bee are about the only motors which could be expected to cover a five mile course on one filling of a 15c.c. tank, and this at a moderate flying speed of some 40—45 m.p.h. The effect of pit stops on the overall average speed for the course can best be summarised in the form of Table II. It should be possible to land, collect, refuel the model and restart the motor and get away again in well under one minute but this latter figure is often quoted as typical.

Long range or high speed?

Given the choice of flying rather more slowly, but with less re-fuelling stops as against short, fast runs, human fallibility would appear to give preference to the former. The less the number of times the model has to be re-fuelled and the motor re-started in the heat of the competition, the less chance is there of the "human element" going wrong and adding to the overall flight time. Against this, of course, is the fact that if the ground crew really *know* the motor and have had plenty of practice at pit stops, there should be no undue delays. The pilot himself will have to bear part of the responsibility here, for it is up to him to land the model as near as possible to the ground crew. Our personal choice would be for the model operating towards the upper end of the possible speed range.

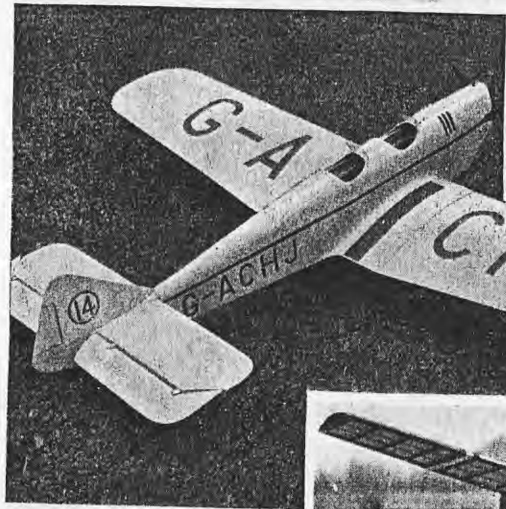
TABLE I

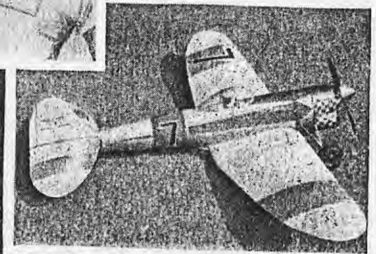
Motor	Estimated Speed (m.p.h.)	Distance Fuel 15 cc.
E.D. Bee	40	5
Mills II	40–45	5–5.5
Allbon Arrow	40	2–2.5
Allbon Javelin	50–55	4
Elfin 1.49	50–55	3–4
Elfin 1.8	55	2–2.5
E.D. II Comp.	50	2.5–3
Elfin 2.49	60	1.75–2
Mills 2.4	55	2

TABLE II REQUIRED FLYING SPEED FOR OVERALL SPEEDS OF 50 M.P.H. (CLASS A)

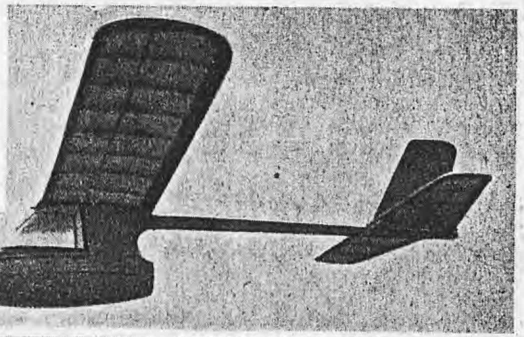
Course	Number of Pit Stops							
	1 of		2 of		3 of		4 of	
	30 secs.	60 secs.	30 secs.	60 secs.	30 secs.	60 secs.	30 secs.	60 secs.
5 miles	54.5	60	60	75	67	100	75	150
10 miles	52	55	55	60	57	67	60	75

The 3.5 c.c. class PAA-Load model has to carry an 8 oz. occupant in a cabin with forward visibility. Jimmy John's design shows American influence at left. Below: A 7 ft. 6 in. low-wing model with 10 c.c. and built co-operatively by members of the Loughton Skyrangers. Below, left: a grand example of the low-wing scale model is John Fozard's Miles Hawk for the E.D. 2.46 diesel.

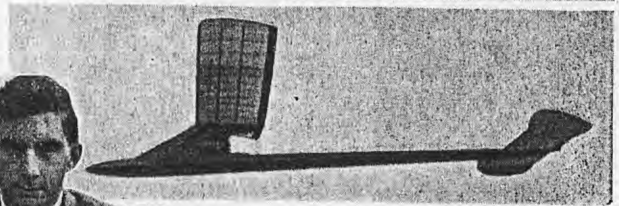




"Consul," a low-wing sport model for 1.3 c.c. by B. L. J. Neal, has unusual ribless wing structure and curved sheet fuselage. This is another A.P.S. design which is very suitable for beginners. Left: A 1.5 c.c. class PAA-Load contest model which makes interesting comparison with the larger model at top. Much larger fin is employed on the shorter tail moment.

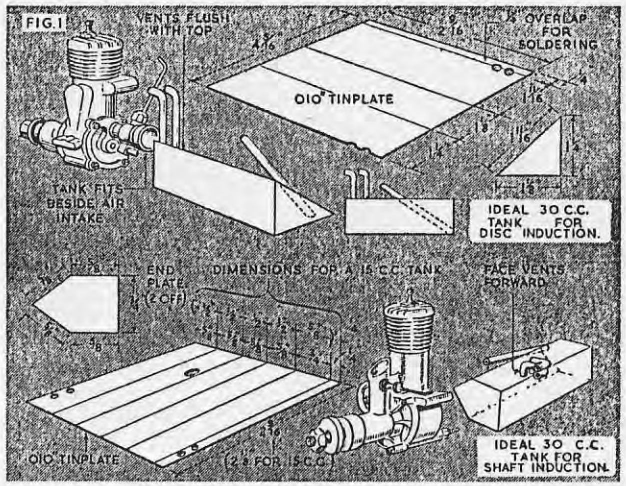


Jetex 200 is mounted atop of fuselage on Twizzler (above), whilst Kit Carson's semi-scale pod and boom design has a low thrust-line. Below, right, is the happy medium in Bill Henderson's Jetex 350 "Vindscreenviper" with central thrustline.



High speed climb with pylon mounted Jetex controlling looping tendencies on this ultra-lightweight design by Dick Twomey at left. Model is known as the "Stilletto" and weighs, complete with unloaded Jetex 200, only 2.2 ounces. Climb is straight and after the style of a rocket!

A good looking stunt design by Bill Morley for the American Fox 35 Glow plug engine. Flaps co-ordinate with elevators for maximum manoeuvrability, whilst the tailplane is built up to a symmetrical section in place of the customary flat plate.



In the Class B sizes, there are fewer motors to choose from. Data corresponding to the figures for Class A motors are as in Tables III and IV.

The same generalisation as regards fuel consumption and speed apply, but it is interesting here to compare the performance of a spark-ignition motor in this class. Operating on petrol/oil mixture a good 5 c.c. spark ignition motor may be expected to give an average flying speed of around 65–70 m.p.h. with a possible range of 6–7 miles on a 30 cc. tank.

On balance the glow plug motor still appears to be the best choice for Class B work. Most glow plug motors in these sizes are extremely easy starting, especially ringed motors, and reliable enough in running, although rather more influenced by tank position and fuel feed than spark motors.

Tanks

It is very important to get the tank position correct—or best suited to the particular motor—so that the motor is running at its best throughout the power run.

For most purposes the simple rectangular tank will suffice, proportioned so that it is relatively long and narrow, but not so deep that the change from static head under starting conditions to actual flight conditions is such as to alter the mixture setting.

Some designers prefer the wedge type of tank as commonly used on stunt models, and there is some justification for this in that team racers often have to be pulled up sharply into tight manoeuvres to avoid collisions. Some typical proportions are given in Fig. 1.

Vent positions are another feature which should receive careful attention. The vents should be at the forward end of the tank and the overflow vent right at the top of the tank so that the full 30 c.c. (or 15 c.c.) internal capacity can be filled with fuel.

Cowlings

Finally on the question of power plants there is the point to consider of whether to mount the motor upright, sidewinder or inverted, remembering that the motor has to be fully cowled and at the same time readily accessible to adjustment,

TABLE III

Motor	Estimated Speed m.p.h.	Distance 30 cc. Fuel
E.D. Mk. IV	65	4–5
Amco 3.5	68	2–2½
D.C. 350	65	4
Yulon 5	70	2–2½
Eta 29	85	2
Frog 500	75	2

TABLE III
FLYING SPEEDS REQUIRED FOR 60 M.P.H. OVERALL FLIGHT AVERAGE (CLASS B)

Course	Number of Pit Stops: 1 of		2 of		3 of		4 of	
	30 secs.	60 secs.	30 secs.	60 secs.	30 secs.	60 secs.	30 secs.	60 secs.
5 miles	66.6	75.0	75.0	100	85.8	150	100	—
10 miles	63.0	66.6	66.6	75.0	70.5	85.8	75.0	100

and, possibly, quick fault-finding.

From the point of view of operational simplicity, particularly with rotary valve motors, upright mounting is to be preferred, with the cowling flared back into the cockpit or cabin lines, for realism.

Sideways mountings is the next choice, which calls for "apple-cheek" cowlings as used on many modern full size lightplane racing machines. This can give a definite, and attractive, semi-scale appearance, but calls for a dummy cowling on the side opposite the cylinder, with resultant extra weight and extra drag. Upright mounting is still first choice, while inverted mounting would appear to have little to recommend it, other than the fact that it enables a good "scalish" appearance to be maintained—and a belief that the inverted two stroke can run on a leaner mixture.

It is important, however, that whatever type of cowling is employed it should be properly ducted. Motors may be called upon to run anything up to ten minutes at a time and need a proper flow of air for cooling. Some of the smaller diesel and glow plug motors run very hot and if completely cowled in with no circulating air, may overheat and even seize up.

Design

The aerodynamic and structural design of the model is the next thing to consider, and these should be developed together. The lighter the airframe the better, for this means that, with a fixed wing area, the model can fly with the wing at a lower angle of attack to generate the required lift. This means, in turn, less drag and therefore greater speed from the same thrust. Wing drag increases rapidly with increasing angle of attack and wing drag contributes a very considerable proportion of the total drag of the model.

At the same time it is no good obtaining a low total weight and this enhanced performance, at the expense of making the model fragile. Team racers must be essentially robust machines. They have to be "put down" often quite roughly, may have to withstand quite violent manoeuvres, and be capable of standing up to quite a lot of punishment. Not the least point of which, is that they will take quite a pounding from motor vibration during the course of a number of ten mile runs—and be liberally sprayed with fuel and oil.

Sheet covered wings can withstand handling better than tissue covered wings, and can be more effectively "proofed."

Similarly with the fuselage. Sheet sides and bottom with a sheet or planked turtle back offers the most attractive solution, hollow log construction would be good, but is rather on the heavy side, and costly. The compromise—hollow log underbody with built up sheet covered sides and top is generally excellent.

What efficient design layouts and component shapes fit in best with these practical requirements? Provided adequate tail area is used, 25 per cent. of the wing area being adequate, the pivot point located on or forward of the centre of pressure of the wings and the centre of gravity of the whole model on or in front of the front line—no stability troubles are likely to be experienced.

If there is any aerodynamic preference it would be for the mid-wing, which then has the additional advantage that the lead out wires can be taken through the wing to emerge at the tips and save a possible source of drag. The same can, of course, be done on low and high wing layouts, but in such cases it is more usual to run the lead out wires above and below the wing surface, respectively, emerging directly from the fuselage side and passing through a wing guide.

TABLE V : DESIGN DATA

Model	Motor	Prop. Dia. X Pitch	WINGS Span	WINGS Root chord	WINGS Tip chord	WINGS Section	TAIL PLANE Total area	TAIL PLANE Elevator area	INS. Overall length	INS. Tank cc.	Wheels ins.
Class A	0–2.5 cc.	7×8	21½	4½	3½	10% Clark Y	20	8	19	15	1½
Class B	2.51–5.0 cc.	8½×10	27¼	6	4	10% Clark Y	30	10	24	30	2

It will, whichever layout is adopted, be advisable to make the wing in one piece from tip to tip. This will give the greatest strength for the minimum weight. It is easier to accommodate such a wing in the high or low position rather than mid-wing.

Wing planform is of some importance. For high-speed flying, induced effects are relatively unimportant. This means in practice, that tip shape is not critical, nor is it necessary to use a reasonably high aspect ratio for efficiency. From the structural point of view a low aspect ratio is very much better, giving a more rigid, stronger wing for less weight. This is really the deciding figure: with maximum aspect ratio not exceeding 6. Corresponding tip shape can be blunt or raked, with slightly rounded edges.

The tapered wing looks better and is possibly slightly more efficient, but any possible gain is not sufficient enough to justify an elliptic planform on this score, except solely on appearance.

A moment arm equal to the wing root chord or slightly greater—and a tail surface area of 25 per cent. of the wing area should then give ample longitudinal stability. At the same time, using an elevator of one third of the total tailplane area with range of movement of about 25 degrees up and 20 degrees down should give snappy response to control when necessary, without danger of mushing or stalling.

Some designers prefer to save a certain amount of weight and drag by using a dihedralled or "V" tailplane dispensing with the fin entirely. This is quite satisfactory on speed models, but where good stability may be required at the lower end of the speed range, such as in landing and taking off, we feel that a fin is most helpful.

This fin may come in for a fair amount of abuse. In the early days of control-line flying when fixed undercarriages were the rule, nose-over landings were common—most of the landing shock, in fact, often being taken by the fin!

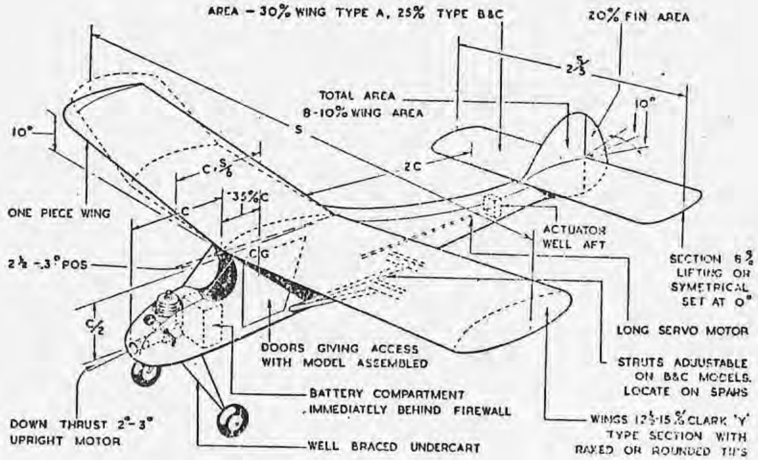
The landing gear itself must be strong enough to withstand the roughest of landings without deformation. The model may have to land and take off again a number of times during the course of one competition flight and if time has to be wasted straightening out wire legs before the wheels will track properly for take off again the unit is obviously too weak.

For Class A models, at least, simple wire cantilever undercarriages will be sufficient—or the American type of bent dural bracket with stub axles bolted on. Such legs must be of dural—not aluminium. Aluminium is too soft and will simply bend and "spread" under load.

The layout, for a low-wing model, is essentially very simple. The wing is located on or around the bottom line of the fuselage. Above this is located the thrust line, as near to it as possible. Mid wing position would be located approximately on the thrust line. The cowling line, proportioned around the motor then fixes the basic height of the fuselage. The full height of the cowling can be maintained back to the cockpit position.

TABLE VI : STRUCTURAL DATA

Model	WINGS L.E.	WINGS Spar	WINGS Cover-ing(sht)	FUSELAGE Sides (sheet)	FUSELAGE Bottom (sheet)	FUSELAGE Top	FUSELAGE Bearers	Tail-plane	Fin (balsa)	Undercart (s.w.g.)	Lead wires (s.w.g.)
Class A	—	—	1/16	3/32	3/32	1/16	3/8×1/4	1/16 ply	1/8	14	22
Class B	1/4	1/4	1/16	1/8	1/8	1/16	1/2×3/8	5/64 ply	3/16	2	20



CHAPTER ELEVEN . . . . RADIO CONTROL

SUCCESSFUL radio control flying can be quite easy—and not all that expensive—provided you go about it the right way. The main thing to aim at is to keep everything as simple and straightforward as possible, so that the chances of anything going wrong are minimised. Nobody in this country has, as yet, achieved *consistent* success with any multi-control system and we are firmly of the opinion that *every radio control flier should start off with a model employing simple rudder control only.*

Now your attitude towards modelling will largely determine the type and size of model to build. If you are building the model to do some radio controlled *flying*, then the model part of it wants to be as simple and straightforward as possible. At the same time, the model itself need not become too functional. It can, for instance, incorporate a cabin to improve appearance, but it should not be elaborate. The more refined design, with semi-scale features, should follow later—after you have gained sufficient experience in radio control work.

The radio as payload

A radio controlled model is, in a sense, a payload model. It has to carry around a certain amount of dead weight in the form of radio gear, batteries and so on. Thus it is to be expected that it is both heavier and more heavily loaded than a comparable free flight power model. It has also to fly differently. The motor on the radio control model is allowed to run for some three or four minutes at a time, or even longer, and hence a "duration" climb is both unnecessary and undesirable.

By duration or normal free flight standards, in fact, the radio model is heavily loaded and underpowered. The former is a disadvantage only as regards take-off and landing, particularly landing. The undercarriage unit has to be robustly constructed to stand up to abuse and the single wire cantilever leg is no longer satisfactory.

Wing loading is one of the most important design factors. With increasing wing loadings, the risk of damage to the model in landings is increased. Thus, whilst a model might *fly* quite successfully with a wing loading of perhaps as much as 2 lb. per sq. ft. wing area, it is not considered advisable to work beyond a maximum figure of 16 ounces per sq. ft. wing area or roughly 11 ounces per 100 sq. in. wing area.

Unfortunately, this does not hold true for all model sizes. Wing loading becomes less important as the model size increases, and conversely. Working down to the smaller sizes of models, a 16 oz. wing loading is too high for comfort. For a 400 sq. in. wing a 12 ounce loading is really quite enough—Fig. 1. The small radio model, therefore, starts at a disadvantage.

It is obvious that the size of the model must be determined by the weight of equipment which has to be carried, and the weight of the motor used. Broadly speaking, we can divide receiver units into two classes—the standard type employing ordinary miniature valves and reasonably sized batteries, weighing about 16 ounces complete, and the thyratron receivers with smaller batteries weighing somewhat less than one-half this amount—say 8 ounces.

Type of motor

Since weight is critical in the smaller sizes of model, the lightest power units are required. This immediately rules out spark ignition under about 5 c.c. motor capacity, which is a pity. For reasons which are not clearly defined, most modellers now appear to have a definite prejudice against spark-ignition motors. Yet from the standpoint of ease of starting and running, consistent and *flexible* performance, and economy, they have much to recommend them. Radio control models do not need a lot of power. They need steady, consistent power, which is the essential feature of any good spark ignition motor with a reliable ignition circuit. Such a set-up lends itself particularly well to two-speed motor hook-up for later development.

In general, diesel and glow motors are rough running by comparison and trouble has been experienced on some smaller designs on this count. Motor vibration has, at times, reached prohibitive proportions, causing the receiver relay or actuator itself to skip and get out of sequence. Some motors are worse than others in this respect, paricularly those which are nitially unbalanced due to he employment of a relatively heavy piston. Experimentation with different propellers—and even locking the same propeller in different positions—can often reduce vibration to an acceptable level.

The net result of the discussion so far is that, broadly speaking, there are two distinct "sizes" for radio controlled models, one relatively small for the lightweight radio equipment and the other considerably larger and suited to a 5 c.c. spark ignition motor or its equivalent. There is, of course, really no upper limit—except on the score of economics—for if we can get the "standard" radio gear into a 6 ft. span model it will go equally well into a 9 or 10 ft. model.

Model A. Lightweight radio equipment. Wing loading 12 ounces per sq. ft. Glowplug or diesel motor 1 to 2 c.c. capacity.

Model B. "Standard" radio equipment. Wing loading 14/16 ounces per sq. ft. 2.5–5 c.c. glowplug or diesel motor; or 5 c.c. spark-ignition motor.

Model C. "Standard" receiver. Wing loading 16–18 ounces per sq. ft. 10 c.c. spark-ignition motor.

Type A models present the greatest scope for ingenuity in design and construction, saving weight to reduce model size and produce a proportionately smaller model. They are also the most inexpensive both as regards time and materials.

Type B models are about the best to start with. Weight control is less critical. Construction can be relatively more robust, without becoming complicated. Crutch construction can be used for fuselages—or normal box construction with sheeted

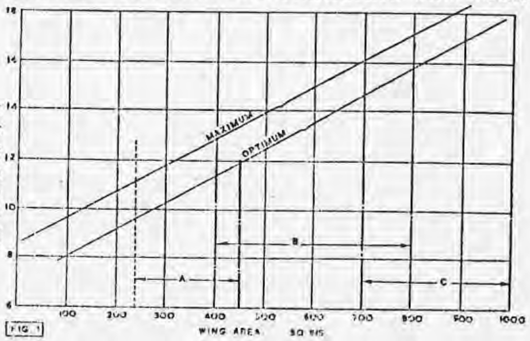


FIG. 1

sides in highly stressed regions. They will, however, cost more than Type A models and take some four times as long to construct. But to offset that, is the fact that they will be less critical on adjustment.

The large Type C models lend themselves readily to experimental work—the fitting of additional equipment, etc., and can be most impressive in flight. They will, however, demand far more time than the average flier is likely to be able to afford, unless he wishes solely to concentrate on radio control flying.

The same generalised design outline can apply throughout this range of sizes, about the only noticeable difference being that the smaller models demand a larger tail-plane area for adequate longitudinal stability. Design proportions are not critical, for all we need is a reasonably stable free flight model which is to be underpowered—by duration standards. The only special feature is that we are going to control this model by means of rudder movement and so we need a design layout which is reasonably stable in turns. Moving the rudder over some 15 degrees on most orthodox free flight models would immediately put them into a spiral dive.

Performance requirements

Another difference between a normal free flight model and the radio model is that we want a fast forward speed under power with only a shallow climbing angle. A radio model is no good if it cannot make headway against a moderate wind drift. If trimmed to have a steep climb, although flying fast, its *groundspeed* will be low. We need a reasonably high ground-speed. We also need a fairly high gliding speed, with as flat a gliding *angle* as possible for the best landing approach. So, ideally, the radio model is trimmed for an under-elevated power flight (either with excessive downthrust or under-elevated rigging condition), and a glide flight corresponding to flattest glide—Fig. 2.

The outline design suggested is an orthodox cabin-type high wing layout, this giving greater latitude in proportions, adjustment and control in turning flight. There is no reason why a shoulder-wing or low-wing machine should not prove equally successful, but it would be more tricky to produce and less suited to a "generalised" layout. About the only differences in outline design between this model and an orthodox free flight cabin model are the reduced tailplane area and increased fin area. The latter is still a debatable point—whether good stability in turns will come from smaller or larger vertical surfaces. But since we have witnessed definite spiral instability troubles directly traceable to too small a fin on a radio model, we prefer to err on the large size.

More theoretical-minded readers who are familiar with C. H. Grant's articles on his C.L.A. theory and placement of side areas, may care to adopt his design suggestions for ensuring a level or nose-up reaction when the model is rolled into a turn.

We are suggesting a similar but purely practical rule for determination of fin area distribution—Fig. 3. Very good results are achieved if the fin area is balanced about a horizontal line through the *actual* C.G. of the model, when the model is inclined at its *actual flight attitude*. The latter is difficult to determine, and so here we must work on a "guess-timation." The figure adopted is a wing angle of attack of between 4 and 5 degrees.

Many present radio control models suffer from the fact of having too much rudder area, or too much rudder movement, or both. Yet at the same time, unfortunately, different conditions demand different rudder power. More rudder power is desirable in windy weather, for example; and the response to rudder under power is different to that on the glide. Regarding the latter, there is something to be said for using endplate fins and rudders, where the rudders are clear of the slipstream and should have a more nearly equal effect under power and on the glide.

A total vertical tail surface area of 10 per cent. of the wing area should be adequate for directional stability. Of this area certainly no more than a quarter, and preferably a fifth, should be rudder area. Five degrees rudder movement in either direction should then be adequate to produce turns, although for various reasons it would generally be advisable to double this travel. It is desirable to be able

to lose height by holding on a turn, but if every turn results in excessive speed being picked up, then neutralising the control and letting the model level out again will generally tend to nose it up into a stall.

If there is too little rudder power, the model will be slow to respond. Control will have to be held on for some time before any appreciable effect is seen and there will be the danger of over-controlling, which does not make it easy to fly out a pre-determined flight pattern.

Correct rudder power is very important and well worth a considerable amount of time spent on its adjustment under flight tests. The exact amount of movement required will vary with different models, even to the same design (on account of slight rigging differences) and it may be found advisable to have alternative high and low power (large and small movement) for different conditions—Fig. 4.

Although rigging and balance are seldom critical, a radio model needs just as much trimming out and careful adjustment as any duration machine—if best results are to be obtained. Rudder neutral must coincide with straight flight, and it is quite a good plan to incorporate a trimming tab on the rudder itself, or the fin, to trim out any asymmetric rigging. Glide path with neutral rudder should be straight, although some fliers prefer a wide circle on the glide in "neutral" as a safeguard should the model fly out of transmitter range.

Similarly, under power the model should fly straight in neutral.* Having first established the trim for straight glide in neutral, any adjustments to power-on trim can be made by giving the motor sidethrust, as required.

To combat sideslipping in turns, a dihedral angle of about 7–10 degrees should be used on the wings. Anything less is likely to lead to trouble, particularly on the smaller models. There is, actually, considerable evidence to support the use of a polyhedral wing as giving smoother turning flight.

Structurally the model can follow con-

* Straight flight should be obtained from *both* neutral positions of the actuator. It is a common error to get *two* neutral positions due to not setting up the actuator and rudder linkage accurately. This can prove most annoying in flight.

FIG 2

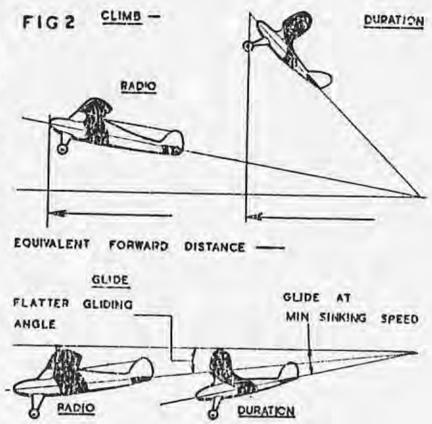


FIG 3

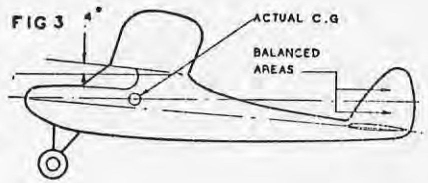


FIG 4

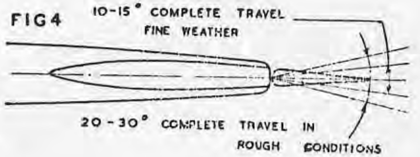
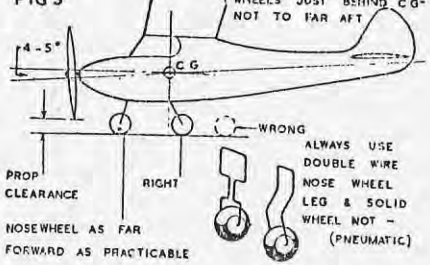


FIG 5



ventional free flight practice, but strengthened up all round, particularly the wing centre section and the fuselage fore-body. The undercarriage especially demands careful treatment. On theoretical grounds, the nosewheel or tricycle undercarriage is undoubtedly the best proportioned as shown in Fig. 5. This has far less tendency to bounce than the conventional two-wheel type. Unfortunately, it has several practical disadvantages. The nosewheel must inevitably be long to give adequate propeller clearance, which at once makes it more vulnerable. Even if the gear is proportioned so that all three wheels touch down at about the same instant on a normal landing approach, on any poor landing approach the nosewheel takes the whole landing load initially. In other words, in any bad landing, the mosewheel takes a really hard knock. Even with the toughest steel wire the leg will be bent back in use. A bad landing will wrap it around the bottom of its fixing former and it is always advisable to leave an opening in the bottom of the fuselage into which the wheel can be knocked without structural damage.

Provided you are willing to accept the fact that a bad landing *will* bend the nosewheel leg in this manner, a tricycle undercarriage can be used quite satisfactorily on models up to 6 ft. span and 6 lb. weight, but larger models should employ a rigid leg with some form of springing.

Practical requirements

Orthodox undercarriages appear to be more favoured for the smaller models—one particular advantage being that they are lighter; but again need to be more rigid than that of a free flight model counterpart, and "V" wire legs with a spreader are not uncommon and quite practical.

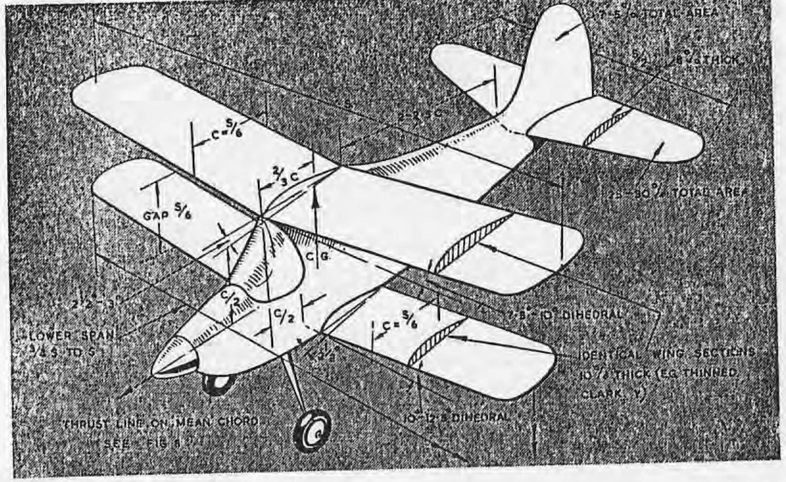
From the point of view of structural efficiency, a four component assembly is best. The wings are in one piece, which is generally stronger and lighter than a two-piece wing joined with dowels. The motor unit is complete and detachable, so that any damage to the bearers, etc., in a crash landing is restricted to this component; also thrust line adjustments are simplified. The fin and rudder are built as an integral part of the fuselage, which is complete with all radio gear, batteries, etc. The tailplane is the fourth unit.

Practical limitations, e.g., transport, may dictate certain modifications, e.g., a two-piece wing in the larger sizes; or it may be thought advisable to mount the motor unit integral with the fuselage, especially with spark ignition.

Access to the radio gear, batteries and actuator is very important. It should be possible to reach all these components for adjustment, checking or replacement with the model completely assembled. In other words, it should not be necessary to take the wings off, for example, to adjust the receiver relay. This generally means that access doors or hatches have to be cut in the fuselage and it is very necessary to do this *sensibly*. Cut-outs should be made as small as possible, without making adjustment or access awkward, and main fuselage members should never be cut through at these points. The doors or hatches when fitted should fit *tightly* so that they will then restore the fuselage strength under compressive loads. Obvious weak points in the structure can be strengthened up locally, one of the main things to avoid being an abrupt change in loading where a relatively strong part of the fuselage continues as a simple box frame.

AERODYNAMIC DATA

Model	Motor cc.	WING			TAILPLANE			L.O.A.	WEIGHTS		
		Area sq. in.	Span	Chord	Area	Span	Chord		Total oz.	Radio oz.	Air-frame oz.
A	1.5	396	50	8	120	20	6	36	30	10	16
B	2.5–5	850	74	12	215	29	7½	50	80	18	40
C	10	1300	100	13	300	35	8½	60	160	24	120



CHAPTER TWELVE . . . . BIPLANES

BIPLANES appear always to have had a more limited appeal to aeromodellers. Befor the war there was an annual S.M.A.E. competition for rubber model biplanes and a number of contest models of this type were produced. Some of the best performances, however, were put up by orthodox monoplane duration models "converted" by the addition of another wing, often with no further modification than this. In other words, tail and fin area was unchanged, the additional wing slung beneath the fuselage appearing to have but little effect on stability. In the post-war years the biplane rubber model is a rarity.

For various reasons the performance of a biplane does not compare with that of an orthodox monoplane as regards duration work. Basically the biplane layout is adopted to obtain more wing area at reduced structural cost. In full size practice it was, until recently, easier to obtain wing area at light overall weight with a biplane wing than a cantilever monoplane wing. The same does not hold true for models. If anything, the weight comparison would be in favour of the monoplane and so on this score there is little or no justification for the biplane layout.

In the power duration field only a very few successful biplanes have appeared. None have been as good as their monoplane contemporaries, losing especially in climb. In other words, the biplane arrangement, area for area of equivalent lifting surface, has greater drag. This is partly due to the fact that biplane wings interfere with one another, reducing the efficiency of each. The *total* area of biplane wings, for example, needs to be more than that of a monoplane wing of the same lifting power.

Certain layouts can be used to minimise biplane interference and thus increase the efficiency of the individual wings. A large gap or spacing between the wings, for example, minimises interference and this is usually adopted, but we shall consider some of these points in more detail later on.

A particular appeal of the biplane is that it is attractive, both in appearance and in flight. It is possible, too, to approach closely to a semi-scale layout on a biplane. Slightly less dihedral is needed, for example, which, coupled with the shorter span, gives a certain "full size" illusion. As a sports model the biplane becomes an attractive proposition and something "out of the rut."

The biplane sports model, in fact, is no more difficult to design than its monoplane counterpart. Of the two the biplane with its higher drag values is likely to be safer.

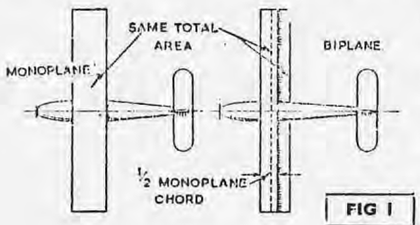


FIG 1

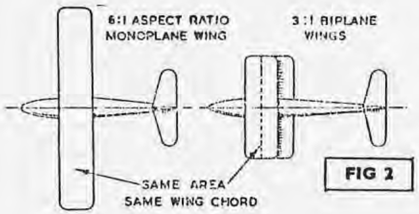


FIG 2

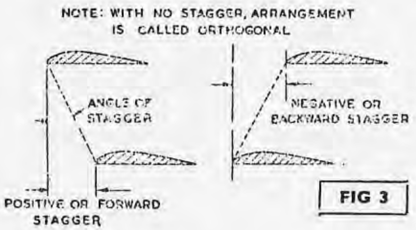


FIG 3

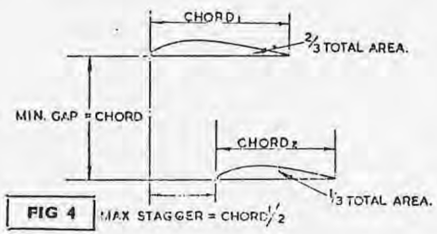


FIG 4

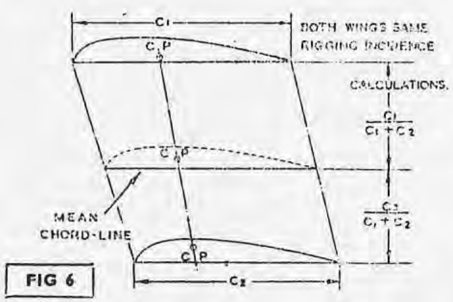


FIG 6

Gap and Stagger

First there are a number of definitions applicable to the biplane which it is as well to understand. Most of these relate to the rigging of the two wings. The gap, as we have previously mentioned, is the distance between the two wings. All biplanes must, obviously, have a certain gap and, in general, this should be as large as possible. For satisfactory efficiency a minimum figure is usually quoted of gap=wing chord (or chord of the largest wing if these are of unequal size). There is no theoretical upper limit. Above a gap of about one and a half times the chord each wing acts as a single monoplane wing with no interwing interference.

This brings up a point that it should be possible with a large enough gap to produce a biplane where the total area is equally as effective as that of a monoplane wing of the same area. Unfortunately, however, this ignores "scale effect" or the fact that, as far as models are concerned, larger wings (and larger wing chords especially) are more efficient than smaller wings. The monoplane and biplane compared in Fig. 1, for example, have the same span and total wing area. Assuming that the biplane gap is such that the two wings are each operating as monoplane wings, in effect, but the chord of each wing is only one-half the chord of the monoplane wing. Each biplane wing, therefore, is less than one-half as efficient as the monoplane wing owing to the reduced chord. Preserving the same chord, for similar aerodymanic efficiencies, the biplane span is reduced to a ridiculous figure with each biplane wing having an aspect ratio of only 3 : 1—Fig. 2. This low aspect ratio will result in increased induced drag and the reduced span will also probably be insufficient for stability, especially in controlling torque. A large gap, therefore, in spite of being desirable, is still no complete cure for biplane inefficiency problems.

Somewhat the same effect as gap can be produced by locating one wing of a biplane backwards or forwards relative to the other. This is known as stagger—backwards or forwards, depending on the relative position of the upper wing—

Fig. 3. Theoretically, forward stagger is best and the use of stagger enables the gap to be reduced for the same overall efficiency. If both wings are rigged to lift to comparable degrees the upper wing with forward stagger actually has less drag than the lower one. In other words, the centre of drag of the biplane arrangement is lowered, which can also have a stabilising effect, under power.

However, some designers prefer to use stagger for another stabilising purpose by introducing *decalage*. Decalage is a difference in rigging incidences between the two wings—Fig. 4. If the top wing is set at a greater angle of incidence the combination is said to have positive decalage; if the lower wing has the greater incidence, negative decalage. Positive decalage is more usual with forward stagger.

With positive decalage the upper wing will reach its stalling angle before the lower one. Used with positive or forward stagger, therefore, the lower wing will act like a short-coupled tailplane to improve longitudinal stability. When the upper wing has stalled, the lower wing, farther aft, will still be lifting strongly helping to correct the stall. The effect, however, is small compared with tailplane power for similar correction, and positive decalage does not seem worthwhile including on this score alone.

Design for Efficiency

Reviewing the biplane arrangement, as far as we have gone, we have established that we want a large gap, whilst stagger can also be used to produce a similar slight increase in efficiency. At the same time our biplane arrangement is still inferior as compared with a monoplane wing.

It is important, therefore, to make sure that both wings of the biplane operate as efficiently as possible. In a sports design we are not concerned so much with low

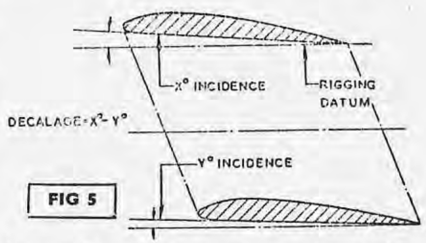


FIG 5

drag values, but require a reasonable amount of lift for slow flight. It would, therefore, seem logical to arrange the wings at a similar incidence and so space them that they are operating virtually as separate monoplane wings. Some of the rubber models entered in the biplane contests, for example, used an added lower wing rigged so that it was operating at a very low angle of attack in flight. The object was to reduce the drag of this second wing as far as possible and not bothering about getting much useful lift from it. The upper wing was relied upon to provide nearly all the lift required. Similarly, rigging one wing of the biplane to act partly as a stabiliser—which it can only do by reducing the efficiency of the biplane arrangement as a source of lift—does not seem worthwhile when we can produce the same, or better, effect with a tailplane of suitable proportions.

The size and proportions of the two wings are the next factors to consider. As far as overall efficiency goes it seems that the larger one wing of the combination is in proportion to the other, the better, until monoplane efficiency is achieved when the larger wing is 100 per cent. There is a limit, however, to what constitutes a biplane and when it becomes a monoplane with an additional stub wing or winglet.

The usual limit is where the lower wing is not less than one-half the area of the upper wing. If the lower wing is smaller

EFFECT OF GAP ON DESIGN LAYOUT

GAP*	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3	1.4	1.5
LOWER SPAN† ...	50	55	60	65	70	75	80	85	90	95	100
TOTAL AREA	120%	116%	112%	105%	104%	100%	98%	96%	94%	92%	90%
STAGGER ANGLE ...	60°	—	50°	—	—	40°	35°	30°	20°	10°	0°

* CHORDS † % UPPER SPAN

than this then the layout is called a sesqui-plane. Some Nieuport biplanes of World War I were sesqui-planes, for example. The question is now whether to proportion the two wings in the ratio 2 : 1 for "minimum" biplane layout.

If for any reason the gap has to be kept small—say, under the chord length of an equal-area biplane—then there are good reasons for adopting this layout—Fig. 5. If, however, there is no particular restriction on the gap, then for general ease of working, identical wings may be employed. These two should be of the same section, in fact there is very little justification for using different sections on upper and lower wings, unless for longitudinal stability reasons, and as we have previously noted, such a move is unnecessary.

Six-to-one is about the optimum aspect ratio for constant chord power model wings. The danger in increasing it to 8 : 1 is the possibility of a weaker wing structure, or greater weight of wing for the same area, and the possibility of reduced efficiency from the smaller chord resulting.

The rest of the model we can then base around the biplane wing arrangement, as shown in the heading diagram. All the other proportions can be related to wing area or wing span. The nose length is the only unknown factor, for this will be dependent on motor weight. A heavy motor will need a shorter length of nose to balance out at the required C.G., a light motor, a long nose. Theoretically this should have an effect on the fin area required, but this does not appear to be critical in practice.

The layout shown in the heading drawing utilises a stagger of one-half of the wing chord, which is about the maximum which should be used. Less, of course, can be employed when the centre of gravity position indicated will move forwards accordingly. Less stagger, however, may well reduce efficiency with a gap of one chord length. This gap already is quite high and demands a very deep fuselage or the upper (or lower) wing mounting away from the fuselage, either on a pylon or struts. It is advisable to raise the upper wing rather than lower the lower wing, for the same reasons that high or parasol wing monoplanes are more desirable, from the stability point of view, than low wing designs.

It is possible, theoretically, to calculate the equivalent monoplane wing of any biplane arrangement and this method can be adopted, if desired, for rigging and balance, as well as overall proportioning. A simple geometric construction for determining the position of "equivalent" monoplane wing is then shown in Fig. 6.

Motor	Equivalent Monoplane Area (sq. ins.)	Total Biplane Area (sq. ins.)
12 str. ¼ in.	160	260
16 str. ¼ in.	220	300
.5 cc.	200	300
1–1.5 cc.	300	456
2.5 cc.	400	600
3.5–5 cc.	600	784
10 cc.	1,000	1,240

GENERAL LAYOUT DATA

UPPER WING		LOWER WING		Stagger	C.G. from L.E. Upper Wing	Moment Arm	TAILPLANE		Fin Area (sq. in.)
Span (ins.)	Chord (ins.)	Span (ins.)	Chord (ins.)	(ins.)			Span	Area	
30	4½	28	4½	2	3	10	15	80	20
32	5	28	5	2½	3½	12	16	100	30
32	5	28	5	2	3½	11	16	90	25
40	6	36	6	3	4	14	18	120	32
44	7	42	7	3½	4	16	21	135	42
50	8	48	8	4	6	18	24	200	50
64	10	60	10	4	6	24	30	300	80

24.0
21.6
45.6

$\frac{120}{18} = \frac{20}{3} = 6.6$

CHAPTER THIRTEEN

FLOAT DESIGN FOR SEAPLANES

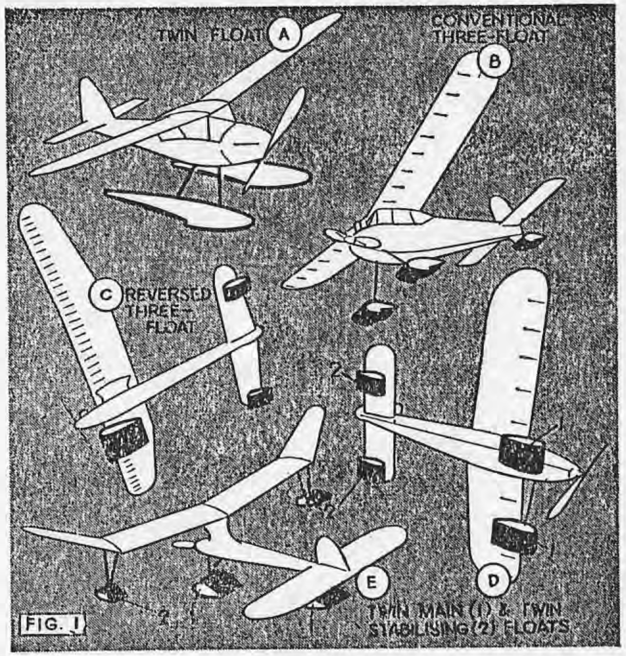


FIG. 1

THE first and most essential function of the flotation gear is to support the weight of the model so that it will rest on the surface of the water. The total volume of float(s) which would do this would be any system where the weight of water displaced is equal to the weight of the model. If this were exactly so the whole of the float(s) would be just submerged. This, obviously is not a practical solution. The floats, must be larger than this minimum size and, in fact, it is a fairly well established rule that the float volume should be capable of supporting *three times* the weight of the model. It is therefore readily possible to calculate the required total float volume, (in cubic inches).

Float volume = 5 W (approx.)

where W = weight of model (ounces)

Five possible float arrangements are shown in Fig. 1. The most used types are B and C. Type C is very popular in America on contest power models, although type B is also widely employed. These two, being the generally adopted layouts, will be described in more detail later. First we will discuss the failings of types A, D, and E.

Twin floats of type A are, of course, the most realistic. Unless the main object is to preserve a certain semi-scale appearance, however, it has little else to recommend it. Water drag is high since the floats are long and thin. They have to be long to

TABLE I. FLOAT PROPORTIONS—TYPE B.

MODEL	TOTAL FLOAT	FRONT FLOATS			REAR FLOAT		
Weight (ounces)	Volume Required (cu. ins.)	Length	Breadth	Depth	Length	Breadth	Depth
4	20	5¾	2	1	5	1¾	1
6	30	6½	2¼	1⅛	5½	1⅞	1
8	40	7¼	2½	1¼	6¼	2⅛	1
15	50	7¾	2½	1⅜	6¾	2¼	1⅛
18	75	8¾	3	1½	7¾	2½	1¼
20	100	9¾	3¼	1⅞	8¼	3	1½
30	150	11	3¾	1⅝	9¾	3¼	1⅝
40	200	12	4	2	10½	3½	1¾
50	250	13	4½	2⅛	11½	4	2

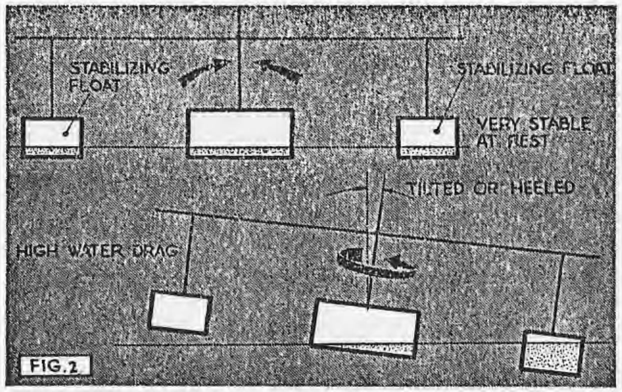


FIG. 2

give sufficient longitudinal stability or resistance to tipping. A float which "drags" fore or aft will give unsatisfactory take-off characteristics.

Where plenty of power is available, twin-floats of adequate length may be satisfactory for sport flying, but in the case of a rubber model, take-off is generally prolonged. The run required to unstick may be longer than the water space available, particularly if a tank is being used.

Type D is a system basically similar to type B, but with twin rear floats for increased stability. Such extra stability, however, is only gained at the expense of increased weight and water drag and so has little to recommend it. Similarly type E has seldom worked out satisfactorily in practice. In the four-float system of type E, the two central floats are the main flotation system, the outer wing tip floats are added to improve lateral stability. Theoretically this is a very good arrangement but should one of the tip floats be depressed during take-off — as is most likely under the torque reaction of the motor—this tip float will simply slew the model round—Fig. 2.

This failing—a float digging in and slewing the model round—is a fault common to all twin-float systems. The increased water drag of the depressed float turns the model off course and may even cause it to tip over completely. It is aggravated by wide spacing of the floats. Thus the wider the main floats are spaced apart, in either A or B, the greater the danger of this happening. At the same time it is necessary to secure some measure of lateral stability on the water, otherwise the model may tip right over at the moment it is released. As soon as it gathers speed the lift of the wings will tend to keep the model level. Hence rapid initial acceleration is a definite asset for seaplane take-offs.

Best Model Layouts

The two systems we shall concentrate on as being most suitable for contest work are B and C. Some details of A will also be given for the sport fliers who are seeking semi-scale appearance. The points to be discussed are the relative sizes of the floats, their location relative to each other and to the model itself and their attitude relative to the model. The actual shape and design of the floats themselves will also be of considerable importance.

As regards the relative sizes of the floats the solution for the twin-float system is obvious. The required total float volume can be calculated very simply

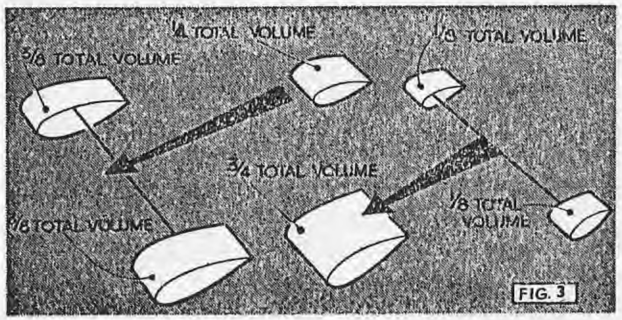


FIG. 3

and this volume is proportioned equally between the floats. Some systems have been produced with one float of a twin-float system slightly larger than the other to counteract torque, but this does not appear necessary, or even desirable.

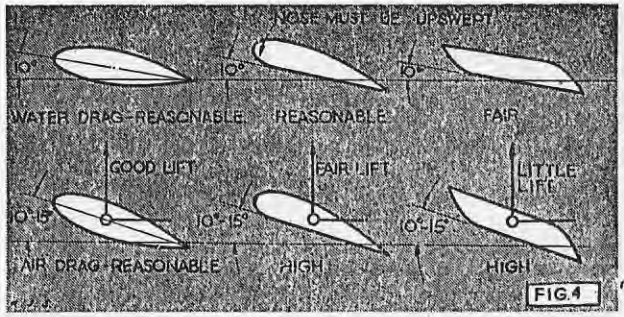


FIG. 4

The solution for the three-float systems—B and C— is also simple, Fig. 3.

Front float(s) = $\frac{3}{4}$ total float volume.

Rear float(s) = $\frac{1}{4}$ total float volume.

If there are two floats at the front, therefore, each float must account for $\frac{3}{8}$ of the total float volume. Twin rear floats will be $\frac{1}{8}$ of the total volume each. These figures have been found to give satisfactory performance both on power models and rubber driven models. In the latter case the rear float volume is sometimes boosted above this recommended design figure, but this does not seem necessary.

The simplest type of scow float is just like a low aspect ratio thick section symmetrical aerofoil. It is necessary to have the nose of the float upturned to prevent it digging into the water as it moves forward. In the parallel-sided scow float this is achieved by sweeping up the bottom line at the bows. In the air this type of float will have a higher drag than the somewhat thicker symmetrical section. Under flight conditions the floats will be at quite a considerable angle of attack. Some designers have used this feature to design floats which will contribute lift in flight —Fig. 4—but all normal floats will generate some lift at such an attitude. Of the three illustrated the streamlined float still has the least drag, and possibly nearly as much "lift" as the aerofoil float.

Typical proportions for floats of this type for schemes B and C are then summarised in Fig. 5. The same proportions apply to front and rear floats. Width is generally about one third of the float length, and depth about one half of this figure. These proportions may be varied somewhat, if desired, but width should never be less than one quarter or more than one half of the length.

The question of whether or not to use a step in the float is an open one. Theoretically there are good reasons for so doing, but in practice none of the three float systems really seem to require stepped floats provided adequate take-off power is available. It is more important to get the model to accelerate rapidly and unstick in a few feet than to bother about correct planing angles for the floats and a prolonged take-off.

Some modellers do use steps, but similar layouts have performed just as well without. A compromise is to depart from the purely symmetrical shape and sweep the top line down to a straight aft underbody. This has a certain beneficial

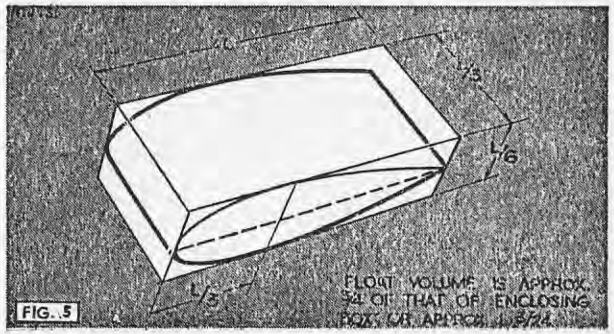
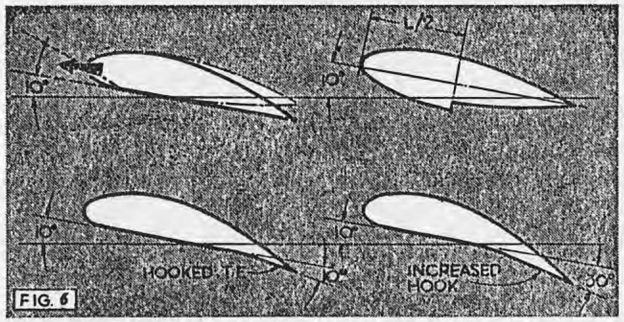


FIG. 5



effect on take-off as it increases the angle of attack of the float—or rather maintains the same angle of attack as the float starts to come out of the water—Fig. 6.

The Hooked Float

Sometimes this is carried a stage further and the rear of the floats swept downwards or hooked. This appears to have a similar action to a step in helping the float to unstick and is definitely effective. The air drag of such a float, however, is higher than that of the other types.

With a twin-float layout the problem is somewhat different. In the first place, being used on a sport model, the model itself has a less powerful motor. The added weight of the floats may bring it near to an under-powered condition. Also the floats themselves have a rather high water drag and, not the least factor, a semi-scale model should have a semi-scale take-off with a rather long run. Hence in such cases stepped floats should be used, either of the scow type or curved section, possibly with a "boat" entry.

Unlike the scow float, too, it is not uncommon to find such floats tapered in planform, although it is always advisable to retain a broad bow.—Fig. 7.

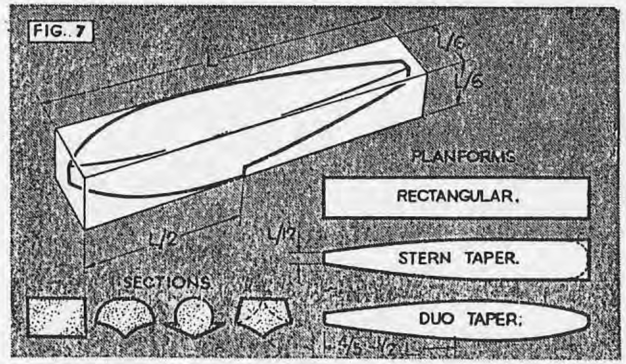
Take-off performance of low-powered twin-float models can be improved by venting the step. This consists of fitting an air scoop to the top of the float which traps air and forces it out through the bottom of the float just aft of the step.

We now come to the disposition of the floats. First, the three-float system—Figs. 3 and 9. The diagrams summarises the basic requirements.

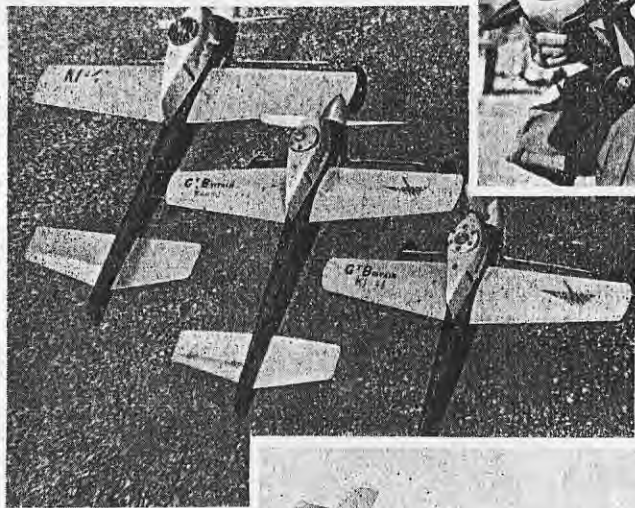
Practice has indicated that the angle of incidence of all the floats, relative to the centre line of the model, should be about ten degrees, certainly no less, although sometimes the floats are rigged relative to the *thrust line*, when the corresponding minimum figure is 5 degrees.

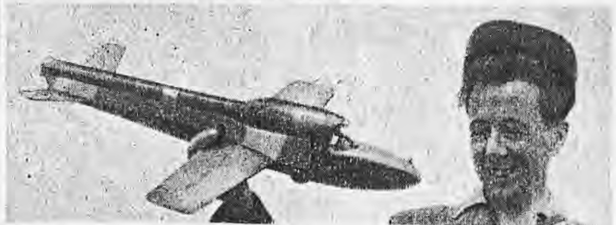
The front float(s) should be as far forward as practicable to prevent tipping. Ideally, the leading edge of the float(s) should come in front of the propeller disc. For properly balanced proportions, the rear float should then come so that its moment about the centre of gravity balances out the moment of the front float. In other words, with the proportions already given, the distance from the rear float to the centre of gravity of the whole model should be three times the distance of the front float(s) from the centre of gravity.

Propeller clearance will determine the vertical location of the front float(s). The height of the rear float should then be chosen so that the thrust line is at least 10 degrees inclined upwards from the waterline. Unless the thrust line



G. J. Rae of Malvern and his colourful class B team racer, known as the Rivetter. Engine is a glow plug ETA 29. (Bill Dean Photo). Below, Three speed models by Peter Wright, each in its turn a record holder, and all with metal wings and tails. Left, a McCoy 49; Centre, a Dooling 29, and right, the famous "Gook" with glow-plugged E.D. 2.46 Racer.

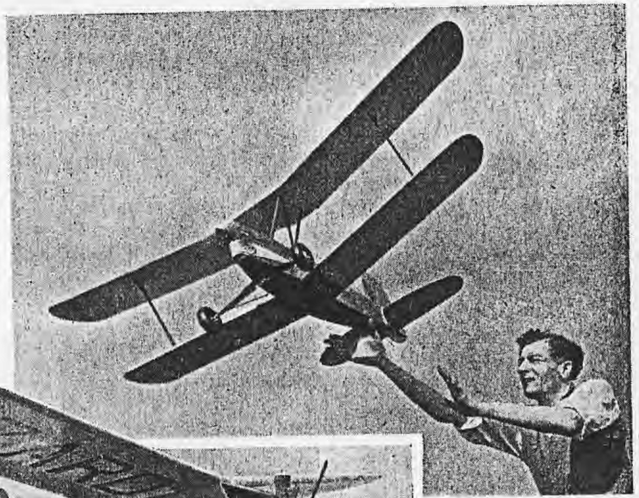




Peter Donavour-Hickie and his Dynajet powered jet speed model. Note the metal fairing between the jet and fuselage, and the upper lip given to the jet intake. Performance is in the region of 130 m.p.h.

Below: R. Davenport's all-British model with Carter/Davenport 10 c.c. racing engine, the first in Britain to exceed 150 m.p.h. with regularity. Top speed at the '53 British Nationals was 158.7 m.p.h.

Right: The charm of the Biplane sport model is such that Basil Brooks has specialised in this type of model for many years. Here he is seen launching his famous "Brooks Biplane" for 2.5 c.c., the plan for which is available through A.P.S. Below, a multi - wheeled heavy-weight radio design by Claud McCullough of the U.S.A. Fuselage parts in two along the centre line.



Roger Clark prepares to launch Sid Allen's Radio Queen, this model won almost all of the principle radio control contests in 1953.

Above, left: Minerva is an old A.P.S. favourite plan and remains as one of the few popular biplanes. At left: Utility is the keynote of Mr. Rhodes radio model (Frog 500): but despite its austere lines, this model has great all-weather perform-ance.

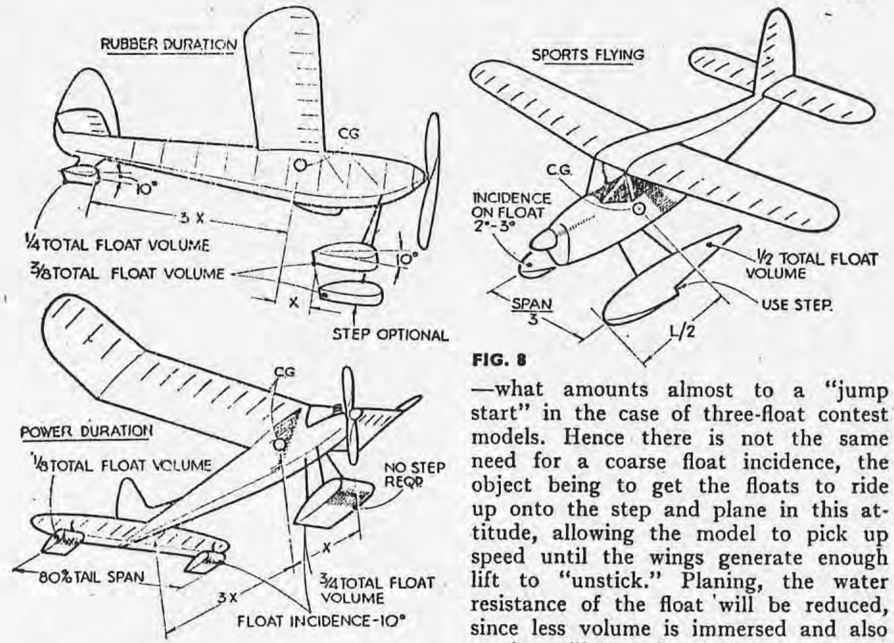


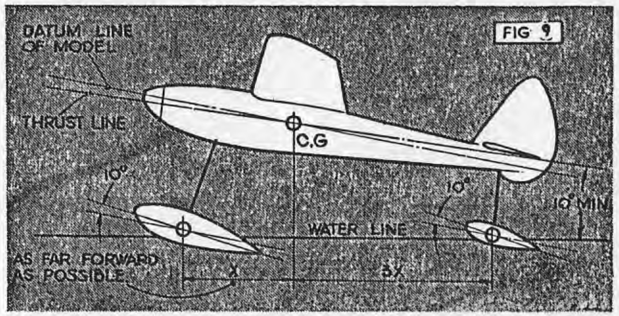
FIG. 8

is directed upwards a short, snappy take-off in impossible and none of the three-float systems is particularly stable for prolonged planing. A study of plans of successful model floatplanes shows that this thrust/waterline angle is often considerably more then 10 degrees, twice this figure not being uncommon on rubber models.

Float spacing for adequate lateral stability—without running into yawing troubles—is rather more of a guess. The quicker the model is expected to take off, the less troublesome the problem. Most designers try to use as wide a track as possible without running into trouble, and some typical figures from successful practice are given in Fig. 8.

Layout of the twin-float seaplane differs somewhat, for in this case we have not got the short take-off run—what amounts almost to a "jump start" in the case of three-float contest models. Hence there is not the same need for a coarse float incidence, the object being to get the floats to ride up onto the step and plane in this attitude, allowing the model to pick up speed until the wings generate enough lift to "unstick." Planing, the water resistance of the float will be reduced, since less volume is immersed and also suction will be reduced since the wetted area of the float is less. Until the float is planing, however, water drag is high. A common fault with such types is poor float design, so that the floats never do reach their planing attitude and all the power is used up in dragging the floats through the water.

It is still desirable, but not strictly necessary, to maintain a certain positive angle between the thrust line and the waterline, but this now need only be a degree or so. An excessive float incidence, in fact, is undesirable. When the model is



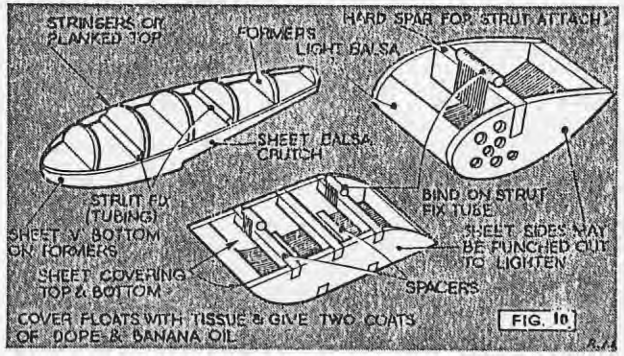


FIG. 10

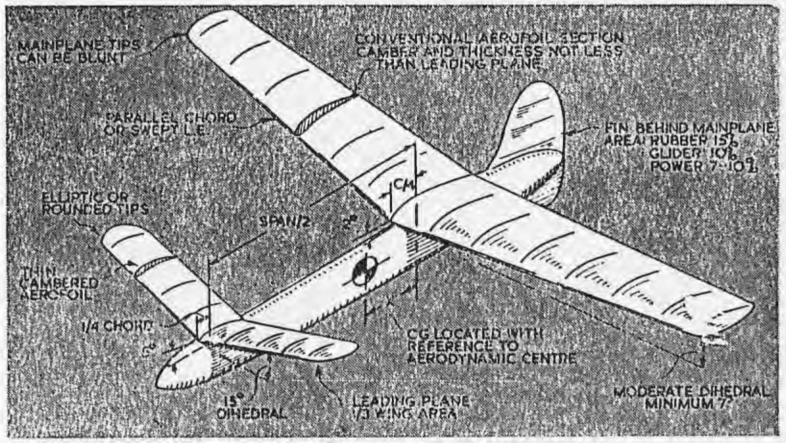
running on the forebody of the floats, i.e., planing, the wings must have a positive angle of attack, otherwise however much speed is built up, the wings will not generate enough lift to unstick. If, for example, the model planed nose-down with the wings at a *negative* angle of attack, increasing speed would build up more *negative* lift, holding the model on the water more firmly. For this reason, therefore, there should be a certain positive incidence between wings and float line, even if this means that the thrust line has a negative value relative to the water-line.

The cocked-up angle of the floats on model floatplanes has often been a matter of comment as (apparently) contrary to full scale practice. The truth of the matter is that model design requirements and full scale requirements are so different. The take-off run of a full size seaplane is prolonged with the planing attitude controlled by the pilot. The successful model floatplane usually hops clear of the water with the minimum of forward run. Excessive forward run is, in any case, often disastrous, particularly for contest work where the take-off area may be restricted in size to that of a relatively small water tank. Twin-float and flying boat designs are, however, capable of planing take-offs when space is available.

To conclude, typical construction details of flotation gear are summarised in Fig. 10, whilst the tables list suitable float sizes and proportions for a range of rubber and power models, together with material specifications. It goes without saying that all floatplanes should be given a more waterproof finish than ordinary models—this is not only confined to the floats themselves. Banana oil is a good waterproofing medium, especially if applied after a coat of ordinary dope. On power models, ignition circuits (where applicable) should be protected by coating with warm paraffin wax. The motors themselves, if ever "dunked," should be washed out with alcohol (e.g. methanol) and thoroughly dried off. It should be remembered, too, that model engines are made from light alloys particularly susceptible to attack by salt water. If operated from the sea or salt water, therefore, a complete clean down and drying of the engine should follow each day's flying—without fail, otherwise corrosion may soon set in on vital parts, ruining the engine for further use.

TABLE II. FLOAT PROPORTIONS. TYPE "C"

MODEL Weight (ounces)	TOTAL FLOAT Volume required (cu. ins.)	FRONT FLOAT			REAR FLOATS		
		Length	Breadth	Depth	Length	Breadth	Depth
4	20	7¼	2½	1¼	4	1½	¾
6	30	8¼	2¾	1⅜	4½	1⅝	⅞
8	40	9	3	1½	5	1¾	1
10	50	9¾	3¼	1⅝	5½	1⅞	1
15	75	11	3½	1¾	6¼	2	1¼
20	100	12	4	2	6¾	2¼	1¼
30	150	14	4½	2¼	7¾	2½	1⅜
40	200	15½	5	2½	8½	2¾	1½
50	250	17	5½	2¾	9¼	3	1½



CHAPTER FOURTEEN . . . . CANARDS

THE Canard or tail-first layout is a neglected design and yet one which holds considerable promise of excellent results—theoretical if not always achieved. Like all the other relatively neglected types, however, successful canards are in the minority, mainly because they are under-developed. Few designers have ventured into this realm and so there is very little data available on proportions, shapes and sizes for other would-be designers. The last of the American CO_2 records was held by a canard layout (the CO_2 classifications have now been abandoned; motors of this type now come into Class ½A) and there have been successful canard rubber power models, gliders and free flight power designs—to say nothing of control line canards.

The simple theoretical advantage of the canard layout is that by placing the tailplane in front of the wing and arranging it at a greater incidence, it will always stall before the wings; and thus such a layout should be virtually stall-proof, or at least have very satisfactory longitudinal stability—Fig. 1.

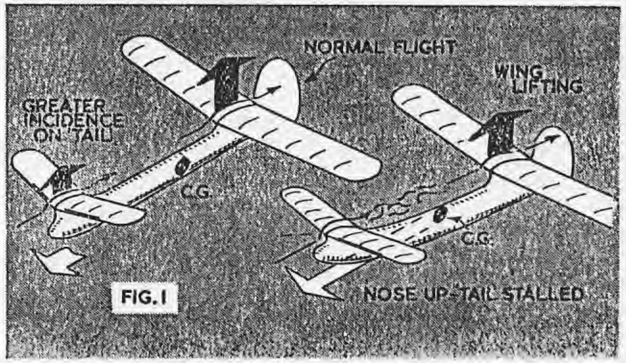
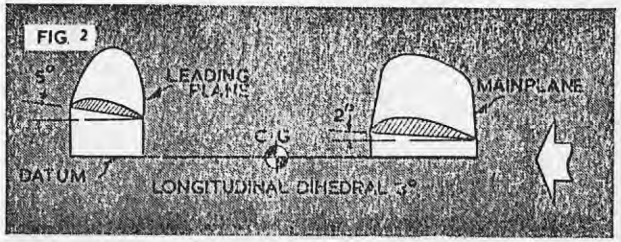


FIG. 1

A second theoretical advantage is that logically, the canard arrangement goes hand-in-hand with a pusher propeller on a powered model and a pusher propeller is, or should be, slightly more efficient than a similar tractor propeller.

However, it is an unfortunate fact that the ultimate performance of a model aeroplane is not always as theory would predict. Almost all the major problems have to be worked out the practical way—by trial and error.

A skeleton canard layout is sketched in Fig. 2. A positive difference in incidence between the leading plane and the wings is essential for longitudinal stability, for the leading plane must always stall before the



wings. The centre of gravity of the whole model is located somewhere between the two planes so that, when trimmed out, leading plane lift times moment arm, equals wing lift times wing moment arm. If this were not so then the model would be out of trim and either loop or dive. In actual fact this simple equation may not be exactly true for there are various drag forces to consider which might demand slightly more "leading-plane power," or "wing power" to cancel out.

Canard Snags

Now with the set-up shown, what is likely to be the best trim for maximum performance? Obviously we have one limit. We cannot fly the leading plane at a higher angle of attack than its stalling angle and this in itself is significant. The wings are rigged at a smaller angle of attack than the leading plane and hence, with the model trimmed with the leading plane just about to stall the wings will still be several degrees below their stalling point.

This does not fit in well with duration requirements for it is an established fact that for maximum glide duration the model is trimmed so that the wings are operating at near their maximum angle of attack (just below the stall). A canard of similar proportions, therefore, would always be operating at a lower wing angle of attack and will have a higher rate of descent.

To minimise this difference it appears that the logical thing to do is to ensure that the wing is lifting as strongly as possible, *i.e.*, design for the most forward C.G. position possible. This means a small difference in incidence between leading plane and wings and/or a small leading plane. The latter approach is not satisfactory. It seems that a leading plane of less than about 30 per cent. of the wing is inadequate.

Balance in Design

The relative position of the centre of gravity will be a critical factor in determining the stability of the model and something more than a cut-and-try method is desirable. Accordingly we recommend the solution suggested by the American designer of unorthodox models—Henry Cole. This consists first of finding the aerodynamic centre and locating the final C.G. position 25 per cent. of the average (wing) chord forward of this point.

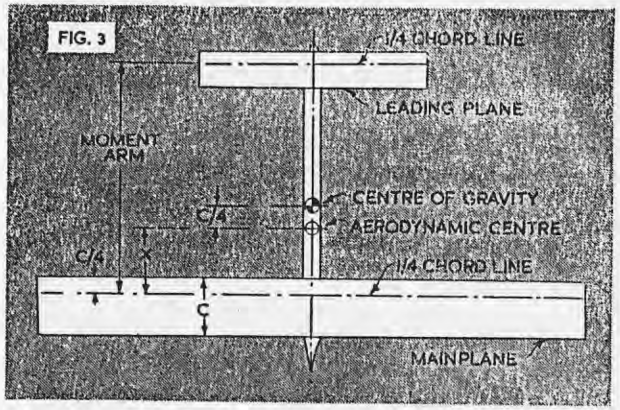
This recommended design layout for canards is shown in Fig. 3 and it is on this that the method of finding the aerodynamic centre will be described. The relative positions of the leading plane and wing are fixed relative to the quarter-chord lines of these two aerofoils, *i.e.*, a line at 25 per cent. of the chord from the leading edge. In the case of tapered aerofoils, the quarter-chord points referred to would be those of the *average* chord. Strictly speaking this should be the mean *aerodynamic* chord, although for all practical purposes the mean *geometric* chord is sufficiently accurate, and easier to compute.

The position of the aerodynamic centre of the combination of Fig. 3 is then given by:

$$X = \frac{\text{leading plane area} \times \text{moment arm}}{\text{wing area}}$$

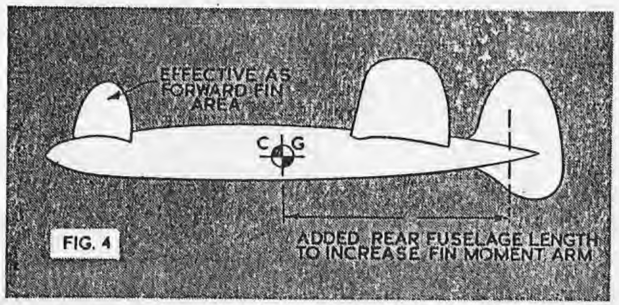
This gives the position of the aerodynamic centre forward of the quarter-chord line of the main wing. A graphical correction for aspect ratio can be applied, if desired, for more accurate results.

This method of approach should lead to a canard layout which is basically satisfactory as regards stability and performance, and it is only necessary now to consider the various other detail requirements before completing the design layout. For example it has been found that lateral stability demands a generous dihedral angle on the leading plane whilst the mainplane needs only a moderate dihedral angle. A very good general rule is to use

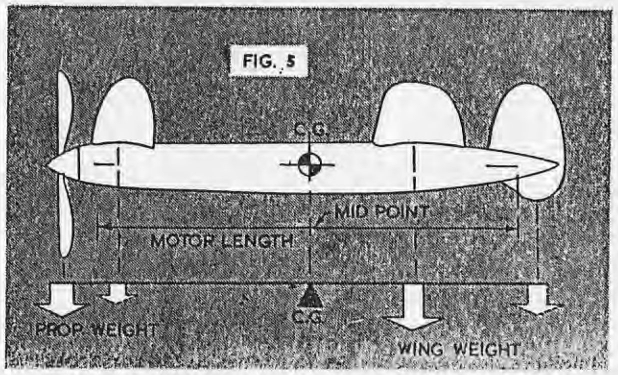


a minimum of 7 degrees dihedral on the mainplane or wing and at least twice this figure on the leading plane. Roughly speaking, the leading plane should always have twice the dihedral of the mainplane.

The considerable side area in front of the centre of gravity then presents something of a problem—Fig. 4—for this will have to be over-balanced by aft fin area for weather cock stability. The aft moment arm is invariably the shorter of the two and it may even be found necessary to extend the fuselage aft of the wings to get a fin of moderate area far enough back. This applies particularly to a rubber model design which needs more fin area, proportionately, than a glider or power model.



This fact we can use to advantage on a rubber model to balance out correctly, for if we proportion the rubber motor equally about the C.G. design position we can use a tractor propeller forwards. The weight of the propeller assembly will then balance out the wing weight—Fig. 5. A pusher layout is not so satisfactory from this point of view since grouping two of the major component weights aft of the C.G. (wings and propeller assembly) may demand an extended fuselage forebody for increased motor length to compensate, particularly if the pusher propeller has been located well aft of the wings to work in maximum fin moment arm. On the other hand, the long fuselage resulting (and the long motor), coupled with the slight increase in efficiency of the pusher propeller, may make the layout of Fig. 6 one to consider with some seriousness for duration work. A pusher propeller of this type



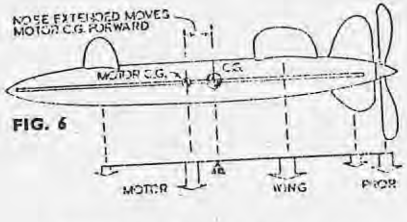


FIG. 6

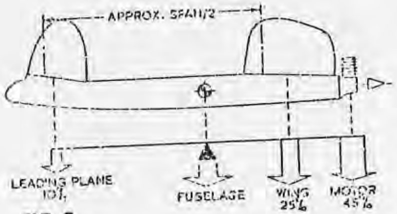


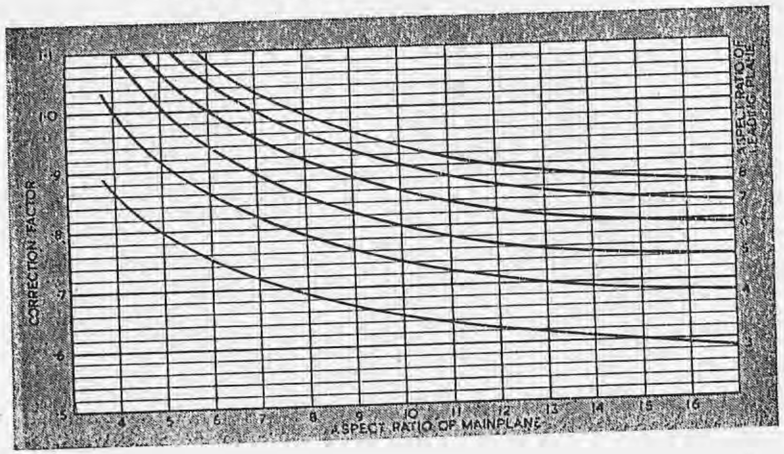
FIG. 7

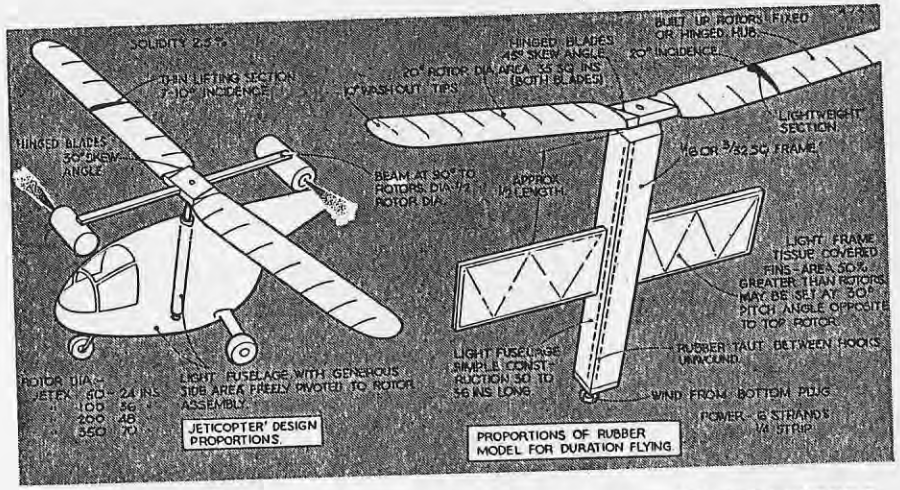
could be feathered for drag reduction on the glide whereas the tractor arrangement of course fits in well with either feathering or folding propeller.

Gliders will be far less critical on this point for there are no major weights distant from the C.G. and ballast can always be added to get the final C.G. in the right position. The fin area required, too, will be smaller, but should again preferably be located aft of the wings. Wing-tip fins will not be particularly effective in providing weathercock stability due to their small moment arm. However, models with small weathercock stability will often tow quite satisfactorily, and there is the distinct possibility of deliberately employing small fin areas aft to produce a model which "wanders" in free flight, once released from the towline. Models with such a trim circle first one way and then the other and always tend to take up a steady circle on entering a thermal. The danger is of overdoing this undercontrol to the point where the model flies for long periods straight downwind.

Power model canards present something more of a problem with regard to weight distribution. The completed model split up into component weights as in Fig. 7 shows that it may be difficult to balance out with the C.G. far enough forwards with a simple pusher arrangement, unless the motor is actually mounted above the wings. A tractor arrangement will be even more difficult to arrange to balance out the forward weight of the motor without, possibly, an extended rear fuselage. The pusher arrangement appears to be the best with the motor mounted as close up to the wing tailing edge as possible, or even above or under it. This will undoubtedly result in some sacrifice of fin power, but the canard arrangement is generally stable enough to absorb this.

THIS GRAPH GIVES CORRECTION FACTOR APPLIED TO "X" FOR VARIOUS ASPECT RATIO COMBINATIONS





CHAPTER FIFTEEN . . . . HELICOPTERS

UNTIL comparatively recently, the most successful type of model helicopter, both from the point of view of stability and performance, has been the simple fuselage, twin-propeller (rotor) layout, with its variations—Fig. 1. Design of models of these types has been more or less standardised for a number of years and some very creditable durations have been achieved. The four types shown in Fig. 1 are fairly representative of standard practice and have remained largely unaltered for a number of years. Small models, suitable for indoor work need only a simple stick for the fuselage, with a thrust bearing bound to each end. Rotors top and bottom connected to the same rubber motor complete the model. As the motor unwinds, the rotors rotate in opposite direction and must therefore have opposite-hand pitch. Simple construction and light weight produce a model stable enough in still air as long as there is power left to keep the rotors spinning.

When scaled up slightly for outdoor work, and fitted with a fuselage enclosing the motor, stability troubles begin to appear. A true vertical ascent is often difficult to achieve, the model tending to tip over to one side or the other, or it may turn over and dive in. Some models of this type, in fact, will tip over on to their side and fly quite happily in a horizontal direction.

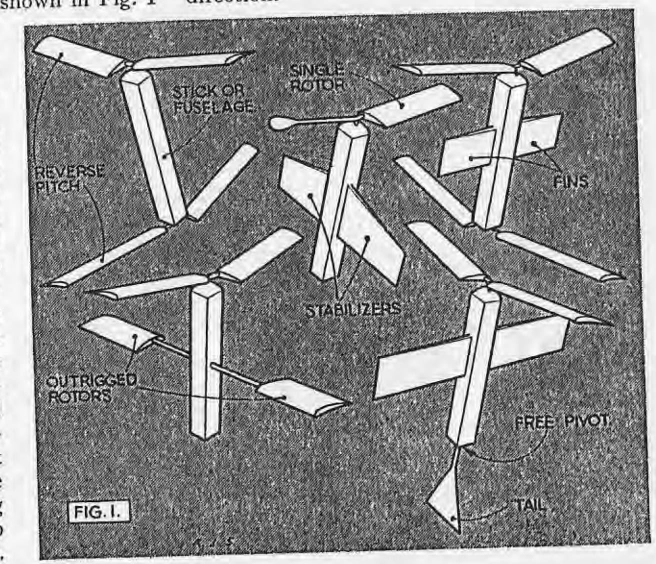


FIG. I.

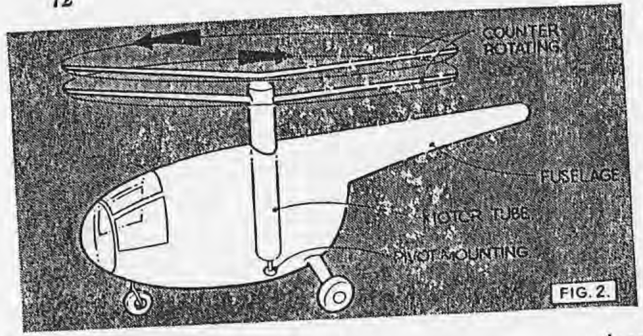


FIG. 2.

There are various reasons why these instabilities should arise. One is that a fixed rotor is itself unstable if displaced. If a rotor mounted on a rigid axis is displaced, a force is set up tending to aggravate the displacement. In other words, once a model of this type deviates from a true vertical ascent for any reason, the reaction is to increase this displacement. Then there is also the effect of side areas. Once the model departs from the vertical it assumes a skid or yaw angle and the fuselage has a definite angle of attack. Depending on the resulting centre of pressure of the fuselage, the air forces on the fuselage either tend to make the model unstable or correct any displacement.

To achieve the latter, fixed fins or winglets can be added. These are adjustable for position up and down the fuselage, so that the best position for stability can be found.

Improving Stability

The simple double-rotor layout eliminates one problem—that of torque. Equal torque is applied to each rotor and so the reaction produced by driving the top rotor is absorbed in driving the bottom one. Generally, however, this arrangement does not give a particularly long power run since the turns are spun out at roughly twice the speed with which they would be used up driving a single rotor of similar lifting power.

One attempt to improve stability has been to suspend what is virtually a tail-plane of simple cruciform layout below the model, as in the last diagram. This does, it appears, produce a more stable arrangement, but is still far from being a solution. In fact no true solution to stability has been found with any of these models, and the problem is made all the more difficult by the fact that duration is almost entirely dependent upon length of power run. Better stability is usually achieved with a fast, vertical climb, which calls for a fair amount of power. Reducing the power for maximum flight duration, the initial take off may be sluggish, and it is here that instability sets in.

There was also another type of rubber model helicopter produced some years ago—the semi-scale layout of Fig. 2. Basically, in fact, it is nothing more than a twin-rotor duration-type assembly mounted in a semi-scale fuselage. The fitting of such a large fuselage could only detract from performance and the type of rotor system has been been found only suitable to relatively small models.

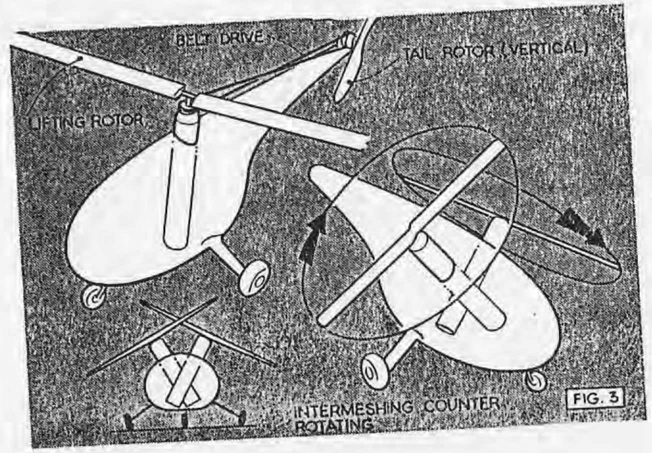


FIG. 3

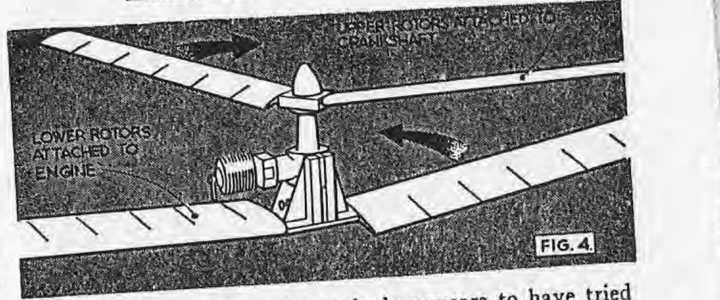


FIG. 4

Some modellers who have persisted along this line, more with the idea of producing a semi-scale model rather than a duration machine, have achieved limited success with some of the layouts outlined in Fig. 3. None has proved particularly satisfactory. Performance, in general, has been poor and almost all have suffered from lack of stability. Those relying on a single rotor system with a drive to compensating tail rotor, as in full scale practice, have been singularly unsuccessful.

To get around the torque problem some very ingenious attempts have been made to attach the power unit directly to the rotors. One such scheme, for example, employs a twin-rotor system using a small diesel or glow plug motor, attaching one rotor to the crankshaft and the other to the crankcase of the motor, as in Fig. 4. The fuselage was freely mounted beneath this assembly.

Other modellers tried attaching the power to the tips of the rotors, as in Fig. 5. One excellent example of the latter was produced by an American modeller, Frank Ehling, the resulting design approximating to two separate models fixed wing tip to wing tip with a flexible joint. Some good times were accomplished with this model, but few people appear to have had any success in attempting to duplicate the scheme with any form of "tip" power.

Stability in the *Jeticopter* rotor system is achieved by hinging the blades—a solution which has been hinted at for many years, but nobody appears to have tried to develop, until F. G. Boreham persisted with his series of experimental Jetex powered models, from which was eventually derived the Jeticopter models.

A rotor system free to flap about a hinge point at the hub will assume a definite coning angle produced by the balancing out of the thrust produced by the blades and the centrifugal force produced by rotation—Fig. 6. They will not simply fold up. If now this hinge is skewed so that as the blades flap up (or down) they also change their incidence (pitch angle) the system can be made inherently stable.

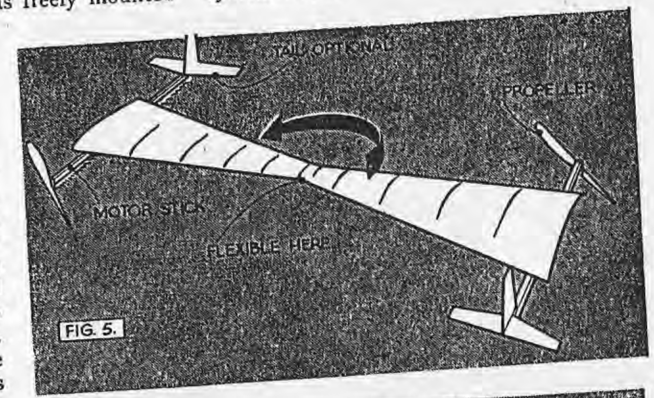


FIG. 5.

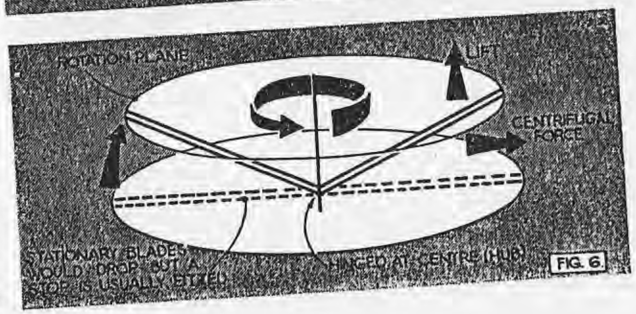
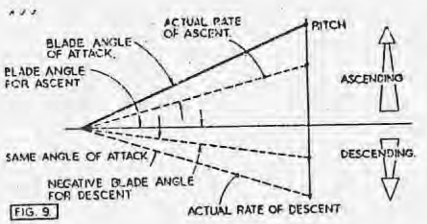
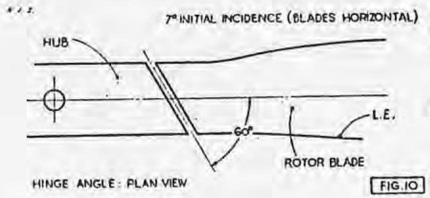
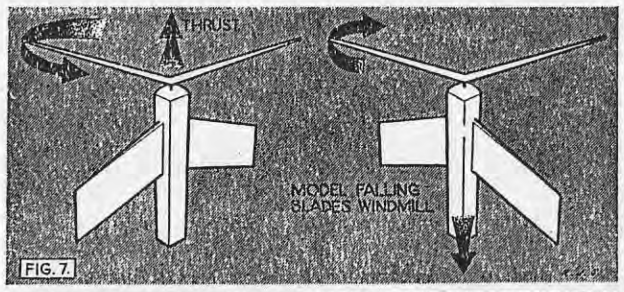


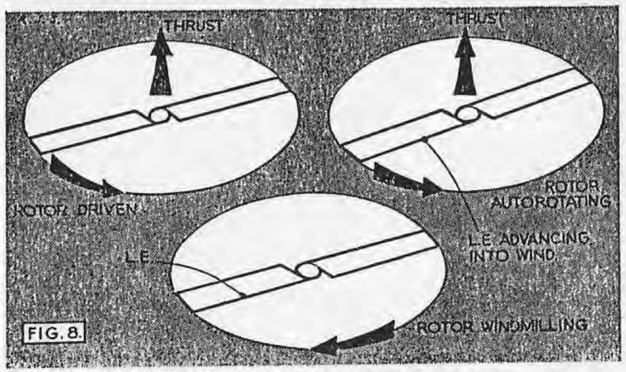
FIG. 6

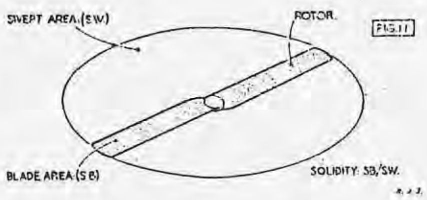




This seems to hold true both for the ascent and the descent. It is interesting to examine what happens when the power drive finishes on a model helicopter. In a simple rubber driven model, Fig. 7, the rotor stops rotating and lift is lost completely. The model simply falls out of the sky. This descent will probably be







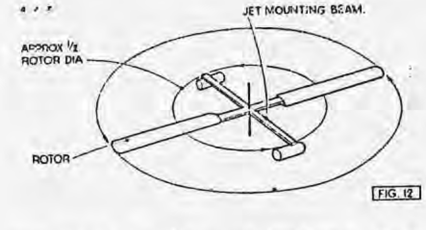
made with the model lying on its side, but the airflow still largely upwards relative to the rotors.

Rotor Design

The rotors, therefore, once they have unwound cannot continue to rotate in the same direction and wind the motor backwards, until they are stopped. In other words, a normal freewheel on the shaft will not disengage. Nor can the rotors be arranged to give any satisfactory form or lift force to slow the descent, even if a suitable disengaging freewheel were used.

The same is true of any rotor system—Fig. 8. Driven one way the rotor is simply a propeller, generating thrust. When the power is run out, and assuming the rotor is free to continue rotation, it will then either stop and reverse its direction of motion or "windmill", when the only upward force or "lift" it can generate is pure drag. If, on the other hand, the rotors continue to freewheel in the same direction as when powered, they will continue to lift. This is called *autorotation*.

If now we consider the actual angle of attack of the rotor blaces — Fig. 9 — we shall see that to get autorotation it is necessary for the blades to assume a negative *angle of incidence* during the descent. If they were



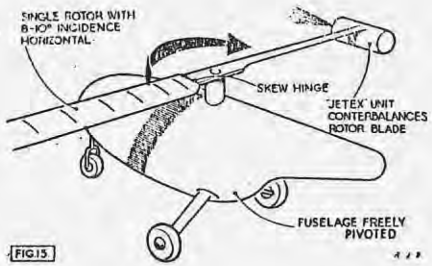
maintained at the same incidence as on the upward power flight, the actual angle of attack would be extremely high on the descent, and consequently the blades would be completely stalled. In other words, they could not autorotate.

Jeticopters

On the Jeticopter arrangements, the required incidence change is achieved by hinging the blades at 60 degrees, with an initial setting of 7 degrees incidence (blade horizontal)—Fig. 10. This setting appears to be most satisfactory and could be adapted to most layouts of this type. Also there is no reason at all why the same system of hinged blades should not be adopted for the rubber model layout, to give both greater stability under power and a *controlled* descent with the blades autorotating.

The normal incidence of the blades would have to be somewhat higher than that adopted for the Jetex models since the rubber model will climb faster, initially, at least. An optimum blade angle (horizontal) of about 20 degrees would appear to be indicated with the skew angle of the blade increased accordingly to give the necessary pitch change to produce a small angle of attack for autorotative descent.

As far as Jetex powered helicopters are concerned, designers could hardly do better than follow the proportions established by the commercial models, for this has proved particularly successful. Respective rotor proportions are sum-



marised in the table. From these figures it would appear that the weight lifting capacity of the rotors is roughly equal to a disc area of 400 sq. in. per ounce total weight to be lifted. Corresponding rotor solidity is roughly 2.0 to 2.25 per cent. Solidity is the ratio of the actual rotor blade area to the total swept area of the rotor disc.—Fig. 11.

Unfortunately, what would have been the simplest and most efficient method of mounting the jet units, on the tips of the rotor blades, has not proved satisfactory in practice. The solution adopted has been to mount the jet units on a separate beam attached at right angles to the rotor hub, as in Fig. 12. This beam needs to be as long as possible, consistent with weight and strength requirements, in order that the jet units have sufficient airspeed themselves. Low forward speed or, strictly speaking, low airspeed means a reduction in thrust and therefore lower efficiency. The Jetex motor would be operating most efficiently at the rotor tips, but as this seems to upset stability, the separate beam mounting is the best compromise. The span of this beam approaches one-half of the main rotor diameter. Structurally, the most suitable material for this beam is thin ply.

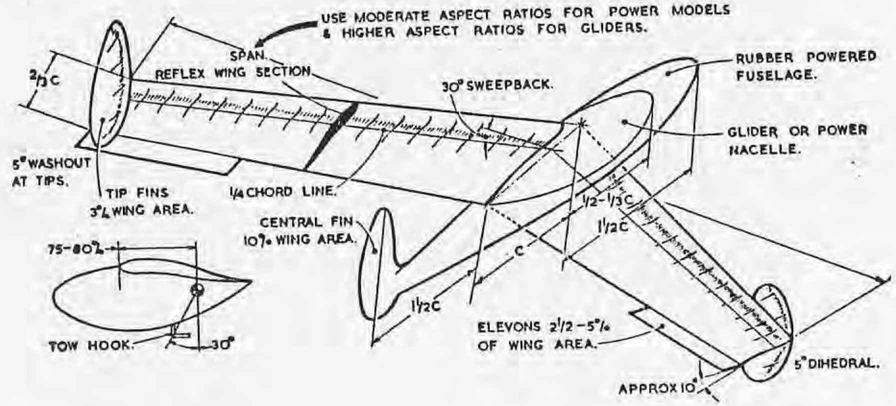
A single rotor system is shown in Fig. 13.

Single rotors. Solidity 5 per cent.

Jetex 50—blade area ...	15 sq. in.
Jetex 100— „ „ ...	30 sq. in.
Jetex 200— „ „ ...	60 sq. in.
Jetex 350— „ „ ...	100 sq. in.

Jetex	Rotor, Dia. ins.	*Blade Area, sq. ins.	Disc Area, sq. ins.	Solidity, per cent	Disc Loading, oz./100 sq. ins.	Blade Loading, oz./sq. ins.
50	23	18	415	2.3	.24	.0555
100	35	42	862	2.05	.35	.0715
350	70	156	3,848	2.46	.39	.096

*Two blades.



CHAPTER SIXTEEN . . . . TAILLESS

VERY few tailless models can be considered to be completed satisfactory. Even fewer have a performance comparable with that of an orthodox machine. Part of the reason for this is that the type, as such, is relatively undeveloped. The number of modellers who concentrate on tailless designs are virtually negligible. The other reason is that tailless models are not easy to design and fly. They introduce specialised problems of their own which are not readily overcome and with very little data available as a guide, design is very much a matter of trial and error.

Considering the tailless aeroplane on the basic principle of being a flying wing—to which later the power unit and other appendages found necessary can be added—let us examine the various problems involved. Stability, not performance, will be the major problem, for once we have found a *stable* layout we can set about making it as *efficient* as possible.

Now an ordinary wing of the type shown in Fig. 1 is not stable. This is just the wing off a conventional aeroplane and it needs a tailplane to stabilise it. The reason for this is as follows.

If the wing is balanced so that the centre of lift coincides with the centre of gravity, the wing can be momentarily stable in a particular gliding attitude. The resultant aerodynamic force balances out the weight. If, however, the wing is distributed for any reason—noses up or down—it changes its attitude relative to the airflow and immediately the centre of lift shifts. The actual centre of lift depends on the attitude of a wing—or its angle of attack. It is a characteristic of most normal wings that the centre of lift shift—or centre of pressure movement, as it is called—is an unstable one; in that any deviation from its original position produces a change in the centre of pressure tending to upset the wing even more. Thus, in our simple example, if the wing noses up slightly from its original momentarily balanced position, the lift force will shift forwards making

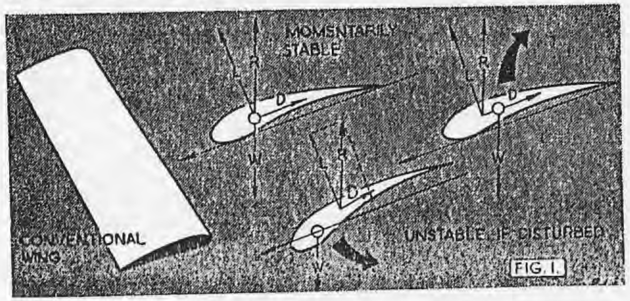


FIG. 1.

the wing nose up even more steeply. Conversely, if the wing nosed down the lift force would shift back and make the wing nose down even more.

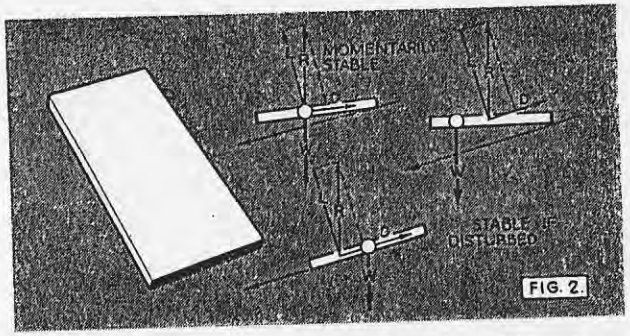


FIG. 2.

On a conventional aeroplane this unstable property of the wings is suitable damped out by the action of a tailplane. It is obvious, therefore, that the flying wing aeroplane has to have a wing which is not only balanced with respect to the C.G. but one which is self-damping or stable on its own.

Airfoil Selection

In model sizes about the only section which can be said to have stable characteristics, (i.e., reverse centre of pressure movement as compared with an orthodox section) is a flat plate—Fig. 2. The flat plate aerofoil does tend to correct any displacement, but is a very inefficient form of aerofoil. The lift it can generate for a given area is small, by comparison, and furthermore, it has an early stall. Some of these properties of the flat plate aerofoil, however, have led to confusing results.

Small solid model tailless gliders—say up to **12** in. span or so, can perform really well. Various people have used them from time to time to investigate wing planforms and layouts for projected tailless designs. The wings are generally constructed of sheet and virtually true flat plate, or camber is sanded on, when, on account of their small size, aerodynamically at least they are still flat plate aerofoils.

Now these models fly very well. They are stable and have quite a reasonable gliding angle. This has mis-led many designers into thinking that a particular layout which they have "proved" on a small model will be equally successful in a larger size. Seldom, however, does this work out in practice, for these small models are working in a region where the aerofoils are giving flat plate characteristics and therefore stability reaction is unduly favourable.

Possibly the nearest approach to the flat plate aerofoil is the symmetrical one. The camber line is still straight but now the section has given depth to accommodate spars and obtain adequate strength in larger sizes.

To get reasonable lift values from model wings, however, it has been found that cambered aerofoils are essential, the more camber the better. Adequate camber is far more important than thickness. However it is just this camber which makes an aerofoil section unstable.

Fortunately the centre of pressure movement of a cambered aerofoil can be reduced by modifying the camber line—Fig. 3. If the camber line is swept up towards the trailing edge centre of pressure movement can be minimised, or even held stationary. The result is an aerofoil with what we term a *reflex trailing edge*. However, this stability (or more truly, less instability) has only been achieved

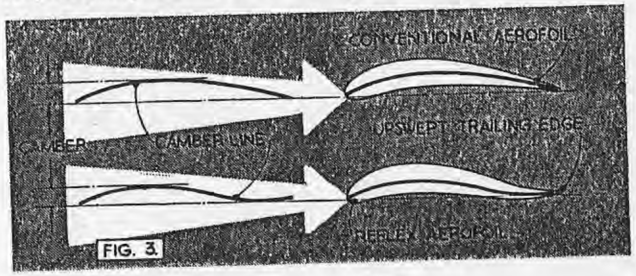


FIG. 3.

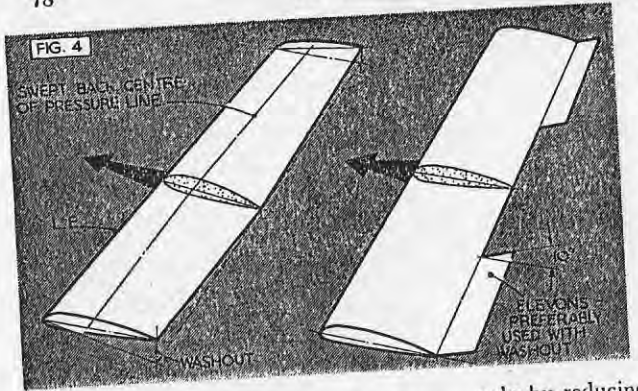


FIG. 4

at the expense of reducing the aerodynamic efficiency of the section. The reflexed aerofoil does not give so much lift per area as a comparable conventional aerofoil, whilst drag values may still remain similar. Hence to get comparable lift we must either operate this section at a higher angle of attack, or add more wing area. Both will increase drag of the reflex-section wing and, as a general rule (especially in model sizes), the conventional aeroplane usually works out more efficient than the flying wing. "Usually," not "necessarily." The larger the model the better chance has the tailless designer of producing a more efficient aeroplane.

Stability Devices

A flying plank with a normal reflex wing section can, however, be given a fair degree of stability by washing out the wing tips, that is, decreasing the incidence of the wings from root to tip by sweeping up the

wings from root to tip by sweeping up the trailing edge. An alternative method is to use controlling surfaces at the tip set at some negative angle—Fig. 4. These give a somewhat similar effect to washout and at the same time act as very short-coupled tail surfaces. But in both cases the reserve of stability which can be obtained is small and achieved only by reducing the overall efficiency of the wing. The degree of washout required may be such that at normal flight attitudes the wing tips are not generating any lift at all, or even producing a slight downward lift. The flying plank at best, then, is going to be a tricky model to trim and handle if the stability margin has been cut to such fine limits in order to get reasonable efficiency, or extremely inefficient if enough washout is used to give fair stability. We must look elsewhere, therefore, for the solution to our problems.

Fortunately, there is a fairly easy solution if the wing is swept back (or forwards) we can make the wing tips operate somewhat similarly to the tailplane of a conventional aeroplane, whilst still retaining the flying wing layout. The reason for this can be explained fairly simply without going into technical details—Fig. 5.

A simple flying wing of the type shown may not necessarily be stable. It is a characteristic of tapered wings that the tips tend to stall before the centre section and so the layout shown would tend to have a catastrophic stall, i.e., the centre still lifting after the tips had stalled tending to nose the model up even more rapidly. If, however, we incorporate washout in the tips so

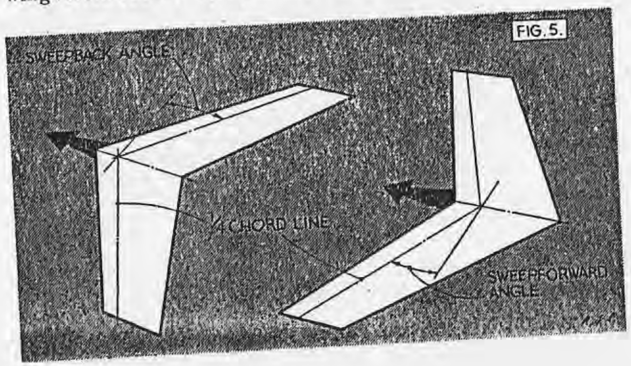


FIG. 5.

that these stall after the centre of the wing the tips will always be operating at a lower angle of attack. Now if the model is caused to nose up the centre portion of the wing will stall first, with the tips still lifting. The tips, being located aft of the centre of gravity, will correct the model.

The same is true of a layout with swept-forward wings, only this time we can leave the tips straight, or even give them wash-*in* to increase the stabilising effect of the trailing portion of the wing (now the centre section). Both types of wing layout are satisfactory, although the swept-forward wing has certain other undesirable stability characteristics which are against its adoption. The swept-back wing, however, is the basis of almost all successful model tailless design. It is used still with a reflex section, and with washout. Elevons can be added at the tips to increase the washout effect and also act as controlling surfaces.

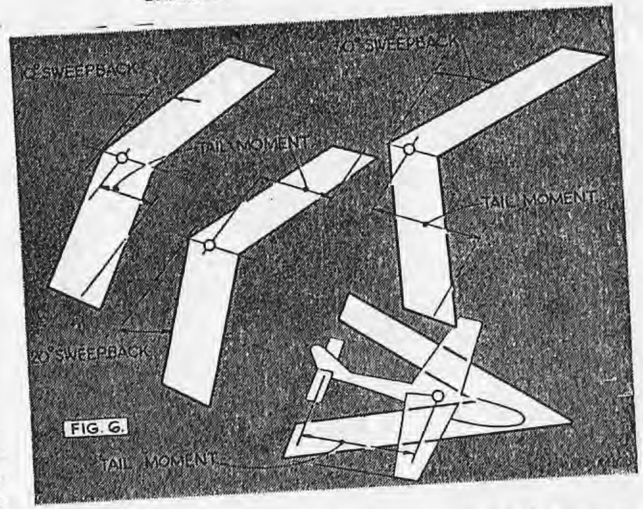


FIG. 6.

The question now is, how much sweepback to employ? The more sweepback we use, the farther aft are the tips carried (and elevon controlling surfaces, if used), and therefore the more marked their stabilising action. Taken to extremes, we could bring the tip portions as far back as the tailplane position on a conventional layout—Fig. 6.

Sweepback Effects

However, the use of sweepback has other effects not so desirable. The aerofoil section, for one thing, is reduced in *effective* thickness (good for high speed flight, but not for duration). Also a swept wing is not so stable in a yaw. If displaced to one side the advancing wing generates more and more lift tending to increase the angle of yaw and roll the model in that direction at the same time—Fig. 7. Directional, and possibly spiral, stability will suffer as a result. The logical answer, then, is to use as much sweepback as desirable for longitudinal stability, and no more.

Minimum value of sweepback for satisfactory results appears to be 25 degrees measured on the aerodynamic centre line of the wing (to all intents and purposes a line adjoining the ¼-chord positions of the root and tip sections)—Fig. 8. There is, of course, no maximum as regards longitudinal stability, only the desirability to limit sweepback to avoid complicating spiral and directional stability problems.

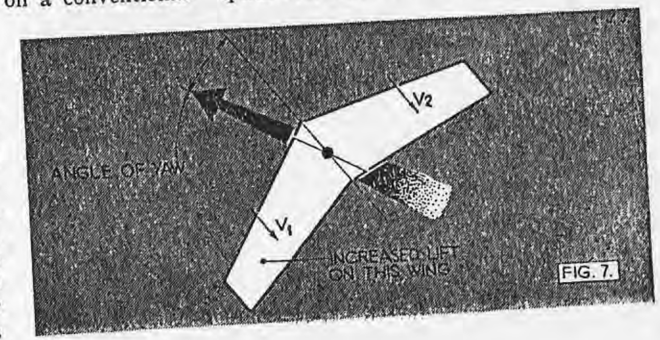


FIG. 7.

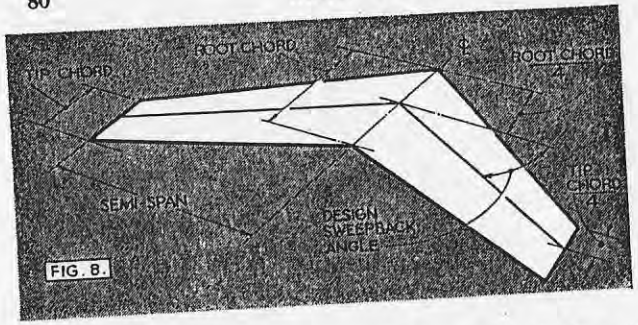


FIG. 8.

A very good figure for design work, therefore, appears to be 30 degrees sweepback on the aerodynamic centre line. This, allied to a suitable taper ratio will give a slightly higher value on the wing leading edge. Associated with this will be required some 4–5 degrees minimum washout from root to tip. It is difficult, or even impossible, to pre-determine the exact amount of washout required, hence the value of adjustable control surfaces at the tips, such as elevons. It must be remembered, however, that such controlling surfaces will be very sensitive and will need adjustment with extreme care. Sweepback also has a certain "dihedral" effect and a swept wing always requires less dihedral. Too much dihedral will result in a wallowing type of flight called "Dutch Roll." An adequate dihedral for the layout specified would be 4–5 degrees, roughly one half that of a conventional straight wing.

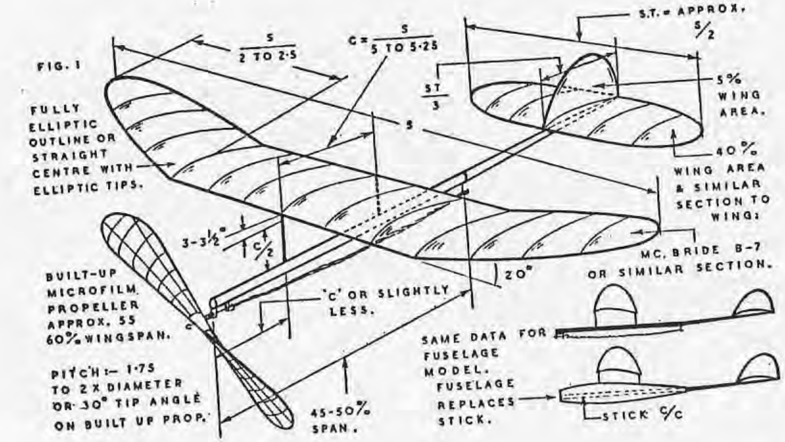
Directional Stability

Directional stability will only be obtained by the addition of vertical surfaces to the basic flying wing layout, which need also to be located as far behind the centre of gravity as possible. A fin stuck on the end of the fuselage ,for example, will have relatively little effect, whereas wing tip fins can be expected to have maximum effect. Wing tip fins appear to be the logical solution, although their adjustment can be critical, unless the ultimate design is to have a fairly lengthy fuselage, such as might be used on a rubber - powered version.

Adjustment for turn on wing tip fins Wing tip fins will turn the model by the drag force they create. Offsetting both fins to the right (or left) an exactly similar amount would have little or no effect. Offsetting one fin (or trim tab) will create drag at that tip and cause the model to turn in that direction. In a similar manner turn adjustment can be obtained by differential setting of the elevons, which is the better method, leaving the tip fins dead true.

Spiral stability is far more complicated and here no definite solution can be given since relatively little is known on the subject. The washed-out wing tips will assist spiral stability, provided they are true and balanced. Unequal washout will *produce* spiral instability. Wing tip fins should, theoretically, be bad, whilst there would appear to be a definite need for some sort of central "keel" are under the wing. An under-slung nacelle, therefore, of fairly deep section may not only be necessary, but desirable.

The basic proportions of what should prove a satisfactory layout are summarised in the heading drawing, incorporating the various features discussed and adaptable directly to either a glider or power-driven model. It must be emphasised however, that adjustment of the elevons will be critical and in the case of the power model only a moderate power should be used.



CHAPTER SEVENTEEN . . . . INDOOR

THE design of indoor free flight models is a specialised one. Performance is almost entirely dependent on power run and it has been fairly well established that maximum duration is realised when just about all the motor turns are used up during the flight. In other words, if the model "deadsticks," i.e., the power runs out with the model still in the air and the final descent is a glide, it is overpowered. If, on the other hand, the model lands with turns still on the motor, it is underpowered—for that particular trim, at least Thus maximum flight duration is almost exactly maximum motor run.

It is necessary to use the smallest possible cross-section of motor coupled with the largest possible diameter and pitch propeller to extend the power run. This, in turn, means the lightest possible model and a very efficient one. Both are equally important. Increasing weight and decreasing efficiency both demand more power. Decreased weight or higher efficiency allow the model to fly on less power.

The indoor free flight model has largely been neglected in this country, one of the main reasons being lack of suitable sites or halls for flying. Before the war there were one or two National meetings at the Albert Hall in London, and the hand-launched stick record established then—18 min. 52 sec.—still stands. Post-war indoor meetings have been restricted to smaller halls and flight times have suffered as a consequence. These meetings, too have been few in number.

Progress in the U.S.A.

America, on the other hand, has gone ahead with indoor model development. Times have gone up to over half an hour, the present record being 32 min. 19 sec. Nor is this performance confined to one outstanding modeller. Several men have topped the thirty-minute mark besides Merrick Andrews, the record-holder. It is also interesting to note that Andrews' record flight was the third of three contest flights, all of which bear the thirty-minute mark.

In America, indoor contests had a popular appeal by the mid 1920's. Models of this era were tissue covered and had flat aerofoil sections for wing and tailplane and times were low—somewhere around the two-minute mark. 1928 saw the introduction of the cambered aerofoil and duration climbed as a result to around the five-minute mark. Hollow motor sticks followed, then an overall lightening of the weight until the ten-minute mark was approached. Times went up to ten minutes.

Then came the greatest single development in the history of the indoor model—microfilm. This covering material, so much lighter and, incidentally, less porous than tissue, made even lighter models possible. The duration record went up to twenty minutes and models were lightened to a degree hitherto thought impossible. Circular, elliptic and teardrop section booms were being used for both the motor stick and tail boom. Propeller diameters and pitch diameter ratios increased enormously.

It was around this period, in fact, that indoor model design more or less standardised itself into a layout which has remained basically unchanged to this day. Carl Goldberg's 22 minutes in 1934 is still better than anything that has been done in this country and the model is still an excellent one, judged by modern standards. Increasing times since that date have been the result of detail modification and development rather than any radical changes in design. Lighter, stronger structures rather than changes in shapes and sizes. This is emphasised by the fact that Goldberg's 22-minute 1934 model weighed .133 ounce as compared with Andrews' thirty-minute model weighing .0656 ounce. That extra ten minutes has largely been made possible by halving the total weight. This advance, however, was slow in coming. Various factors, such as the war, poor rubber and so on, delayed the establishment of the thirty-minute flight.

It took four years—1936 to 1940—for the times to climb from 25 to 26 minutes and then another six to add the next minute (this, however, was largely the influence of the war period). Since then progress has been more rapid and the present holder is quite confident that the limit has by no means been reached.

Size and Duration

In laying out our duration model, the first—and very important—factor is size. In general, the larger the model the more efficient it is, and also the lighter loading it is possible to achieve. High times, therefore, are achieved with the bigger sizes of models. This holds true through almost all conditions, except where flying space is severely restricted and the large model is continually colliding with obstructions or hitting the walls or roof. With plenty of floor space, however, and a restricted ceiling the large model will still score.

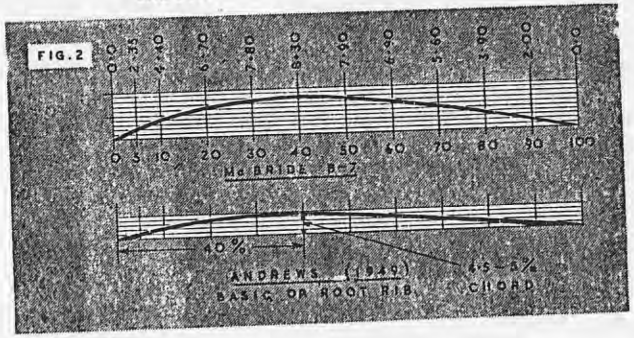
First, then, we want to know what is the upper limit in size, if any. Strictly speaking there does not appear to be any theoretical upper limit although there is a definite practical limit to size beyond which it is difficult to obtain a strong enough airframe without adding excess weight. This is a point which must be borne in mind. The large model is the obvious choice, but it is very much more difficult to make. It is easy enough to construct a large model, but to make it strong enough and still down to minimum weight is quite another matter.

Tailplane Span (in.)	Tailplane Root Chord (in.)	Dia. (in.)
14½	5	18
13	4½	17
12	4	16
10	3½	11/12
8½	3	9

TABLE I: DESIGN DATA

*Wing Area (sq. in.)	Span (in.)	Root Chord (in.)	Centre Section (in.)	Tip Rise (dihedral) (in.)	Motor Stick (in.)	Tailboom (in.)	Tailplane Area* (sq. in.)
150	30	6	17	2¾	14	11	60
125	27½	5¼	15½	2	13	10½	50
100	25	5	14	1¾	12	10	40
75	21	4	11	1⅝	10	8	33
50	16	3½	9	1¼	9	7	24

* Blunt elliptic outline. Area=S2/6 (approx.).



Size, in America, is actually restricted by class rules. We have no such rules in this country at the present time, and it would seem best to follow American practice. The largest models they build, therefore, are restricted to 150 sq. in. maximum wing area, and these are the models which put up the high times.

Design layout, as we have already said, is more or less standardised. *See* Fig. 1. In Table 1 we have given recommended detail dimensions for various model sizes based on this generalised design. Maximum performance will decrease proportionately with decreasing size.

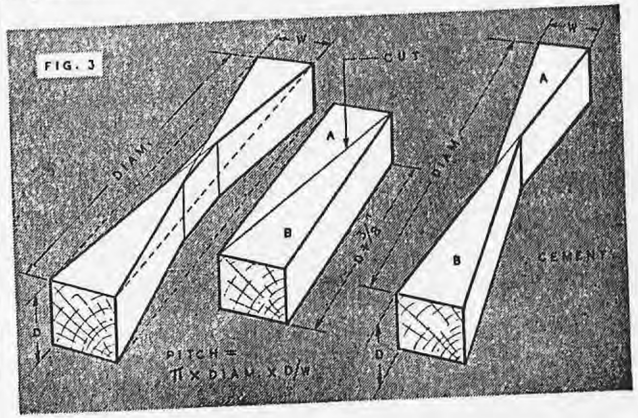
For a really serious attempt at setting new duration standards for this country we would recommend the 150 sq. in. model. The next step down—the 125 sq. in. size—is probably the best compromise for the less experienced modeller, who is then not so likely to run into trouble with weak or floppy construction. Nothing smaller than the 100 sq. in. model will do for serious competition work, especially if it is to come up against the larger designs.

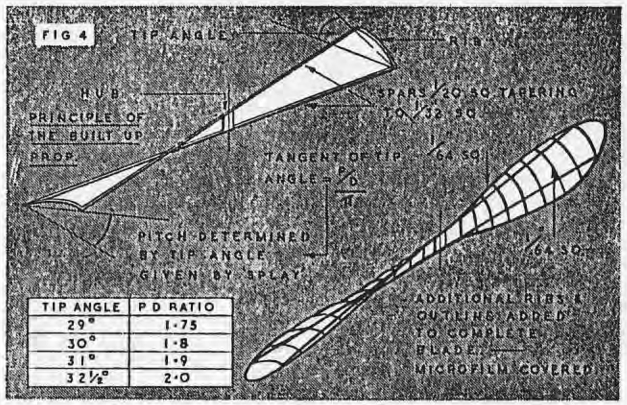
Both wing and tail-plane planforms are of elliptic outline, with rather blunter tips than a true ellipse. Wing root chord should be between 1/5 and 1/5.25 of the span, giving an aspect ratio of between 6.4 and 6.7. This appears the best compromise between an efficient aerodynamic planform and an economic structural one. Tailplane aspect ratio is lower—a root chord of one-third of the span being a good figure.

The Wing

Regarding the wing, there are two other points which we might discuss—dihedral and wing section. Due to the very large propeller diameter—well over one-half of the wing span—polyhedral or tip dihedral seems preferable, for stability, but both necessitate more dihedral breaks or joints than a straight dihedralled wing. More joints mean added weight. At the same time however, it is very desirable to break the wing down into separate sections, if only for ease of covering. Producing and handling a large sheet of micro-film is quite difficult.

Most top designers in the indoor field consider that straight dihedral is not effective enough—or needs too large a dihedral angle to be effective. The best compromise, therefore, appears to be the tip-dihedralled wing.





As regards wing section there is one "popular favourite"—the McBride B-7. This has a universal following, although the modern trend appears to be to regard the wing section as not particularly critical and aim simply at a curved section with a definite camber height and location. Fig. 2, for example, shows the McBride section and also the section used by Andrews on his 32-minute model.

The same section is usually employed for both wing and tailplane and the method of reducing the basic section for taper is a simple one. Wing and tailplane ribs are simply cut down from the rear to the required length.

The remainder of the design process can now be grouped under three main headings: structure design, propeller design and construction, and the rubber motor.

The Propeller and Motor

The simplest way would be to build a "recommended size" propeller and then select the size and weight of rubber motor to suit. Rubber power can be varied initially by different cross section, and then by increasing or decreasing the overall length of the motor, altering the overall weight of the model and thus the power required for flight. The first is an extreme adjustment, the second a finer one.

The question of rubber size is going to be an important one for modellers in this country. We have no rubber available in fractional sizes, varying in width by 1/64 inch at a time and so we are not likely to have enough selection of rubber cross sections to enable us to adjust motor size in this way. It may be necessary, therefore, to use whatever rubber is available and design the propeller accordingly.

On his thirty minute plus flight, Andrews used a 15 in. loop of 1/16—1/30 rubber powering a propeller of 17½ in. diameter. The model had 147 sq. in. wing area, but was very light. Few modellers in this country are likely to get down to the same ultra-light wing loading as the American experts, when a greater rubber cross section will be necessary. Times, of course, will go down accordingly. Typical figures are:

Model weight	*Rubber section (two strands)*	*Potential maximum time**
.030–.045 oz.	1/16 × 1/30 in.	30 mins.
.045–.055 oz.	3/32 × 1/30 in.	27 mins.
.060–.080 oz.	3/32 × 1/30 in.	24 mins.
.080–.100 oz.	1/8 × 1/30 in.	20 mins.

*Based on 15 in. dia. prop. and 150 sq. in. model.

As regards propeller design and construction the standard carved propeller is invariably cut from a diagonal blank with no depth taper, either from a single integral block equal to the diameter, or a block equal to one-half of the diameter plus about ½ in. cut along a diagonal lap jointed, as shown in Fig. 3. Carved propellers, however, are largely out of date. The built-up, microfilm-covered propeller is very much lighter and equally, if not more, efficient. Furthermore, the microfilm propeller is, if anything, easier to make. Much of the recent improvement in American record times is due to the use of the microfilm propeller. This, in fact, became almost standard practice in about 1940.

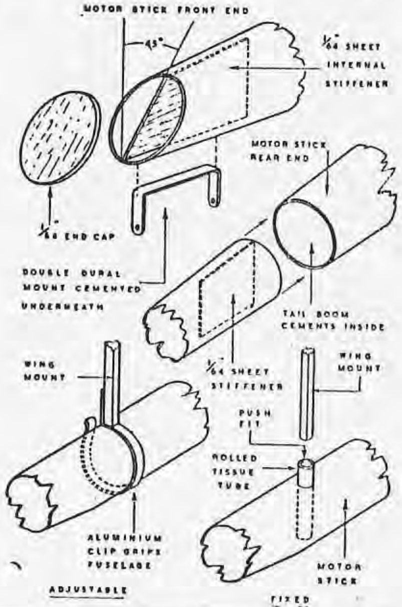
Details are summarised in Fig. 4.

Construction

Here we would emphasise that light weight with adequate strength can only come as the result of very careful selection of materials. Ordinary stock balsa just is not good enough. The right type of wood has to be picked out and it takes an expert to appreciate the qualities really required. Materials, therefore, should be obtained from a first class model shop where an experienced retailer can help, if necessary. The recommended density is 4–6 lb./cu. ft. stock.

Wings and tailplane are invariably of sparless construction, relying purely on the outline spars for strength. To conserve weight, spars should be tapered out towards the tips, reducing the tip sections to the smallest possible figure. Details of wing construction are summarised in Table II. To achieve the lightest possible weight a braced wing should be used—the bracing being .001 nichrome or tungsten wire. Proper bracing, however, is a tricky business and many modellers will prefer to build an unbraced wing, when spar sizes must be increased accordingly. On account of weight it seems better to use solid stock for the outline spars, rather than laminated strips, although the latter type of construction is usually stronger and considerably easier to handle.

As regards fuselage and tail boom construction it is interesting to find that the minimum sheet thickness possible on the very largest models is also the minimum size which can be used for *any* model, emphasising the potential advantage of the large model as regards overall weight saving and thus reduction in wing loading. Only the experts, however, can really handle a 1/64 sheet motor boom and



Boom	Tail Frame	Ribs	Fin
1/64 sheet	1/16 × 1/32	1/64 sheet	1/64 sq.
1/64 sheet	1/16 × 1/32	1/64 sheet	1/64 sq.
1/64 sheet	3/64 × 1/32	1/64 sheet	1/64 sq.
1/64 sheet	1/32 sq.	1/64 sheet	1/64 sq.
1/128 sheet	1/32 sq.	1/64 sheet	1/64 sq.

TABLE II: BUILDING DATA

Wing Area (sq. in.)	Type	WINGS				Motor Stick
		Outline Spars	Ribs	Rib Spacing (in.)	Tip Section	
150	Braced Unbraced	3/32 × 1/16 3/32 3/32 × 3/64 1/16	1/64 sheet	2–2½	3/64 sq.	3/32 1/32 3/32 sheet
125	Braced Unbraced	3/32 × 3/64 3/32 1/8 × 3/64 3/32	1/64 sheet	2–2½	1/32 sq.	3/32 1/32 3/32 sheet
100	Braced Unbraced	3/64 × 3/64 3/32 1/8 × 1/16 3/32	1/64 sheet	2–2½	1/32 sq.	3/32 1/64 3/32 sheet
75	Unbraced	1/8 × 1/16	1/64 sheet	2	1/32 sq.	3/32 1/64 3/32 sheet
50	Unbraced	3/64 × 3/64	1/64 sheet	1¾–2	1/64 sq.	3/32 1/64 3/32 sheet

1/128 sheet tailboom with safety on a large model. The recommended sizes in the structural data table are more common. Fuselage bracing with similar .001 wire is sometimes used but should not be necessary with correct selection of boom material.

Finally, detail fittings are summarised in Fig. 5 representative of modern practice. It is not possible to go into the structural side in detail, on account of space. Similarly, no mention has been made of the production and application of microfilm. There have been other articles on this subject, to which reference should be made. Nor can we elaborate on the effect of different rubber qualities. The recommended rubber sizes, for example, were quoted for T—56 rubber. Other varieties may have more or less power for the same cross section, which is where a simple torque tester will be invaluable for comparative tests.

Nor do we feel that we can give a recommended table of weights. As we have stressed earlier, the lighter the model the better, provided that it is not so weak that it will deform in flight or break up. The aim, therefore, is to reduce weights as far as possible, consistent with this requirement. The figures on page 92 emphasise the importance of this as affecting potential maximum duration.

Microfilm Formulæ

A good general purpose microfilm solution can be made by adding a teaspoonful of castor oil to two ounces of clear dope or banana oil. The following formulae have been used to good effect on pre-war British models and provide a variety of materials that the film can be made from:—

1.	Flexible collodion	1 oz.
	Amyl acetate	16 drops
	Castor oil	10 drops
2.	Plain collodion	1 oz.
	Amyl acetate	16 drops
	Tricresyl phosphate	16 drops
3.	Flexible collodion	1 oz.
	Amyl acetate	16 drops
	Camphorated oil	13 drops
4.	Flexible collodion	1 oz.
	Acetone	18 drops
	Castor oil	12 drops

(This is a heavier film.)

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AMERICAN ENGINES

Designers employing American engines, but using a British model as a basis, may compare their capacities by reference to the accompanying conversion table.

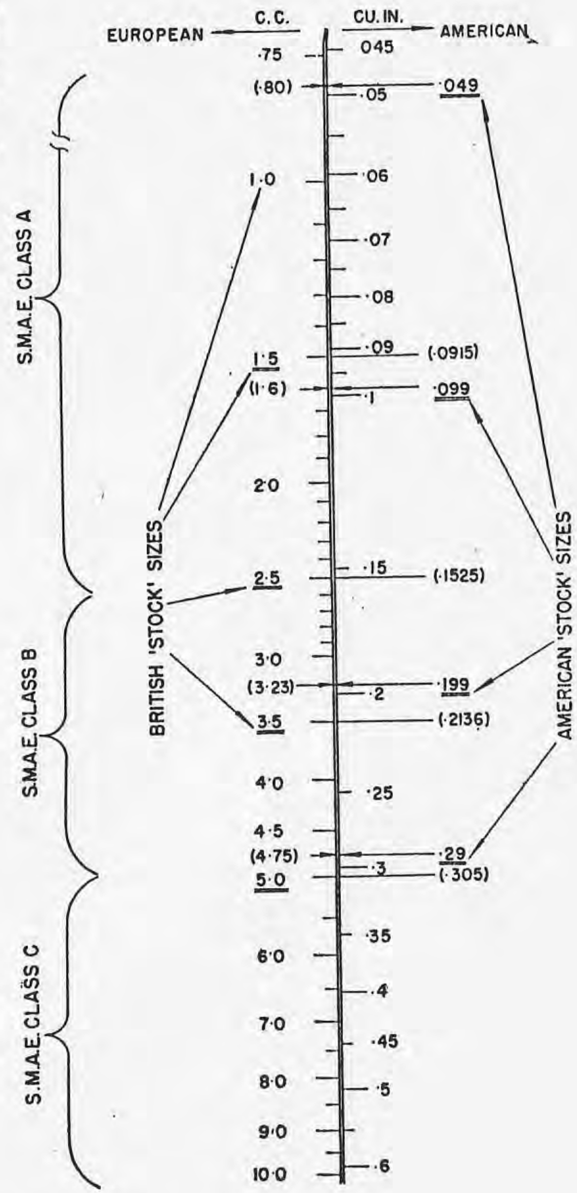
Typical American engines in production are:—

Glowplug Motors

Atwood .049
Atwood .051
Cameron .19
Forster .29
Forster .31
Fox .19
Fox .29
Fox .35
Infant Torpedo .020
K. & B. Glo-Torp. .29
K. & B. Glo-Torp. .32
K. & B. Torpedo .049
K. & B. Torpedo .19
K. & B. Torpedo .23
K. & B. Torpedo .15
K. & B. Torpedo .09
McCoy .9
McCoy .19
McCoy .29
O. & R. .23
O. & R. .29
O. & R. .33
O. & R. .60
O.K. Cub .099
O.K. Cub .039
O.K. Cub .049
O.K. Cub .074
O.K. Cub .14
O.S. .29
Space Bug .049
Triumph .49
Triumph .51
Veco .29
Veco .31
Wasp .049
Wen Mac .049

Diesel Engines

McCoy .049
O.K. Cub .06
O.K. Cub .15



BRITISH PRODUCTION ENGINES—1955 (GENERAL DATA)

	ENGINE	Wgt. (oz.)	Displacement c.c.	Displacement c. in.	Bore (in.)	Stke. (in.)	Bore/ Stke.	oz./ c.c.	Overall Dimensions (in.) L.	H.	W.	Prop. Shaft Dia. (in.)	Intake	Tank
DIESEL	Allbon Bambi ...	.75	.15	.009	.21	.25	.84	5.00	2 1/4	1 1/2	13/16	1/8	Shaft Rotary	Integral
	E.D. .46	1.4	.46	.028	.312	.375	.83	3.05	2 1/2	2 1/8	1 1/4	1/8	Shaft Rotary	Integral†
	Frog '50'	1.25	.49	.0305	.345	.330	1.04	2.6	2 5/8	1 3/4	1	1/8	Shaft Rotary	Integral
	Allbon Dart II	1.25	.55	.0336	.35	.35	1.0	2.26	2 3/4	1 7/8	1 3/16	1/8	Shaft Rotary	Integral†
	Mills P.75 ...	1.75	.75	.045	.33	.52	.64	2.35	3 1/4	2 3/8	1 7/16	3/32	Cylinder Port	Integral†
	Allbon Merlin ...	1.75	.76	.047	.375	.42	.9	2.6	3	2 3/16	1 3/16	3/32	Shaft Rotary	Integral
	E.D. Bee	2.75	.98	.059	.437	.40	1.09	2.8	3 3/8	2 1/2	1 1/2	3/32	Rotary Disc.	Integral†
	Allbon Spitfire	3.0	.975	.059	.425	.420	1.01	3.08	3 1/2	2 3/8	1 1/4	5/32	Shaft Rotary	Integral†
	Mills 1.3 Mk. II	3.5	1.33	.081	.406	.625	.6	2.53	4	3	1 3/4	3/16	Cylinder Port	Integral†
	E.D. Hornet ...	3.125	1.45	.0855	.531	.40	1.33	2.18	3 5/8	2 1/2	1 1/2	3/16	Rotary Disc.	Integral†
	Elfin 1.49 ...	2.6	1.49	.091	.503	.466	1.07	1.75	2 5/8	2 1/4	1 5/16	3/16	Shaft Rotary	None
	Frog '150' ...	3.125	1.49	.091	.50	.46	1.08	2.05	3 3/4	2 3/8	1 3/8	3/16	Shaft Rotary	Integral
	Allbon Sabre ...	2.25	1.49	.091	.525	.42	1.25	1.51	2 1/2	2 5/16	1 3/16	3/16	Shaft Rotary	None
	Oliver Tiger Cub	3.75	1.47	.089	.43	.625	.68	2.5	2 3/4	2 7/8	1 5/8	3/16	Shaft Rotary	Integral
	Elfin 1.8 BB ...	4.1	1.8	.110	.503	.562	.9	2.3	—	—	—	—	Shaft Rotary	—
	E.D. Comp. Sp....	6.0	2.01	.122	.5	.625	.8	2.99	4 3/8	3 1/4	—	3/16	Cylinder Port	Integral†
	Mills 2.4 ...	5.6	2.42	.147	.5	.75	.66	2.29	4 3/4	3 3/4	—	1/4	Rotary Disc.	None
	Allen Mercury 25	4.0	2.4	.147	.57	.562	1.01	1.67	3	2 5/8	1 5/8	1/4	Shaft Rotary	Integral
	E.D. Racer ...	4.75	2.46	.150	.59	.55	1.07	1.83	3 7/8	3	1 11/16	3/16	Rotary Disc.	None
	Elfin 2.49 ...	3.4	2.48	.1	.554	.625	.88	1.4	2 1/2	2 7/8	1.55	3/16	Shaft Rotary	None
	Frog 250 ...	5.5	2.49	.151	.58	.575	1.01	2.21	4 3/8	3 1/4	1.65	5/16	Shaft Rotary	Integral
	Oliver Tiger ...	6.125	2.50	.151	.55	.625	.88	2.42	2 7/8	3	1 3/4	5/16	Shaft Rotary	None
	Allen Mercury 35	4.5	3.42	.209	.687	.562	1.59	1.3	3	2 3/4	1 5/8	1/4	Shaft Rotary	Integral
	D.C. 350 Mk. II	5.5	3.43	.209	.687	.562	1.23	1.61	4 3/4	3	1 1/2	1/4	Shaft Rotary	Integral†
	E.D. Hunter ...	6.5	3.46	.211	.656	.625	1.05	1.87	5	3 3/8	1 13/16	3/16	Rotary Disc.	None
	Miles Special ...	.10	4.92	.30	.781	.625	1.25	2.02	4 5/8	3 3/8	2	5/16	Rotary Disc.	Integral
GLO	Frog 160 ...	2.9	1.48	.090	.50	.46	1.08	1.97	3 5/8	2 3/8	1 3/8	3/16	Shaft Rotary	Integral
	D.C. 350 (Glo) ...	5.5	3.43	.209	.687	.562	1.23	1.61	3 1/2	3	1 1/2	1/4	Shaft Rotary	None
	Frog 500Φ ...	7.75	4.92	.30	.75	.68	1.1	1.53	4 3/8	3 3/4	2	1/4	Shaft Rotary	Integral

*Single fixing holes. Φ Also spark ignition version.

Mounting Dimensions (in.) Beam	Radial	Crankcase Clearance	Bolts	B.H.P. (max.) B.H.P. at r.p.m.	TORQUE (max.) 02/in. at r.p.m.	AEROMODELLER ENGINE ANALYSIS REPORT	ENGINE
3/4	—	9/16	8 B.A.	.0065—12,500	.64—7,000	August, 1954	Allbon Bambi
1*	—	3/4	6 B.A.	.020—11.000	2.7— 7–10,000	June, 1952	E.D. .46 Baby
5/16 × 7/8	—	5/8	10 B.A.	.030—12,500	3.1—6,000	August, 1952	Frog '50'
5/16 × 13/16	—	11/16	8 B.A.	.042—11,500	4.8—6,000	April, 1953	Allbon Dart II
3/8 × 1 1/8	—	7/8	8 B.A.	.059—11,350	—	May, 1952	Mills P.75
1 3/8 × 1/2	7/8	13/16	8 B.A.	.0575—13,000	5.3—9,000	December, 1954	Allbon Merlin
7/16 × 1 3/16	—	15/16	6 B.A.	.062—10,006	—	October, 1949	E.D. Bee
7/16 × 1 3/32	—	7/8	6 B.A.	.084—10,800	9.9—7,000	June, 1953	Allbon Spitfire
.43 × 1.42	—	1	6 B.A.	.078— 7,250	—	July, 1948	Mills 1.3, Mk. II
7/16 × 1 3/16	—	7/8	6 B.A.	.148—10,500	18.0—5,000	February, 1953	E.D. Hornet
7/32 × 1 1/16	—	7/8	6 B.A.	.10—13,700	—	June, 1950	Elfin 1.49
7/16 × 1 3/16	15/16*	7/8	8 B.A.	.12—13,000	—	Sept., 1951	Frog '150'
7/16 × 1 1/8	—	7/8	6 B.A.	.134—11,000	15.8—5,000	—	Allbon Sabre
1 3/8 × 1/2	—	1 1/8	6 B.A.	.12—12,000	.11—9,400	July, 1954	Oliver Tiger Cub
—	—	—	6 B.A.	—	—	—	Elfin 1.8 BB
9/16 × 1 9/16	—	1 1/4	6 B.A.	.11— 7,000	—	May, 1948	E.D. Comp. Special
1/2 × 1.8	—	1 1/4	6 B.A.	.18—10,000	—	May, 1949	Mills 2.4
1 5/16 × 9/16	—	1	6 B.A.	.181—12,200	18.1—7,500	October, 1954	Allen Mercury 25
9/16 × 1 1/4	—	1 1/8	6 B.A.	.260—14,100	—	August, 1951	E.D. Racer
.6 × 1'3	—	1 1/16	6 B.A.	.231—12,300	—	June, 1951	Elfin 2.49
.6 × 1.45	—	1.05	6 B.A.	.192—10,700	—	July, 1951	Frog 250
.55 × 1 19/32	—	1.20	6 B.A.	.315—14,000	28.0—7,000	December, 1952	Oliver Tiger
1 1/4 × 9/16	—	1	6 B.A.	.26—11,400	.27—8,000	November, 195	Allen Mercury 35
5/8 × 1 7/16	—	1 1/8	6 B.A.	.281—11,300	—	January, 1952	D.C. 350, Mk. II
9/16 × 1 9/16	—	1 1/4	6 B.A.	.265—13,300	—	March, 1950	E.D. Hunter
1 5/8 × 5/8	—	1 5/16	6 B.A.	.435—13,500	41.8—7,300	March, 1955	Miles Special
7/16 × 1 3/16	15/16*	7/8	8 B.A.	—	—	—	Frog 150
5/16 × 1 7/16	—	1 1/8	6 B.A.	.262—11,100	—	January, 1952	D.C. 250 Glo
5/8 × 1 5/8	1.35 dia.	1 1/4	6 B.A.	.381—13,300	—	May, 1950 and Feb., 1952	Frog 500

† Plastic

METRIC CONVERSION TABLE

Square inches to Square decimetres

Sq. In	Dm²	Sq. ins.	Dm²	Sq. ins.	Dm²	Sq. ins.	Dm²	Sq. ins.	Dm²
1	.0645	21	1.355	41	2.644	61	3.934	81	5.224
2	.1290	22	1.419	42	2.709	62	3.999	82	5.289
3	.1935	23	1.483	43	2.773	63	4.063	83	5.353
4	.2580	24	1.548	44	2.838	64	4.128	84	5.418
5	.3225	25	1.612	45	2.902	65	4.192	85	5.482
6	.3870	26	1.677	46	2.967	66	4.257	86	5.547
7	.4515	27	1.741	47	3.031	67	4.321	87	5.611
8	.5160	28	1.806	48	3.096	68	4.386	88	5.676
9	.5805	29	1.870	49	3.160	69	4.450	89	5.740
10	.6450	30	1.935	50	3.225	70	4.515	90	5.805
11	.7095	31	2.000	51	3.289	71	4.579	91	5.869
12	.7740	32	2.064	52	3.354	72	4.654	92	5.934
13	.8385	33	2.128	53	3.418	73	4.708	93	5.948
14	.9030	34	2.193	54	3.483	74	4.773	94	6.063
15	.9665	35	2.257	55	3.547	75	4.837	95	6.127
16	1.0320	36	2.322	56	3.612	76	4.902	96	6.172
17	1.0965	37	2.386	57	3.676	77	4.966	97	6.256
18	1.1610	38	2.451	58	3.741	78	5.031	98	6.321
19	1.2255	39	2.515	59	3.805	79	5.095	99	6.385
20	1.2900	40	2.580	60	3.870	80	5.160	100	6.450

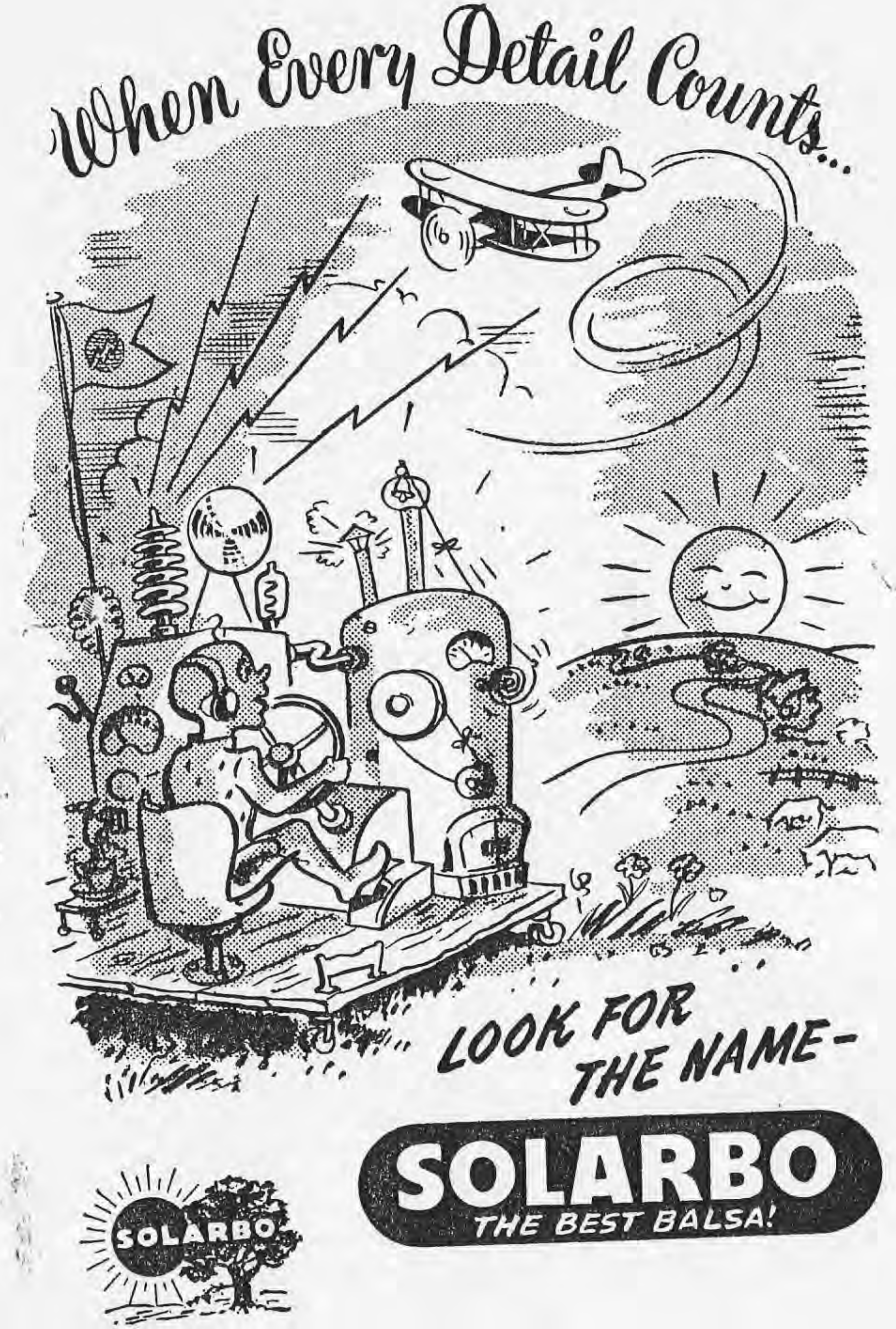
Inches to Millimetres

IN.	0	1/8	1/4	3/8	1/2	3/4
0	—	3.175	6.35	9.525	12.7	19.05
1	25.4	28.575	31.75	34.92	36.1	44.45
2	50.8	53.975	57.15	60.32	63.5	69.85
3	76.2	79.375	82.55	85.72	88.9	95.25
4	101.6	104.77	107.95	111.12	114.3	120.65
5	127.0	130.17	133.35	136.52	139.7	146.05
6	152.4	155.57	158.75	161.92	165.1	171.45
7	177.8	180.97	184.15	187.32	190.5	196.85
8	203.2	206.87	209.55	212.72	215.9	222.25
9	228.6	231.77	234.95	238.12	241.3	247.65

Ounces to Grammes

Oz.	Gr.	Oz.	Gr.	Oz.	Gr.	Oz.	Gr.
1/16	1.772	1	28.35	10	283.5	14½	411.07
1/8	3.544	2	56.70	10½	297.67	15	425.25
1/4	7.088	3	85.05	11	311.85	16	453.6
3/8	10.632	4	113.40	11½	326.02	17	481.95
1/2	14.175	5	141.75	12	340.2	18	510.3
5/8	17.720	6	170.10	12½	354.37	19	538.65
3/4	21.264	7	198.45	13	368.55	20	567
7/8	24.808	8	226.80	13½	382.82	21	595.35
15/16	26.580	9	255.15	14	396.9	22	623.7

We are indebted to Jacques Morisset of Paris for his work in presenting these conversion tables.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