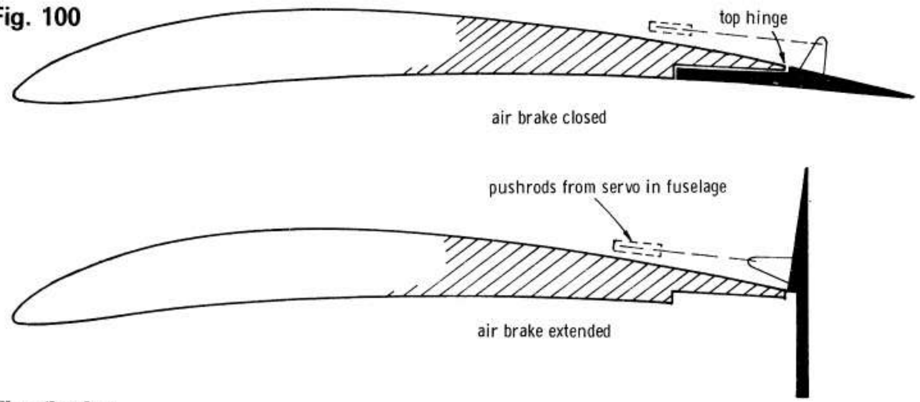
Fig. 100



Flap/brakes

An unusual and ingenious idea from Norway, shown in Fig. 99, is that of dual-purpose flaps-cum-brakes. Bear in mind, however, that the sort of models flown there are more like the "thermal soaring from the slope" models seen in Germany and the rest of the Continent—not like our own slope models, which are more often of the aerobatic type.

The idea behind these devices is to have a flap which may be used as a lifting surface for slow flight and, using the same servo, with the secondary rôle of serving as an effective airbrake/spoiler. The diagram shows how the system works in theory, but it will need careful structural design to give the necessary strength and rigidity in practice.

Although we have not yet seen these interesting devices in operation on a model in this country (and they could well be more suited to thermal soarers than slope soarers) the Norwegians claim many advantages. These include a much lower landing speed, steeper descent at lower speeds, increased longitudinal stability (as compared with ordinary brakes), improved thermalling performance, permitting safe turns of much smaller diameter without stalling—and improved efficiency, by virtue of the elimination of air leakage and contour breakaway at a critical location on the wing.

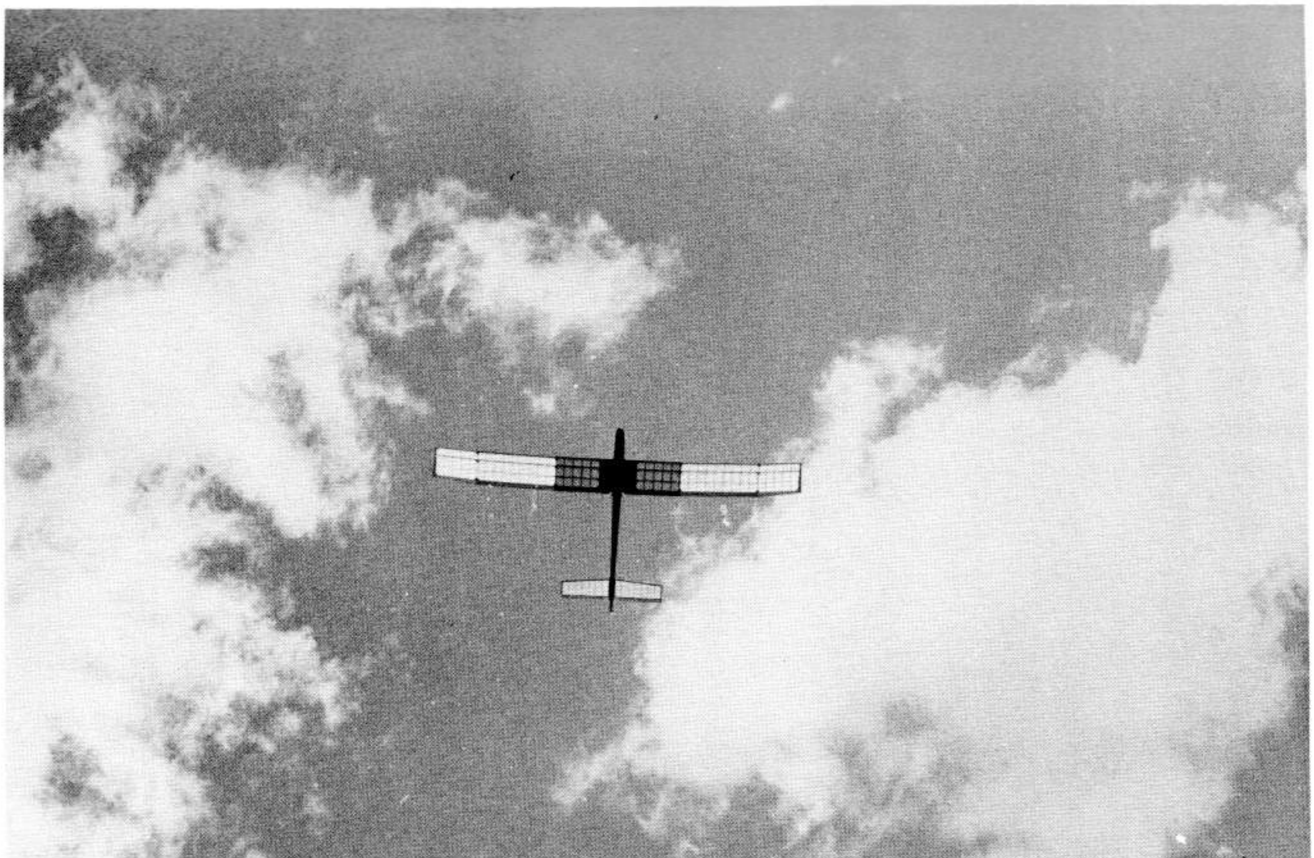
Trailing-edge airbrakes

The trailing-edge flaps, as used in Germany, are really a simplification of the Norwegian idea, dispensing with the higher lift position, as will be seen from Fig. 100. Again, these will have a wider application on thermal soarers, but could be used, with advantage, on slope soarers which have to be landed in confined spaces, into lift. When they are deployed, the model may be pointed at the ground, at something like 60° to 70° and will lose height at something less than its normal flying speed. Any tendency to "float" on the landing approach can be killed, and excess height can be lost at the correct moment, by their adroit use.

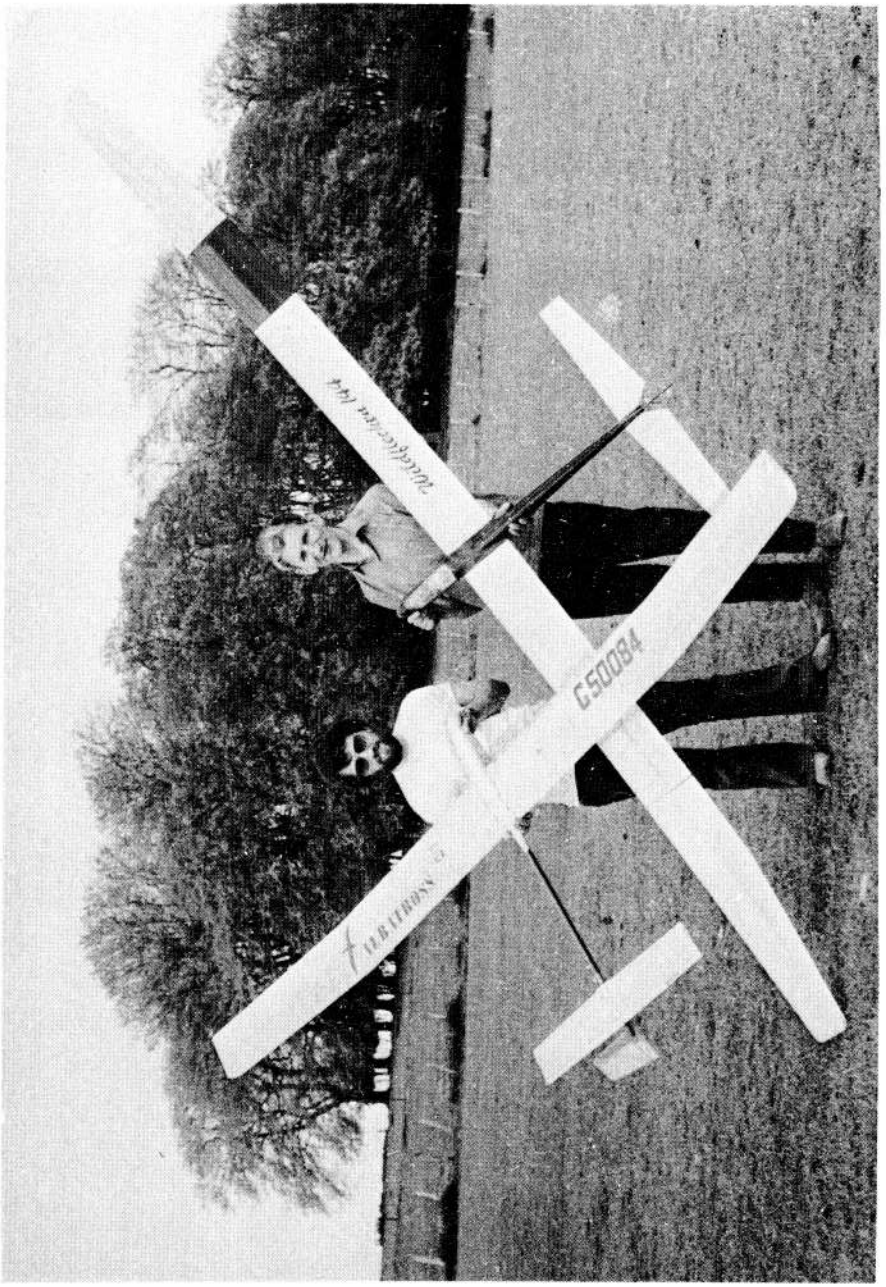
There are many refinements, both in configuration and in mechanical detail, that have been—and will be—devised by the keen and ingenious soaring modeller. The foregoing, however, are probably the most significant, and are certainly those which seem to puzzle the newcomer most, as to their whys and wherefores.

SECTION TWO

THERMAL SOARING



"Overhead release" – a picture which brings to mind all that's most enjoyable in thermal soaring. A warm summer's day and the model rising towards the fleecy clouds in good lift.



Co-authors of our introduction to thermal soaring, Dave Dyer (left) and Geoff Dallimer.

CHAPTER 14

AN INTRODUCTION TO THERMAL SOARING

By GEOFF DALLIMER and DAVE DYER

A WARM summer day, bright pillars of white cumulus cloud drifting across a clear blue sky, birds circling over the treetops. . . . Climbing quietly up to join the birds comes another winged creation, circling in the warm summer air. Soon it out-climbs the birds and rises eerily towards the clouds, for this bird is man-made and embodies his scientific knowledge to produce wings more efficient than those of our feathered friends; this, then, is a thermal soaring glider.

This idyllic scene is how any enthusiast of soaring flight will visualise his Sunday flying. Above, the air buoyant with warm thermal currents to sustain his model's silent flight; below the peaceful countryside. Not for him the hot concrete runways, the sickly smell of alcohol fuel, or the raucous noise of the soulless engine. But wait!—not always does our elegant model climb swiftly on a summer thermal—often it sinks dismally as though invisible hands were clutching it out of the sky—now nature adds a challenge that will increase man's enjoyment of his hobby!

The simple facts

How can a model—or any other aeroplane for that matter—fly without an engine? Firstly, one might ask, what is the purpose of the engine? We can say it is a means of providing power for movement, and this forward movement is translated into lifting flight by the aircraft's wings. There are, however, other means of propulsion; gravity, for instance, will provide power for movement, as anyone who has chased a ball downhill will testify.

A glider is continually flying "downhill," using the potential energy of its height, to create the forward motion needed for its wings to sustain its weight. The wings create lift by means of their reaction with the air through which they are passing; we say that an aircraft has "airspeed" and moves "relative to the mass of air surrounding it." Thus the glider, in *still air,* will fly steadily forward, sinking down at a constant angle until it reaches the ground. This angle is known as the "glide angle" and is a measure of the model's efficiency. The more efficient the model, the further it will glide for a given height loss.

But did you notice we said "still air"? Herein lies the key to long gliding flights and the ability of a glider to climb instead of sinking. *Always* the glider is sinking, relative to the air surrounding it, but what if this air is *rising* relative to the ground? Fortunately the air around us is very rarely, if ever, completely still. The heating effect of the sun causes masses of air to rise vertically, while other masses are sinking.

A good indication of how the air behaves can be seen in autumn, by watching the smoke generated by your local farmer burning off the stubble from a cornfield. Columns of rising air are known as "thermals" and are caused by some air becoming warmer than that surrounding it. Flying in these columns of rising air is therefore known as "thermal soaring." Later on we will discuss in more detail how thermals are formed and how to find them.

Thermal soaring gliders . . .

Thermal soaring is not new in itself, since both full-size gliders and free-flight model gliders have been flown in thermals for many years. However, with the advent of radio control systems light enough—and, incidentally, reliable enough—to enable the glider to be fully controlled, a whole new field of possibility has opened up to the model glider enthusiast.

The design of models for thermal soaring is still in the developing stage and, although at first the models used for r/c thermal soaring were fairly heavy ones, designed for slope soaring, but adapted for flat-field launching by the fitting of tow-hooks, the current trend is towards a much lighter "free-flight" type of glider, usually of around 8ft. to 12ft. wing span. The evolution of specialist models is bringing a steady improvement in performance, with an "all-weather" flying capability. How much influence the weather environment has on the design of thermal soaring gliders may be seen by comparing the very large (12 to 16ft. span) models flown in the United States, with the smaller (8 to 12ft.) models flown in the quite different climate of the British Isles.

This difference in climate also makes the formulation of acceptable International competition rules more difficult, since the flying techniques and models' performances are somewhat different, too. The larger models are able to circle and "work" a thermal as it drifts downwind, and then return upwind to the starting point; the smaller models, however, are less able to penetrate upwind, so remain near their starting point and only "work" the thermal as it passes by.

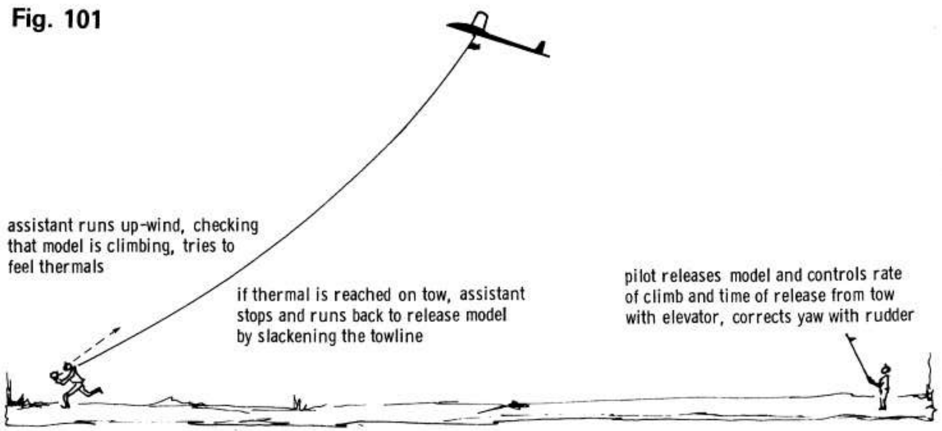
Thermal soaring, then, consists of launching the model over flat land (as distinct from a hillside), either by means of a tow-line or catapult, to a height of about 500ft., and then seeking out areas of rising air to sustain the model's flight—and even gain height. Sufficient height is often gained to allow the model to perform aerobatics, such as loops or spins, although the more efficient, high-performance, type of thermal soarers are not generally suitable for this purpose.

Getting started

By now we hope to have fired the reader with our enthusiasm for thermal soaring, to the extent that he is already thinking about building a suitable model. There are a number of excellent kits available, both of Continental origin (thermal soaring is very popular on the Continent) and from British manufacturers. Alternatively, the modeller may, if he wishes, choose from the wide variety of plans published by the modelling press. Building from a plan is probably the most economical way, although it will, of course, require rather more work on the part of the constructor.

To some extent the choice of model will depend upon the type of radio control equipment the modeller is going to use. The controls required for a thermal soarer are basically rudder and elevator, and these may be operated either by proportional radio

Fig. 101



equipment or by single channel systems—or even the old-fashioned "reed" outfits, or "galloping ghost." *(For details of the development of radio control systems, the reader is referred to* The Theory and Practice of Model Radio Control, *published by the publishers of this book.)*

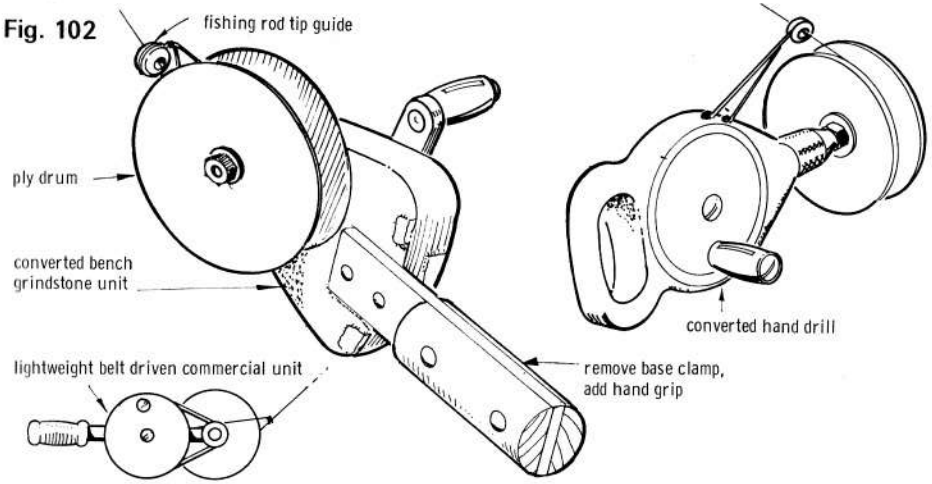
One cannot deny that the modern proportional systems are by far the most satisfactory, but this should not discourage those considering using simple single channel outfits, since these can still give excellent results on a cost/enjoyment basis. Being able to steer proportionally—and point the nose up or down—however, does make a whole world of difference, so proportional is really to be aimed at, if at all possible.

Launching technique

There are two main methods of launching thermal soarers, these being the tow-line and the Hi-start. Other methods, such as powered winch or pulley, have been used but have not gained popular acceptance, in this country, at least.

Hi-start, or Bungee launching, as it is more commonly called, is dealt with in another chapter, so here we will only say that, for competition work, it is now generally accepted that the tow-line is the more practical and efficient. Basically, this is simply a length of line, attached by means of a ring, to the model's tow hook, and by which the model is pulled along and into the air, in much the same way as a kite is flown. (See Fig. 101). The difference

Fig. 102



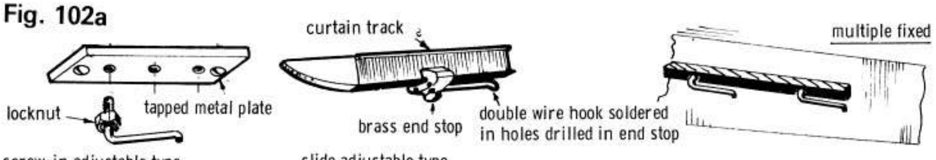
is, of course, that when the model reaches its maximum height (this often being vertically above the head of the man doing the towing) it is released, by the ring on the tow-line sliding from the hook, to fly where the pilot directs it.

The most commonly used line length is 150 metres, although International rules call for a *maximum* line length of 300 metres, at the time of writing. For models of up to approximately 800sq. in. wing area and weighing up to, say, 3lb. the use of a line of about 22lb. breaking strain would seem to be the best choice, and the material used is almost universally nylon monofilament (fishing line). For models of greater area and weight, the breaking strain of the line used should be increased accordingly.

Care must be taken, when choosing a line, to have a fairly low cross-section area in order to minimise drag, and thus height loss. When in use, the tow-line must be regularly inspected for flaws, as the 3 Kg pull test used in contests will quite easily break a line if it has been chafed or cut, or even badly kinked.

To house the line, some form of drum is required, fitted to a geared hand-winch. By this means, the line can nearly always be fully winched in, after release of the model, before it touches the ground at all, thus avoiding its snagging or becoming tangled. To this end, a gear ratio of a fairly high order can be of great help. There are a few commercial winches on the market, but most modellers prefer to make their own. These can either be made up from scratch, or based on existing mechanisms such as small workshop hand-cranked grindstones—the stone itself being replaced by a drum of suitable proportions. Fig. 102 shows some typical examples, while Fig. 102a shows some methods of arranging for different tow points on the model. Fig 102b shows the method of determining the optimum hook position.

Fig. 102a



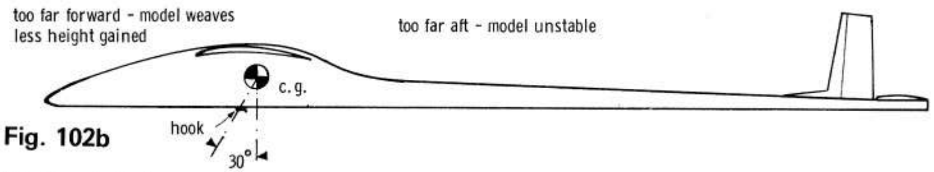


Fig. 102b

Towing technique

Here one has the choice of either towing the model oneself or finding a willing (and able) assistant to tow the model, while one concentrates on controlling it. Ideally, it is better to tow your model yourself but, as usual, there are snags. Quite apart from the obvious difficulty in running with the transmitter in one hand and the likelihood of bending the extended aerial, and the virtual impossibility of giving any form of precise control while on the run, there are other considerations. For competition flying, especially, where one has to land the model in a specified area, there is a definite disadvantage in towing for oneself. If you are flying the model in calm conditions, quite a long towing run can be involved and the result of this will be that the release point will be perhaps 300 to 400 metres upwind of the landing/launch area. Most modellers will agree that trying to control the model will be difficult while running or trotting back to the landing area. (If your landings are accurate at 300 or 400 metres, then you can ignore this point, but you will probably be unique!)

Another disadvantage of towing your own model is that, when the pilot is immediately beneath the model it is difficult to effect accurate pitch control—because he cannot observe the model's behaviour in that plane easily from this viewpoint—so several seconds are easily lost because of a non-optimum trim, or even a severe stall. It will be seen, therefore, that if an assistant tows the model, the pilot can relax and assess the wind and lift conditions while the model is gaining height, and he can also ensure that the model does not deviate from the desired straight tow, by giving any necessary correcting control. At the same time, the assistant can concentrate entirely on towing and, if necessary, run to his limit (boundary and physical) in the all-important search for lift, while the pilot stays in the launch/landing area and concentrates on the moment of release for the model.

For launching the model should be held up high, with its wings level and its nose well up, as shown in Fig. 103. As the line tension increases, due to the assistant commencing to run, the pilot begins to run with the model for a few yards, not letting go of it until he feels that it has reached flying speed.

Towing itself is not difficult, once one has mastered a few simple techniques. At first one

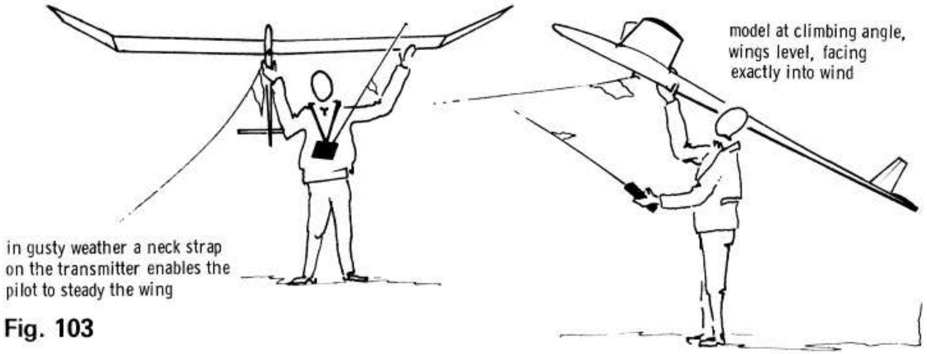


Fig. 103

has to run fairly fast to take the stretch from the line and to achieve the model's airspeed. Once the nose of the model lifts and it starts to climb at 30° or 40° to the horizontal, the speed of tow can be reduced and the model held in a steady climb until the "top" of the line is reached. Allowance must be made here for the wind component, in that, if calm, one must run faster and *vice-versa*. In fact, in strong winds it may even be necessary to run *towards* the model part of the time, to relieve the wing of what could otherwise be an excessive load.

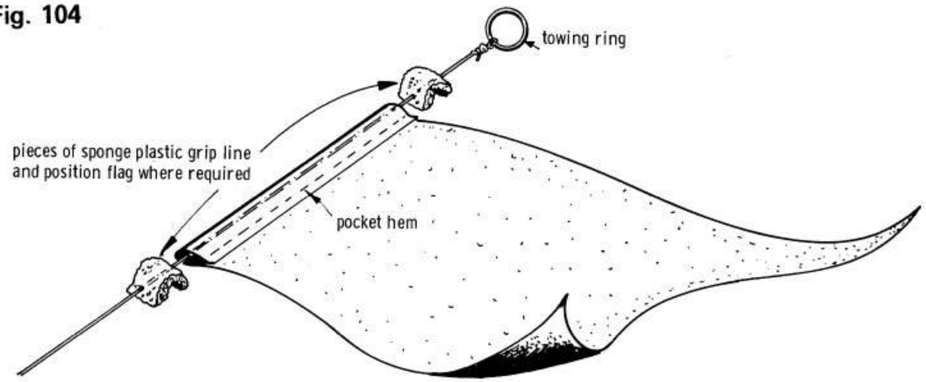
Some models tend to yaw and pull away to one side while being towed, due to either a shortcoming in the design, or to warped flying surfaces. If the model does veer, then a reduction in the towing speed should help the model to swing back naturally onto a straight climbing course, with the minimum of assistance from its pilot. (In fact—to revert to the "other end" for a moment—it is generally better to under-control than over-control while the model is being towed, as over-controlling can result in the model's oscillating wildly from side to side, if the pilot gets just a little bit "out of synchronisation" with his correcting commands.)

Once the model has reached its maximum height, on tow, one should be able, by slow running, to hold it there and wait for it to show signs of being in lift. However, as contest rules may call for a maximum allowable time spent on the line, there may not be many seconds left in which to do this. On the other hand, if you are only flying for your own pleasure, rather than in a contest, the man towing may "walk" the model around for several minutes until he feels it pulling, telling him it is in lift. To be able to launch a model straight into an area of strong lift is, of course, a great benefit, and should result in a better flight than simply trying to find lift "on the way down." The model is released (if the pilot is not using a radio controlled tow-hook release) by simply stopping and releasing any remaining tension on the line by jerking or shaking the line towards the model, being careful not to jerk (and so possibly stall) the model itself in the process. To aid both the release of the line, and the timekeeper's chance of starting his stopwatch at this precise instant, a pennant is used on the tow-line. In contests, a certain minimum area is laid down for this pennant, namely 2·5dm² or approximately 39sq. in. A suggested method of fixing the pennant to the line, so that it may be positioned as required, is shown in Fig. 104.

One of the biggest problems for the beginner to thermal soaring—or, rather, his helper, is in deciding just exactly how fast or slow the model should be towed, in a given set of conditions. Many people new to it, simply tear off across the field at a constant speed, irrespective of the strength of the wind. As a result, the model may, at best gyrate madly and perhaps even barrel roll on the line—and, at worst, the wings could fold up. Some helpers, however, are less energetic and do not run fast enough, when (especially in near calm conditions) the model simply follows behind them, about 15ft. up, and eventually gains on them, slipping its tow ring as the tow-line sags.

If at all possible, it is really the best plan to secure the services of an experienced glider flier—either radio or free-flight—to tow your first model up for you. By doing this you will know that it is being given a good launch—much better than having inexperienced men at

Fig. 104



both ends, no matter how enthusiastic! After a flight or two, ask your own helper to go along with the experienced man, and get the feel of the towing end of things. After that, it is simply a question of practice, practice and more practice.

Flying

The model will be quite some distance away from the pilot, at the point of release—the length of the tow-line plus the distance covered by the man towing—but this should be no cause for concern. It is, in fact, easier to detect thermal lift when the model is some distance away, than when it is near, since one is more easily able to detect any rising-up of the model, relative to the ground.

Old-hand power fliers tend to become a little disconcerted at the necessity for this long-distance control—and, indeed, sometimes find their control movements "out of step" with the model's requirements. If one is to continue thermal soaring, however, one should practise flying the model around the release point and some way *up-wind* of it, since it is here that often the best lift is to be found. More will be said about thermal lift and how to find it, a little later on.

Judging the landing approaches of thermal soarers can be quite difficult for even the most experienced power fliers since, of course, their rate of sink is very much lower and the glide angle a great deal better. They tend to float on, and on, and on, in fact, when only a few feet from the ground. The beginner can expect to make many "overshoot" landings before he gets the measure of his model. For that matter, this can apply almost equally to the experienced thermal soaring enthusiast with the first few flights of his latest (and best!) model. In this case, however, he does have the encouraging thought that, if it *does* overshoot, then it must be better than his last model.

THERMALS AND THEIR DETECTION

The use of thermals, as a method of prolonging soaring flight, is a well-established practice. Both full-size and model gliders have been doing it for years—and birds, of course, have been doing it since the dawn of life on earth.

First we will discuss the formation of thermals and then give some information on thermal utilisation. A generalisation of thermal shape and airflow is shown in Fig. 105. It will be seen that the overall shape is that of a ring doughnut, with the central core of the thermal moving upwards and the perimeter moving downwards.

On most sunny days more heat is supplied by the sun's radiation to a piece of ground than can be carried away by convection and wind turbulence into the air, and by conduction into the ground. Consider, then, a parcel of air thus heated. The air in this parcel becomes

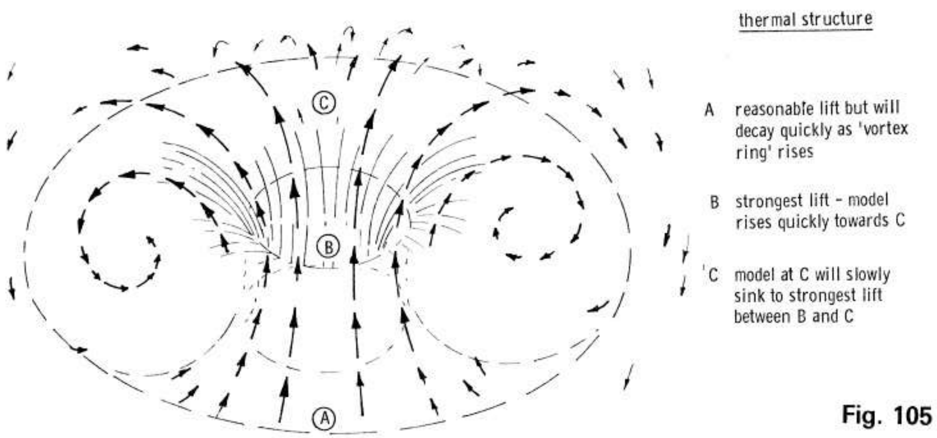


Fig. 105

very unstable and thus, either because it is slightly warmer than its immediate surroundings, or because of its buoyancy and turbulence, this parcel begins to rise. As this formation moves upwards more air is encompassed and so the thermal grows in size. It follows that, because this parcel of air is rising, then other air must take its place, and this is how down-draughts (negative thermals, if you like!) are formed. A point which should be realised here is that, on some days when very strong thermals are abundant, there must also be very strong down-draughts existing, so flying becomes a matter not only for contacting lift, but also of avoiding down-draughts.

As we have seen, some areas must become slightly warmer than their immediate surroundings to produce a thermal; such areas are called "heated thermal sources." The strength of such a source is dependent on two factors: the rate of temperature rise of the ground surface and the length of time an amount of air is resident over that particular area, before moving in the general wind flow.

The rate of temperature rise is dependent on several factors, namely (i) moisture content of soil—more heat used to heat damper soil; (ii) reflection of sunlight by the surface. For example:

Surface	Wasted sunlight
Crops	3—15%
Bare ground	10—20%
Grass fields	14—27%
Snow, ice	45—85%

(iii) angle of incidence of the sun's rays and (iv) foliage cover. (This causes a reduction in ground heating due to the foliage using the heat for transpiration.

The period of time for which a parcel of air is in the vicinity of a thermal source, is dependent on wind strength and the degree of sheltering present. It follows that if an area is downwind of an obstruction, the air behind that obstruction will reach a higher temperature than that which is unprotected. This effect is even more pronounced if the area protected is in direct sunlight and that surrounding it is not. The effect of obstructions, for example, trees on a field boundary, can sometimes be to cause turbulence *and* have a sheltering effect, thus increasing the probability of thermal production. Another point is that thermals of different strengths will have proportionately different ground speeds—see Fig. 106.

Whilst the foregoing should be used as a guide to possible location indications, it should also be realised that what is normally a poor thermal source—for example, a wood or group of trees—can become a very reasonable area of lift production at a different time of

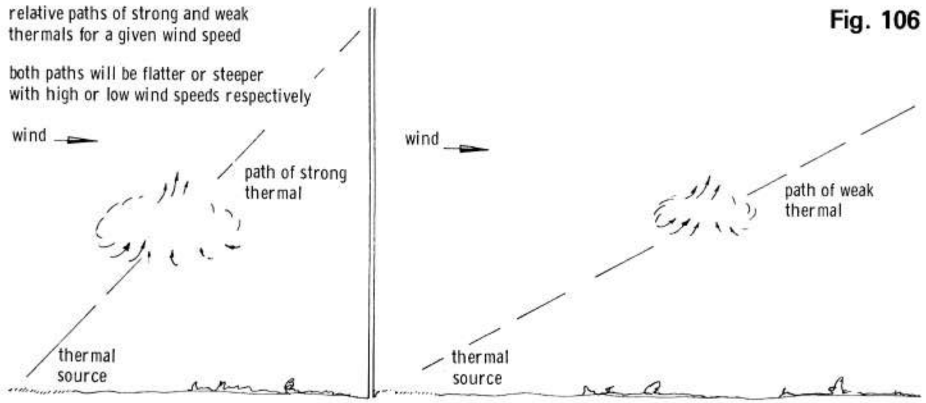


Fig. 106

day, since, in the evening, the woods become reasonable sources when most normal sources have ceased to be active. Combination effects of all the aforementioned phenomena make accurate prediction of thermal sources difficult, so it is necessary to study carefully any particular area and notice the location and frequency of any lift produced.

Thermal shape and form

In all gliding circles there is still much discussion and argument as to the actual form that thermals take. Because of the many different factors involved in the actual formation of the lift, it is very difficult to predict exactly what type of thermal emanates from what type of surface.

A general form of thermal can be considered as a vortex ring (the ring doughnut shape described earlier and shown in Fig. 105). However, this is not the complete story. Peter Goldney has described* a series of experiments he undertook with a heated plate in a wind tunnel, where a jet of smoke was allowed to drift over the plate. At first only a dome of smoke formed but, as the temperature and wind speed were increased, the smoke formed first a rising plume, which later became small clouds (or vortex rings?) building up into the phenomena known as "cloud streets."

It should be remembered here that we are only interested in relatively low level lift, and so most of the thermals are of the plume or continuous type we have just mentioned. Occasionally one encounters a low level bubble, or vortex ring. The situation here is rather a case of "swings and roundabouts" since, for these bubbles to form, a breeze is normally required. It follows that, because of the relatively short distances we fly our thermal soarers up- and down-wind, their usefulness is small.

Thermal detection

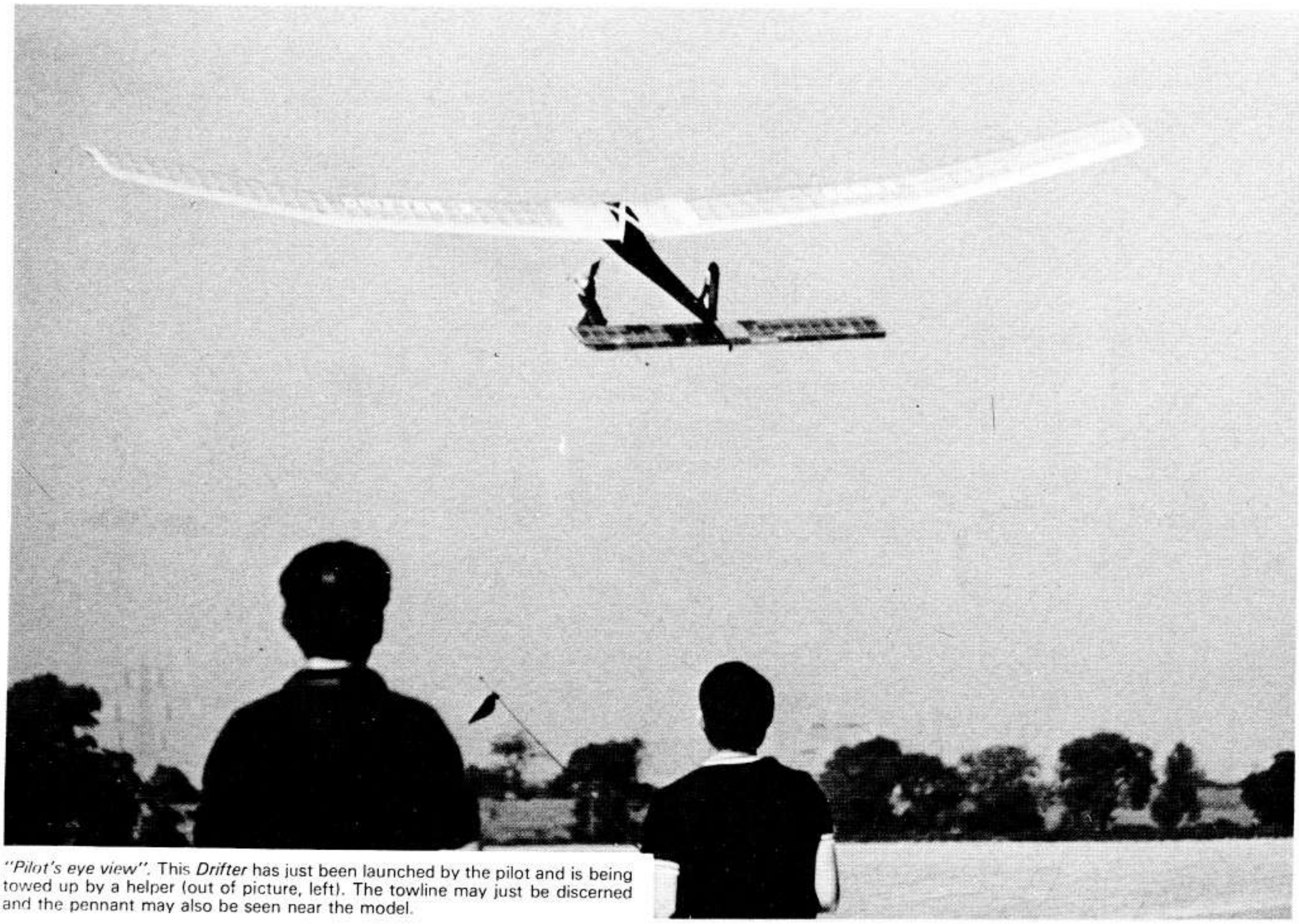
The detection of thermals by instrumentation has been much investigated in free-flight model circles, even to the extent of fitting chart recorders to sensitive temperature detectors. These detectors usually take the form of simple units comprising a d.c. bridge with a thermistor as one arm. Bridge detection is by means of a meter (or recorder, as mentioned). Results from these devices tend to be inconclusive in that, as only small differentials of temperature exist in and out of lift, it is very difficult to discriminate between an actual thermal and changes in direct sunlight and cloud screening. A circuit of this type of detector appears in Fig. 107.

The most sensitive of practical lift detectors seems to be the one using soap bubbles (the children's type, sold in small tubs with a ring to form them on). Devices have been tried for automatic bubble formation by means of a unit suspended from a helium balloon, but it is not known whether any appreciable success was achieved with this method.

* *Sailplane and Gliding*, journal of the British Gliding Association.

"Up and away". Pilot releases a thermal soarer whose design obviously owes much to its builder's previous free-flight experience. A towline pennant hangs from the line, which may just be seen going out of the picture, right.

Lightly loaded models like this sometimes need support at the wingtips if the weather is at all breezy, to keep them level for a good straight launch.



"Pilot's eye view". This *Drifter* has just been launched by the pilot and is being towed up by a helper (out of picture, left). The towline may just be discerned and the pennant may also be seen near the model.

This V-tail model is typical of a breed of relatively heavily loaded (9oz./sq.ft. in this case) models that are being developed to fly the international "triple task" events.

Coming down to ground level, so to say, the use of bubbles is not, in practice, very helpful, due to the effects of ground turbulence.

A device which has been used in other countries is a miniature version of the electronic variometer, currently used in full-size sailplanes. There is great scope here for direct model rise/descent to be detected, the only problem being that of getting the information back to the pilot, since the use of airborne R.F. transmission would be illegal in the United Kingdom.

One of the most useful everyday methods of thermal detection is simply to study the visible signs. Birds are naturally very good thermal detectors and, if one sees a group circling, it is pretty certain they are in lift. By noticing where any birds start to circle when they are fairly low is also a reliable method of locating a thermal source.

By watching smoke emanating from a chimney it is often possible to see when lift is present, because the smoke starts to rise unnaturally fast. It should be realised that the lift produced is *not* from the chimney smoke source, but usually caused by heating of the surrounding buildings by incident sunlight.

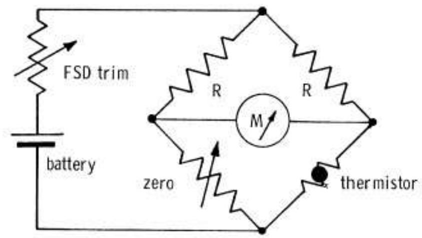


Fig. 107

Clouds are good thermal indicators. The subject is fairly complex, but here it is sufficient to say that the formation of cumulus type cloud indicates the presence of a thermal. The clouds are formed in the following manner. The thermal reaches condensation level and a cloud begins to form, which continues growing until the thermal activity ceases. Decay of the cloud begins when the air ceases to reach condensation level and the cloud slowly collapses at approximately the same rate as growth. As a hint, the decaying clouds are usually darker owing to the larger droplet size.

When locating lift below clouds, the best method seems to be up- and down-wind travel at the approximate crosswind location of the cloud-indicated thermal. Again, because of wind strength, thermals feeding cloud will tend to lag behind that cloud, and it is thus necessary to notice the usual time lag on one particular day—or at any site—as this figure will then usually hold good for that day, provided the wind strength remains fairly constant.

About the most helpful method of lift location for models seems to be the phenomena surrounding thermal formation. Usually one feels a cool breeze or, perhaps, just a lull in the normal windflow. This is the cool air moving into the thermal base. Following this, one feels the passing of warm air, and one is then at the approximate centre of the active thermal.

When towing a model it is possible to sense thermal pull by line tension, though this is not very easy, especially with longer lines, which tend to damp out any small fluctuations, due to their elasticity. As the model enters the start of a lift area, it first starts to sink; the pull then increases slowly until it is at a maximum when at the core of the lift. When flying in very calm conditions it is best to launch the model in the core of the thermal to enable the pilot to use the strongest lift by circling the model. However, when conditions are more normal, that is to say, with some breeze, then it is better to keep the model heading upwind all of the time that lift is present. As soon as the model begins to sink, then it is best to move away from the area, to avoid the down-draught after the thermal.

The most difficult part of thermal detecting seems to be that of discriminating between gusting and true thermals. Once free of the tow-line, lift detection with the model is not so easy. By careful flying, in order not to disturb the model's flight path by coarse control, it is quite possible to detect the model gently oscillating as it enters the swirl of the thermal.

It is also possible to sense lift by noticing if the model lifts one wing tip sharply as lift passes that side. The immediate reaction should be to turn the model towards the lifting wing in order to try to find the strongest lift.

TYPES OF CONTEST

While there are probably many modellers who enjoy the flying of thermal soarer models simply for its own sake, the high performance thermal soarer has usually been developed as a competitive machine. In fact, one tends to think of a "thermal soarer" as a contest glider, whereas a large proportion of slope soarer designs are "sport" or "fun" models.

Despite this contest-specialisation, however, there has—until quite recently—only been one type of contest for thermal soarers in this country, namely the "duration" event. In this, the competitors endeavour to keep their models airborne for as long as possible, up to a "maximum" fixed by whatever rules are being used. Flight times in excess of this are not recorded (*i.e.* the excess is not recorded, the flier being said to have scored a "max"). As a rule, the models are also required to be brought down within a specified time (usually a minute) of having reached this maximum, penalty points being deducted from the score for further excess time. In addition, the model must land within a prescribed area for the flight to count at all, but bonus points are awarded for a landing in a small circle within the main landing area.

Two, three, or sometimes four "rounds" are held, so that each competitor is called upon to fly a number of times during the day—he does not take his flights consecutively. This is supposed to even out the chances, and reduce the possibility of one flier having all his flights in "good air," while another has his all in "sink." The results are usually based on an aggregate of times, though sometimes a system is used calling for the "best two out of three" or "best three out of four" flights only, to be counted. This, also, is in an endeavour to avoid handicapping those who, though generally flying well, have found "sink" on one flight, resulting in a very poor performance, which would put them out of the running were all flights to be totalled.

Eliminating the "luck" element has occupied many modelling minds, especially in r/c thermal soaring, and various statistical systems of doing this have been devised, including some very ingenious—and complicated!—ones. We do not propose to go into details of these here, because, as with any developing art or science, they are constantly changing.

That, then, is the basic "duration" event, with its variations and trimmings. We said, earlier, that it was, until recently, the only type of competition, in this country, for thermal soaring fliers. On the Continent, however, there have been for quite some time, contests which put the accent less on flying the glider in thermals, and more on simply flying an r/c glider.

These contests are the "Fixed Task" or "Multiple Task" events, in which the models are required to perform certain specified operations, or "tasks," with precision. The triple task event, now favoured internationally, comprises (a) Spot time/spot landing, (b) Distance covered in a specified time and (c) Speed over an out-and-back course of a set distance. (Again, we are not quoting actual figures, as these may be changed several times in the lifetime of a book such as this—and a set of the current rules is normally available from those organising contests).

It will be seen that these task events call for models with perhaps more speed and manoeuvrability than is required for the duration events—and not necessarily the out-and-out glide efficiency. Models which can combine all three attributes, therefore, are to be desired, and it may be that variable camber aerofoils (*i.e.* flaps and their variants) could play a large part in achieving this.

The multiple task contest is now finding a much greater place in British thermal soaring, and is certainly an interesting and stimulating way of helping to rule out the luck element. However, there is an "organisational" problem, in that these events require a relatively large number of officials, flagmen and so on, so that it is unlikely that they will ever completely replace the simple duration format for "domestic" (club and inter-club) events.

CONTEST TACTICS

To the casual onlooker, thermal soaring competitions may seem simply to be a matter of keeping the model in the air for as long as possible. This is, perhaps, the case but, since we are flying in a contest, it is as well to make the best effort to win. This can be achieved without necessarily having the best model on the field, provided one is effective in applying a practised contest technique.

In some ways, the development of tactical flying in any competition class spoils the atmosphere for those who take a less serious attitude to contest flying. In the long run, however, it is often the tyro competitor who gets most enjoyment from his competition flying, since he has nothing to lose and everything to gain! Tactical flying has become the order of the day in free-flight competitions, so that it is now a highly specialised part of competitive flying, the model being used simply as a "tool of the trade" in achieving a contest score. Unfortunately this has led to free-flight contests being more a trial of one's patience, than a test of the model.

Radio controlled thermal soaring may eventually become similarly "cut-throat," but it is certainly to be hoped that this will not be the case, and perhaps the restrictions imposed, due to time and frequency limitations, will prevent this situation developing. In the meantime we can but make use of all our knowledge to record as high a score as possible and keep ahead of the other "pot hunters." If, on the other hand, you are one of those in the enjoyable position of entering a contest simply because you enjoy flying in the company of fellow modellers, you may happily ignore the rest of this piece. . . .

Use the rules to your advantage

The first essential is to be fully conversant with the rules to which the particular competition is being run. How important is this understanding of the rules? Well, it is obviously undesirable to be towing with a 300ft. tow-line when the rules allow 600ft., but how about using 300ft. when the rules allow 100 metres? Now, 100 metres is 328ft.—approximately 10% longer. In still air this means the model's flight time would be reduced by the same amount, so that you would lose 6 seconds of every minute flown, which of course, can make a lot of difference to your total score.

Can you choose the time that you fly? If so, you will be able to choose a favourable time, when the biggest thermal of the day is about to develop. If, on the other hand, times are allocated by the organiser (tending to be the rule rather than the exception these days) but with the option of going to the end of the queue, then if it is pouring with rain when your turn comes up it might be prudent to put off the flight until later!

At one time, two attempts at each flight were allowed, since landing outside the square records no score. This rule, however, has largely been dispensed with, as it tended to be "used to advantage" when the model was turning in a poor time, with pilots deliberately "dumping" the model outside the square, and thus gaining another attempt. The main reason for dispensing with this rule—apart from those who consider this "use" of the rule to actually be abuse—has probably been due to the time factor involved, since, if a large number of fliers elected to try for a better flight in this way, the length of the contest would be considerably extended. There may be some local contests which still incorporate this second attempt rule, and, if so, there is no reason why it should not be taken advantage of in this way. It is as well to have a helper calling off the time towards the end of the flight, to enable you to make the decision of whether or not to abort the flight on the approach to the square. This tactic must, however, be used with discretion, especially on windy days, as no room for error is left on the second attempt. If you miss the square accidentally the second time, then you are virtually eliminated from the contest. The decision to abort should not be left too late since, if the square is large, you might not be able to fly out of it.

Remember local conditions

It will soon be realised that no two contest sites are alike, and advantage can be taken of local conditions that prevail around the particular site at which a contest is held. Often this will mean a particular area that initiates thermals, or perhaps avoiding turbulent air downwind of a nearby building. At one site we know of, it is advantageous to tow some 400 yards upwind, since this point is higher than the normal starting point. At another it has been found possible to make a flight of 30 minutes plus, without thermal assistance! In this particular case a convenient building was used as a "slope" and the model soared back and forth along the "ridge" of the roof, making use of slope lift. (Unfortunately, this was only discovered after the contest had taken place!).

In approaching the landing square, there is always the danger of overshooting and losing the flight by touching down outside the square. For this reason it is useful to make the approach towards the pilot, so that height and distance may more easily be judged. (One is tempted to say "so that if all else fails, the pilot can catch the model"—but this would not be allowed in most contests today!) Usually it is advisable to land into wind in the normal manner; however, for rudder-only models, when conditions are calm and the landing area has a pronounced slope (not all contests are held on flat airfields), then it is as well to approach "up" the slope to avoid overshooting. Obviously if the slope has a fall of about 1-in-15 and the glider has a glide angle of 16-1, a landing *down* the slope is not possible without elevators!

A proper "square approach", as practised by the power fliers, is by far the best and safest method of landing approach for thermal soarers, too. By flying the model through the four sides of an imaginary square, it is far easier to judge its height, speed and rate of descent, than when simply bringing it in willy-nilly. One often sees thermal fliers bringing their models in, near to them, in ever-decreasing circles, but this is not good practice, as it means that it is most likely to touch down cross-wind, on a wing-tip, then cartwheel and overturn. Far better to judge your model's rate of sink on the square approach, and then land *into wind*, straight towards the spot—not in a stalled side-slip!

Draw the line somewhere

Please remember that this is only a hobby. By all means win if you can, but the first essential is to enjoy your flying. Don't let thoughts of tactics, thermal hunting and so forth, obscure the real pleasure that comes merely with competing in the company of fellow enthusiasts of silent flight.

CHAPTER 15

BASIC DESIGN FOR THERMAL SOARERS

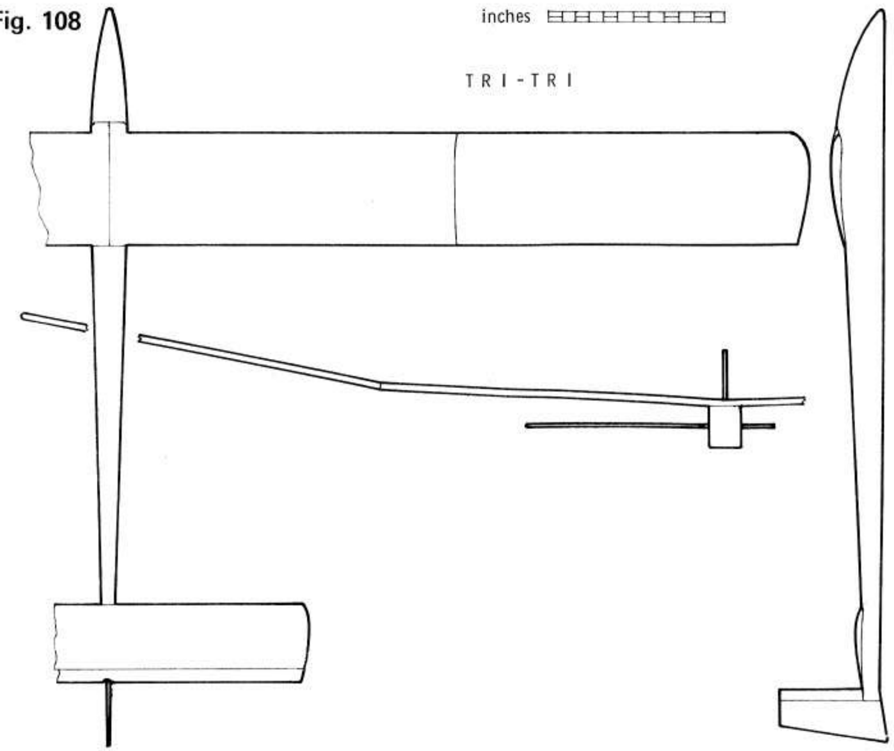
By GEOFF DALLIMER and DAVE DYER

THE design of gliders is far from difficult, and most keen modellers will wish to try their hands at this aspect of their hobby. It can be said, with some certainty, that any "design" will fly with at least some measure of success. It is a matter of degree, however, and this can only be improved with experience—and experiment.

Since gliders, generally, fly slower than powered models, they are usually more tolerant of design parameters and although, of course, the most efficient designs are to be preferred for contest flying, the designer has a wide range of possible configurations within which to create his own particular aircraft. Figs. 108-111 show some typical designs.

As with all designs, one must have at first some idea of what the finished model is to look like. That is to say, size and shape—high-wing, low-wing, T-tail or V-tail and so on. Once this is decided it is possible to work out the other proportions. It is convenient to start with the wingspan which is, commonly, between 6ft. and 12ft. At the same time, the

Fig. 108



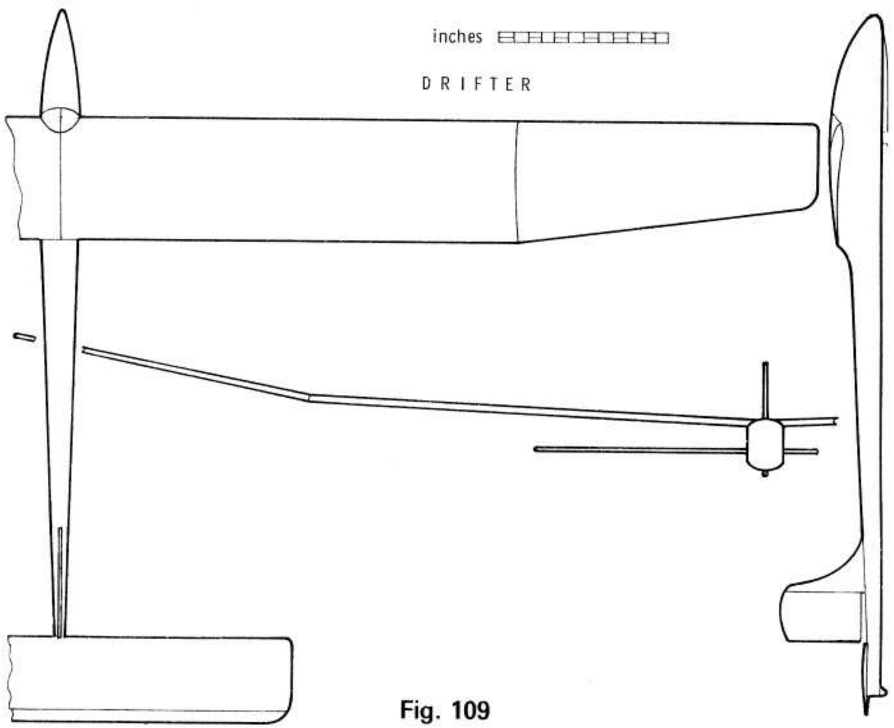


Fig. 109

intended wing-loading should be chosen, since this will determine both the model's flying speed and the total flying weight of the model. The wing-loading is arrived at by means of a simple sum; the wing area in square feet divided by the model's weight.* Loadings of between 4½ and 9oz. per square foot are usual, though it is usually preferable to aim for the lowest possible loading consistent with reasonable strength. With the wing loading chosen, the wing area can be calculated.

The aspect ratio of the wing is the next consideration. Again, a simple sum—$\frac{\text{Span}^2}{\text{Area}}$—or mean chord divided into span. The aspect-ratio will, for thermal soarers, lie typically in the range of 10 : 1 to 14 : 1. The higher the ratio, the more efficient will be the wing, although, for practical considerations, higher aspect ratios are not often used, since it becomes more difficult structurally to prevent wing flutter, due to twisting under stress. How stiff the wing can be made depends somewhat on the aerofoil section chosen.

We will read about the aerodynamic considerations of aerofoil sections in another part of this book, and each designer usually has his own ideas on the subject—indeed, often his own "pet" section—which may be either based on full-size data, or a hand drawn "zip-zip" shape. Variations of the good old standby, Clark-Y may be used for flat-bottom wings (easy to build), or perhaps NACA 6409 for an undercambered wing. (The model with an undercambered wing will tend to fly more slowly, though perhaps will not have the degree of penetration afforded by the flat bottomed wing). The type of section to use may possibly be best decided by looking around at contemporary designs, since the performance of the section at model size may then be observed. Full-size wind tunnel data is not very relevant to

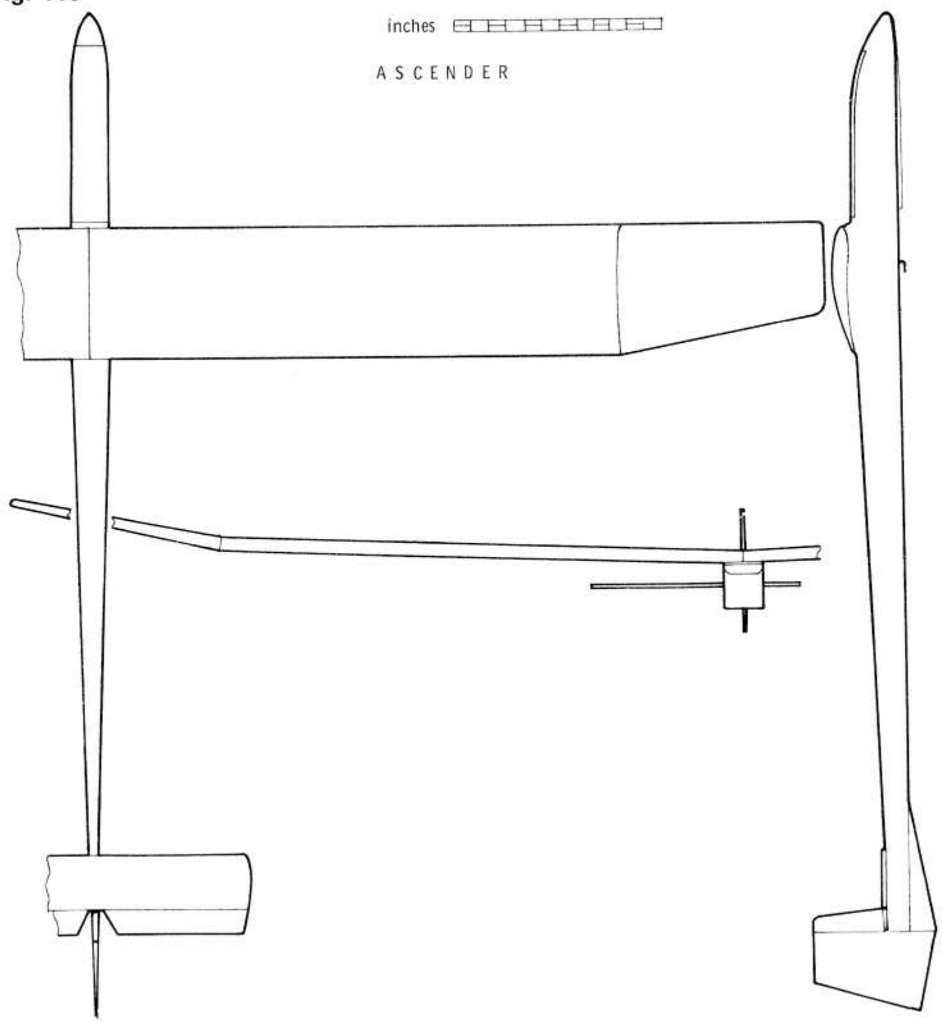
* See also wing loading nomogram page 32.

model applications, due to the extremely low speeds at which our models work.

Having now "designed" (for want of a better description!) the major component of our model, the proportions of the other parts may be worked out. The tailplane area should be between 15% and 20% of the wing area, and again we may have a flat-bottomed or undercambered aerofoil section. It is not unusual to use the same aerofoil as on the wing, but "thinned" by some 20 or 30%. The elevator area will be about 10% of the tailplane area.

The fin area is rather more difficult to decide, since it depends upon the length ("moment arm") and the frontal side-area of the fuselage, together with the dihedral used on the wing. "Cut-'n'-try" is a good method! However, a fin area of between 12 and 15% of the tail area is a good average. A large rudder is usual—about 40 to 60% of the total

Fig. 110



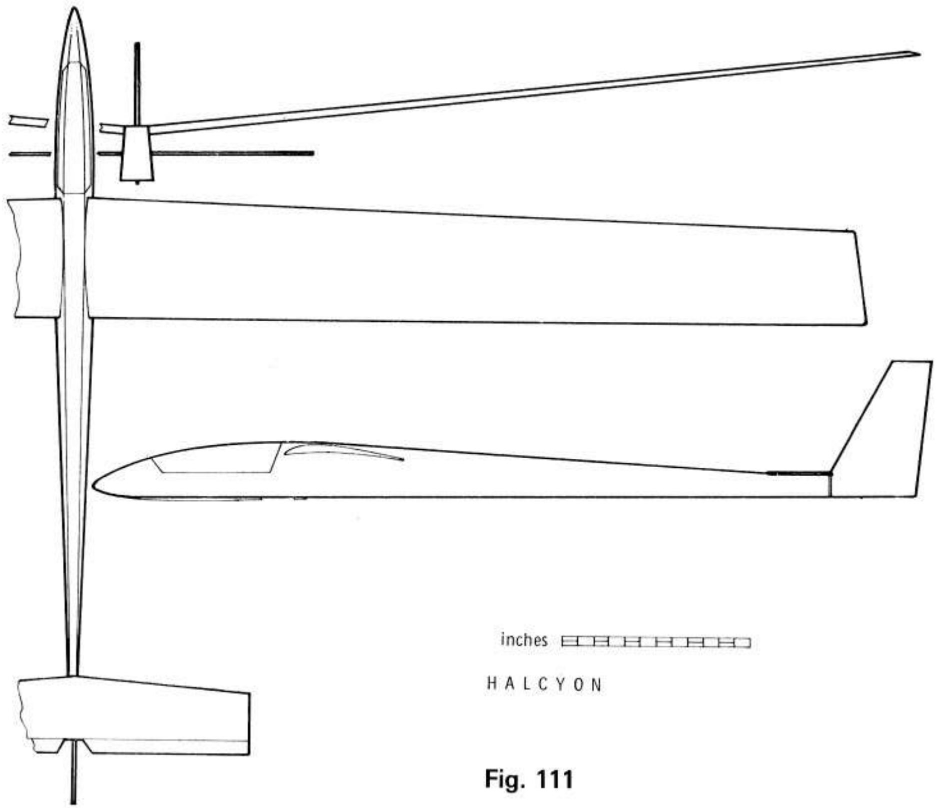


Fig. 111

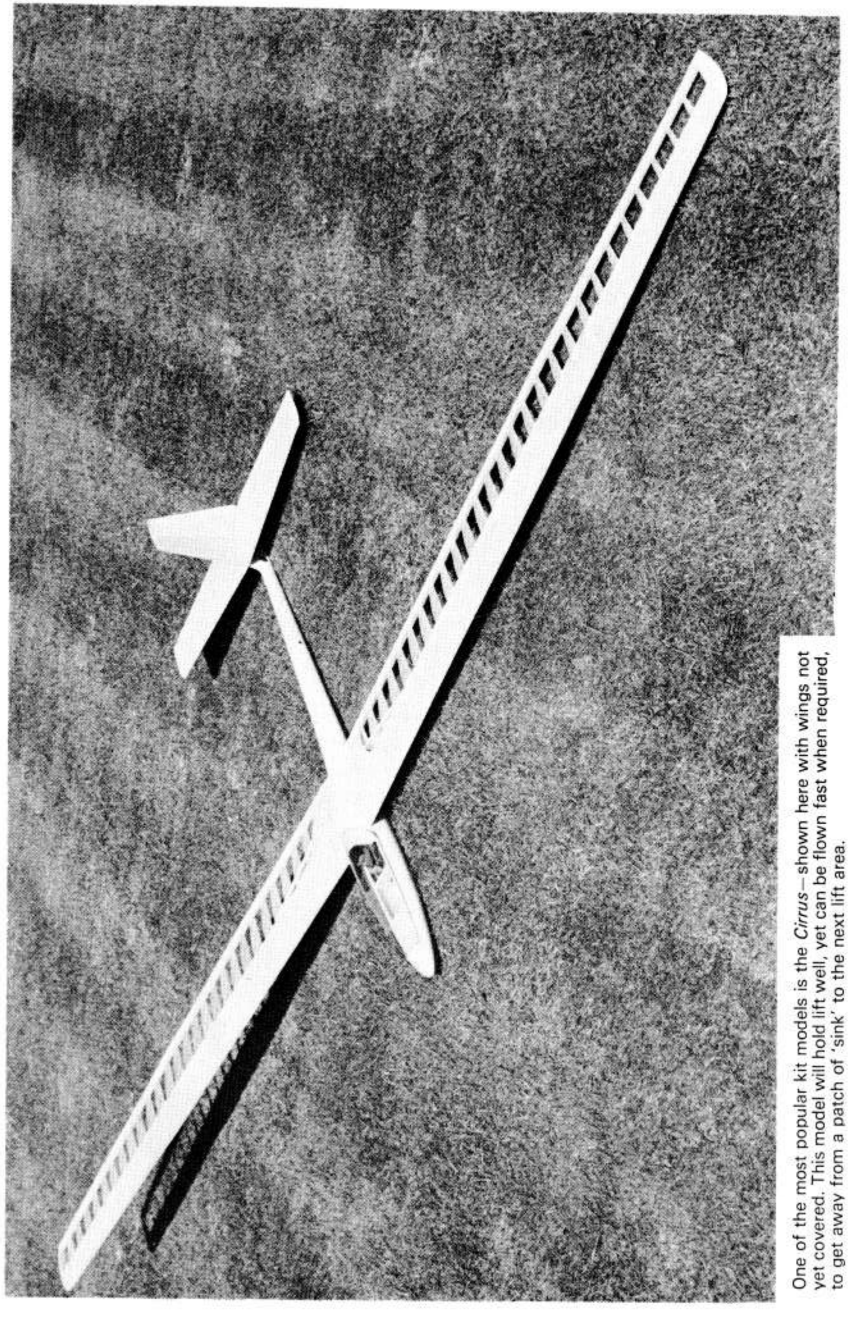
vertical stabilising area, or even greater. Some thermal soarers, in fact, feature "all-moving" vertical stabilisers, with no fixed fin at all.

The term "moment-arm" was mentioned earlier, and this is the name given to the distance between the wing and the tailplane, and of course, largely governs the overall length of the fuselage. It is convenient to express this length in terms of the wing's chord (width) and, from this, it can be said that a moment-arm of about 3 to 3½ times the wing chord will be satisfactory. The length of the nose should be about equal to the wing chord.

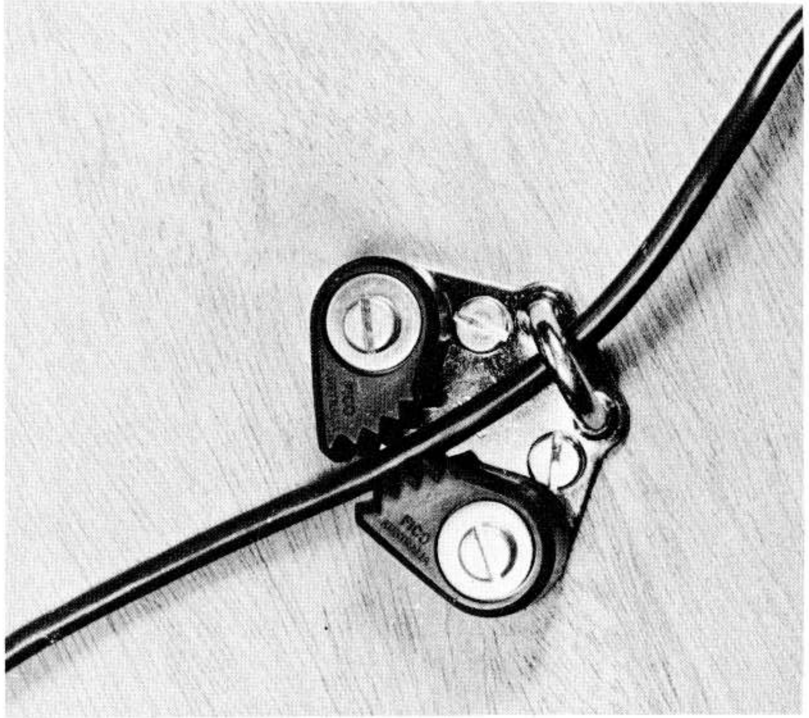
At this point, the model should be drawn out to scale and the shape of the various parts sketched in (perhaps elliptical wing-tips, or swept-back fin, and so on) and, when doing this, one can make small adjustments to the sizes calculated earlier. A good axiom, used by all the best designers, is that "if it looks right, it will fly right." Obviously one will try and make the model look "different"—although this is not easy since most models—particularly contest models—will tend to have rather similar proportions.

Finally, the centre of gravity should be positioned at about 50 to 70% of the wing chord, aft of the leading edge, and the wing set at about 3-5° incidence from the fuselage centre line.

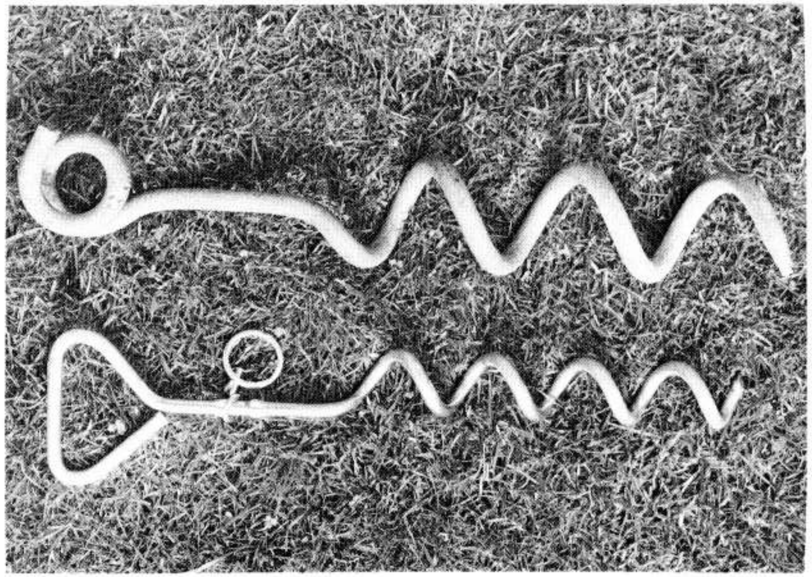
This, then, is the "basic design." Of course, experience will enable one to improve on each model, and enable one to choose the best parameters. We have not mentioned "washout," tow-line stability, turbulators, underfins, down-wash, etc., but then, if you do not know about such things, you will not worry about them! We would, however, like to say a little more regarding the controls and control surfaces used on thermal soaring models.



One of the most popular kit models is the *Cirrus*—shown here with wings not yet covered. This model will hold lift well, yet can be flown fast when required, to get away from a patch of 'sink' to the next lift area.



The cam-cleat, mentioned in Chapter 16, is a useful device, obtainable from marine suppliers, for locking the bungee cord to the required length, according to wind strength. The spring loaded cams allow the cord to be pulled through in one direction only. *(Note: plastic cord is shown here, not bungee.)*



Preview of the next Chapter. For Hi-start launching, a good anchorage for the bungee is essential. Here we show two types in general use. The more substantial one is a galvanised boat mooring screw-stake, while the other is a dog tie-out stake—available at pet stores—much lighter and really quite strong enough. Length is 16in. and weight just under 1lb.

Controls

Control of the thermal soaring glider is required in pitch and turn; the pure "roll" and "yaw" functions are not required for all practical purposes.

The consideration here is that the model is only required to be tow-launched, circle or fly straight, and land. At no time are aerobatics called for and, in fact, indulgence in these may well result in a bent model—unless so strongly constructed that it must have a high wing loading, in which case it will not be a very good thermal soarer anyway!

Because of the limited requirements, it should be possible to control the model efficiently with two functions, as we have said—pitch and turn. For pitch control, either a conventional elevator or an "all-flying" tailplane may be used. At first sight it would appear that the all-flying tailplane is the more efficient of the two, but experiment has shown that, unless the tailplane section has a "steep" coefficient of lift and a "shallow" coefficient of drag (as seen on a graph) then the advantage is lost. Elevators, on the other hand, seem to be very effective for small deflections, thus rendering them most useful. From a practical consideration, elevators are easier to fit, and allow a simple form of attachment of the tailplane, with rubber bands.

For the "turn" control, either a rudder or ailerons may be used. From an efficiency and structural point of view, ailerons are not very useful, as they tend to cause drag where they are hinged, disrupting the airflow over the wing's surface, and they also add extra outboard weight to the wing, which is not desirable.

From experience, it would seem that the best answer is a large rudder of approximately 70% total vertical tail area which, when coupled with adequate dihedral, produces a fast and reasonably efficient turn. The advantages of a rudder are that it is light in weight and simple to fit and adjust.

Auxiliary controls

Whilst not imperative, it can be helpful to use flaps and/or spoilers to assist during the landing phase of a flight. The most commonly used spoiler is the type which extends above the top surface of the wing approximately at the point of maximum camber. Its purpose, as its name implies, is to "spoil" the lifting properties of the wing. When the spoiler is extended, the airflow over the wing is disrupted, causing virtually complete loss of lift in the spoiled area. In doing this, the model's sinking speed is increased, thus enabling a steeper approach to be made to the landing area—without recourse to putting the nose down, which would increase the model's forward speed.*

The use of wing flaps (usually of the split trailing-edge type) will enable the model to fly at reduced airspeed and thus make a *slower* approach to the landing area. One is thus given more time to position the model for landing and consequently one should be able to make a more accurate approach. (Against this, in windy weather, the slower flying model is more easily upset by gusts of wind, and can be less readily corrected, whereas the model with spoilers will get the whole landing operation over quicker, with resulting lessened likelihood of being upset by gusts or turbulence. It is a question of "horses for courses," as it were).

The flap functions by increasing the lift coefficient of the wing (also the drag coefficient!) thus enabling a lower airspeed to be maintained before the stall occurs.

It is doubtful whether flaps have any real applications in "pure" thermal soaring. Our reason for saying this is that, at present, models of 6-8oz./sq.ft. wing loading are used, and their flying speed is already low enough for all practical purposes. On a more highly loaded model—perhaps of a type developed on the Continent for flying speed courses, or "multiple task" events—these devices could well be used to advantage. Now that the latter are becoming more numerous here, however, flaps may yet come into their own.

The main argument against fitting either of these additional controls is, once again, the penalty of weight and drag, which must always be assessed very carefully before their incorporation into a particular model design.

An auxiliary control which can be well worth while, and has seen virtually universal

*Shown diagrammatically in Section One, Fig. 98

adoption in competition thermal soaring, is the tow-hook release. This can take various different forms (Fig. 112) but, basically, is a means of releasing the tow-line from the model by a mechanical means fitted to the tow-hook itself. Thus, the actual moment of release is decided by the *pilot*, and not the man towing the model. It is also helpful on occasions when the model is already in strong lift before it can be released, and is stretching the tow-line to such an extent that the man towing the model is unable to release it in the usual manner—by paying out a little extra line held in reserve for this purpose.

The use of a tow-hook release mechanism does not necessarily entail the use of an additional servo. It can be made to operate on the brief application of "full-down" elevator, for instance. As this amount of control is unlikely to be used under any other circumstances, it is not liable to be used inadvertently—and the brief application of the down control required will not upset the flight pattern nearly so much as the stall that would be induced were the model to be suddenly released when pulling upwards under strong lift conditions.

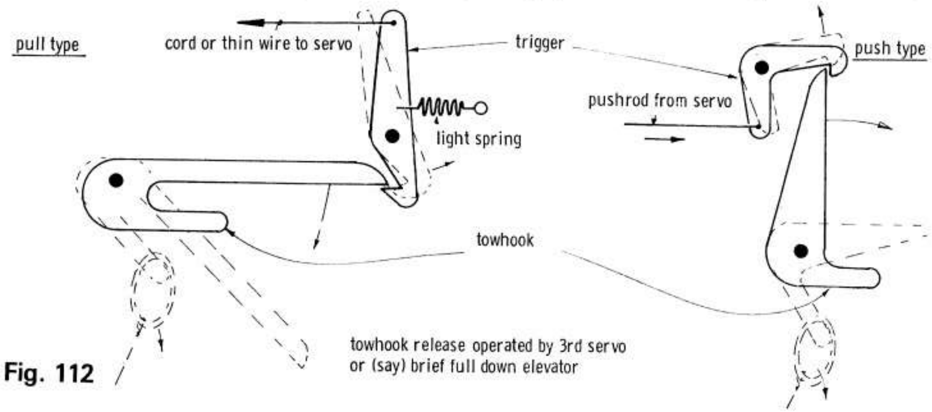


Fig. 112

Those with three or four function equipment will often opt to use an additional servo, however, for complete reliability—the additional weight of the modern proportional servo (say 1½ to 2oz.) hardly increasing the wing loading of a large model by any very significant amount.

THE DESIGN OF STRUCTURES

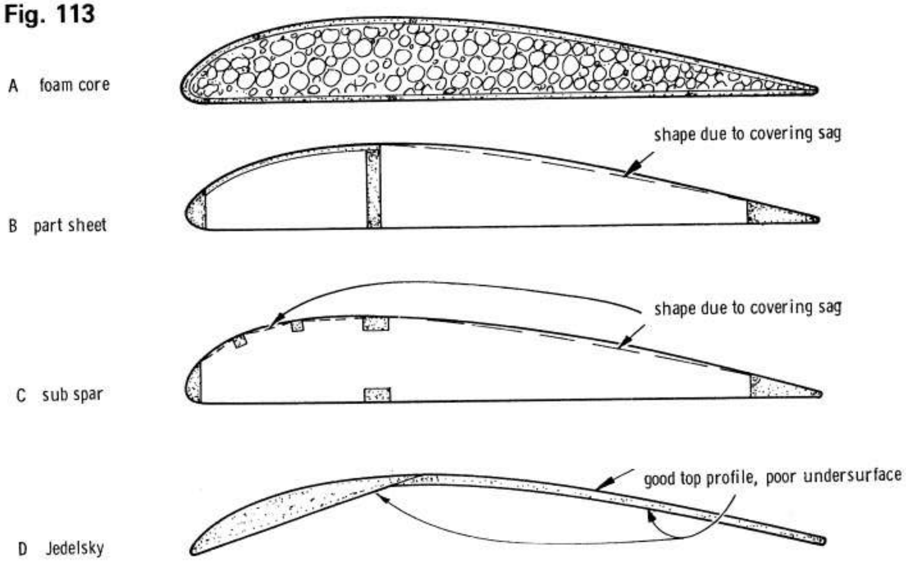
Although considerable attention is often given to the aerodynamic features of a model, it should be realised that the structure of the airframe can not only play a part in the mechanical strength of the model, to enable it to resist the rough and tumble of all-weather flying, but may affect significantly its aerodynamic performance. In this respect, three factors are of particular concern. These are: *(a)* effect of its structure on a wing's profile; *(b)* resistance to incipient warping; *(c)* inertia-destabilising effects.

Along with so many other aspects of model aerodynamics, these factors can only be discussed in general terms, since a detailed analysis is not possible, due to there being so many indeterminate variables. Rather one must pose the question, "I wish to achieve *this* feature," and then look at the model to ensure there is no clearly conflicting constructional feature, whilst endeavouring to reach a reasonable compromise in balancing the pros and cons to one's satisfaction. Let us now look at the aforementioned factors in turn.

Effect of structure on wing profile

How well will the chosen aerofoil section be reproduced on the model? It is clear that a foam-core wing will most accurately reproduce the section, provided it is accurately cut. Equally a sheeted leading edge surface will be better in this respect than a wing with

Fig. 113



sub-spars to support a shrunk tissue or nylon covering. These effects are illustrated in Fig. 113.

It is perhaps relevant at this time to include the covering as part of the structure, since the surface finish will certainly have some effect upon the airstream past the model. *How* relevant is, again, a matter for conjecture, since we cannot tell whether the airflow across the wing has laminar or turbulent conditions in its boundary layer—*i.e.* that part of the airflow nearest the wing surface. If the designer expects laminar flow, then a polished finish might be expected to produce least drag, so that the choice for covering would be one of the adhesive-backed iron-on Melinex/Mylar films, which are on the market under various trade names. However, if the aerofoil is expected to be operating with a turbulent boundary layer, then the ridges obtained from a rougher surface, or sub-spars (as in Fig. 113c), might well prove beneficial in propagating the required turbulence.

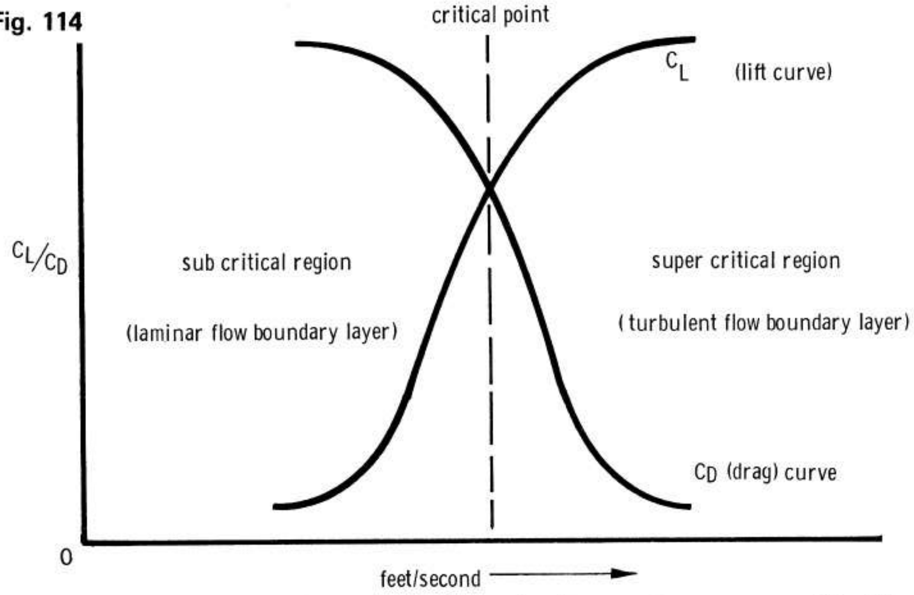
We are, perhaps, digressing somewhat from "structures" but it is worth mentioning at this point that, for best efficiency, the aerofoil needs to be operated in the "supercritical" region, as indicated in Fig. 114. It will be seen that the critical point occurs when the boundary layer (not the main airstream) changes from laminar to turbulent flow, this point being determined by the "Reynolds Number" at which the wing is operating. (Reynolds Number is a function of wing chord, density of air, and airspeed—in effect, being a measure of displacement volume. But now we really are digressing!).

Returning to the subject—correlation of the wing structure with wing profile—we can say that, having chosen the aerofoil section, one needs to consider the effect of the structure on the "ideal" profile. In more practical terms, a particular source of trouble can often be the trailing edge member. If this is insufficiently strong to resist the pull of the top surface covering, then it curls upwards resulting in a "reflex" section, which is detrimental to the lift-producing qualities of the wing (Fig. 115).

Resistance to incipient warping

We have already mentioned the effect of trailing edge warps on the aerofoil section, and this warping can also result in changes to wing incidence along the span of the wing. More simply—the wing twists! Whatever the particular cause of this trouble, it can be said that

Fig. 114



r/c thermal soarers are no different from others when it comes to warps; a model with a warped wing will fly like a . . . model with a warped wing!

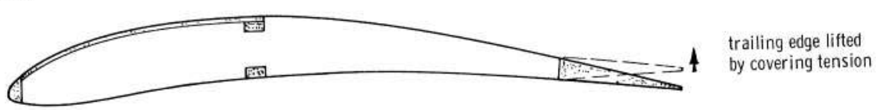
Worse than warps built-in, are those that come and go with changes in atmospheric conditions. Even a model with warps can be trimmed to fly reasonably well but, if the warps keep changing, it will not be possible to have the model correctly trimmed before a contest. Or, if you are not contest-minded, shall we say, to obtain any degree of consistency in its performance. If you find it necessary to make several flights to get the model trimmed right, on a particular day, suspect warps of this transient kind. However, we are concerned here with preventing rather than curing warps—by structural design. Geodetic or diagonal rib-spacing, or straight ribs with diagonal bracing struts, and trailing edge gussets are all commonly used methods of increasing the twist-resistance of wing structures.

Apart from wing warps, which are by far the major cause of troubles, changes in longitudinal dihedral, due to fuselage warps, represent the second most troublesome feature. On this score, fibreglass fuselages probably offer the most resistance to warping, and small cross-section balsa fuselages the least. In the case of sheet balsa fuselages, warp-resistance is best built-in by choosing evenly matched wood for the sides, or for longerons, and so forth. Beware, too, of leaning the fuselage against a wall since, over a long period, even this could cause a warp.

Inertia-destabilising effects

Impressive heading, isn't it? Perhaps it would be simpler if we said "pendulum effect." This is the tendency of weights at long moment-arms to oscillate about a pivot axis and disturb the model's flight path. The weights that cause us concern in a model are, effectively, the wing-tips and tail unit. See Figs. 116 and 117.

Fig. 115



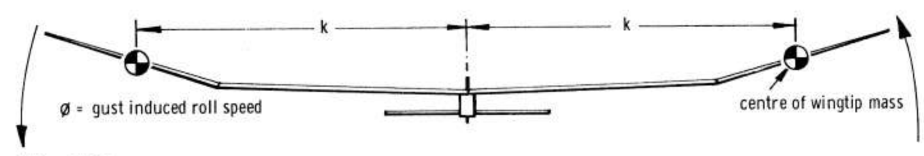


Fig. 116

Why should this pendulum effect be a problem in soarers? Those who fly four-function power models will probably never have experienced any trouble in this respect at all. Unfortunately, the laws of mechanics are working against us when we begin to increase the aspect-ratio of the wing, and the tailplane moment-arm, as is the case with thermal soarer design. As you will no doubt know from your schoolboy physics (if you can remember that far back!) the Moment of Inertia of a mass is proportional to the square of its distance from the axis of rotation. In layman's language this means that a wing-tip weighing, say, 1oz. on a 60in. span wing has a moment of 900oz.in.^{2} whereas the same wing-tip on a 120in. wingspan model has a moment of 3600oz.in.^{2}—that is to say, four times as great! Now, so long as the model is moving along a straight flight-path all is well, since the two wing-tips balance each other out but, if the model's flight-path is disturbed by, say, a wind gust under one wing-tip, then the two tips are moving in the same direction (of rotation about an axis) and the model must correct an out-of-balance force of 7200.Øoz.in.^{2} (Ø equals the speed at which the wing-tip is being disturbed).

The dynamic balance of forces exerted on a model in three-dimensional flight are, of course, far more complex than we have suggested above, but at least this gives one an idea of the problem. What happens in real terms is that a model with heavy extremities, when disturbed, needs extra correction on the control-surfaces to bring it back into equilibrium. Since each deflection of the control surface causes additional drag to be produced, this results in a steeper glide angle, more rapid loss of height and, thus, a shorter flight time. The problem is further aggravated since we need the model to be sensitive to vertical air movements to enable us to detect thermals.

From all this you will see that, here again, we have the internal structure of the model directly affecting its performance, so attention must be paid to the distribution of weight in a soarer. There is an old aeromodelling expression—"To increase performance, add lightness." How to do this? Three areas are worth attention. Firstly, design for lightness; that is to say, use as little wood as is necessary to obtain the required shape without losing an excessive amount of strength. This can be achieved, for instance, by replacing block wing-tips by sheet or, perhaps, by covering the tailplane with tissue instead of sheet balsa. Fig. 118 shows structural details of a fairly typical thermal soarer.

Secondly, considerable weight can be saved by choosing the correct grade of wood. Some balsa is graded by colour, to help with just such selection of different grades, so we can select light wood for wing tips, tailplane and fin, while using the harder wood, or even spruce, for the spars and other more highly stressed parts of the model. Choosing the right grade of wood is not nearly as difficult as finding a model shop with an adequate selection!

Finally, avoid using excess amounts of colour paint and decoration, since these can add

Fig. 117

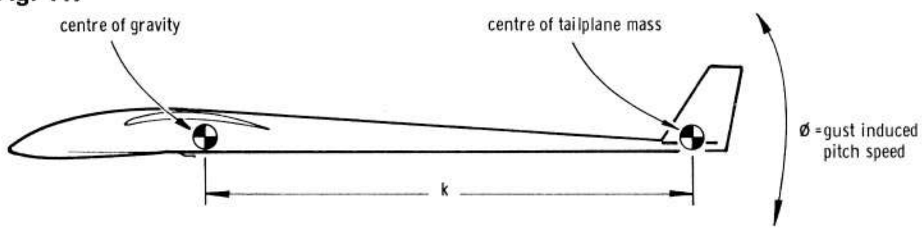
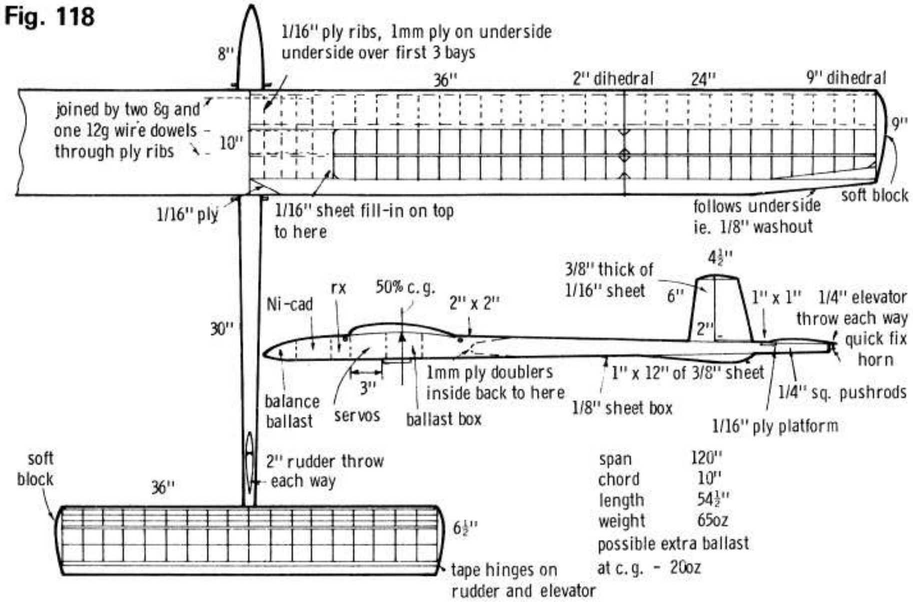


Fig. 118



quite appreciably to the weight of the model. Metal control-rods, clevises, hinges, horns and so on, whilst all small in themselves, do tend to accumulate and, unless care is taken, can result in a tail-heavy fuselage. A lighter alternative to the usual push-rod system is the use of spring-tensioned control surfaces operated by a taut link (thread, for instance) to the servo.

A last word, on building from kits. Generally most improvement will result from the things you leave out, rather than those you add on! If you think it must be "beefed up"—think again. Wait until it breaks; after all, it may never happen—and if it does, remember the repair can be stronger than the original!

CHAPTER 16

HI-START LAUNCHING

By GEORGE BUSHELL

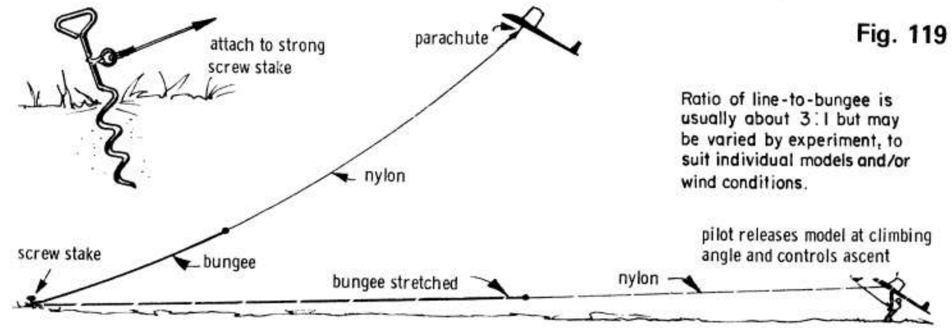
MANY modellers seem to feel that there is an air of mystique surrounding the Hi-start, or "bungee" launch method for gliders. This is probably because it is particularly suited to the "lone hand" flier, who flies on his own, and has no one to tow up his model for him in the conventional way.

To clear up one great misconception first—"Hi-start" and "bungee" launching are one and the same thing. The former seems to be the American name for the system, whereas the latter actually applies to the type of cotton- or nylon-covered rubber cord which is used! Such is the persistence of the idea that there's something different in a Hi-start launch from a bungee launch, that it is hoped that this chapter will forestall a lot of unnecessary correspondence! Some users of electric winches, of late, are tending to call *that* method of launching "Hi-start"—which could lead to further misunderstandings. They would be better advised, I am sure, to call it simply "winch launching."

Having made it clear that the name is only the handle, so to speak, just what *is* a Hi-start or bungee launch? Very basically, it consists of using a length of rubber cord, attached to the "towing" end of a nylon (fishing line) tow-line, and anchored to the ground by some suitable means. The line has a towing ring on the "model end" and—usually—a form of drogue or parachute as well. This 'chute serves the threefold purpose of (i) pulling the line free of the model, for release (ii) deploying the line in a downwind direction, under some tension, ensuring that it is near at hand and tangle-free when next required, and (iii) acting as a marker, being brightly coloured, so that it is easily seen and retrieved.

In operation, the line is pulled back, away from the anchor point, until it has a good tension (this will be discussed later). The model is then hooked on and released, when it climbs at a good angle. Contrary to what many people expect, there is, in fact, very little "snatch" effect and the model behaves, on release, in a very similar manner to a model being towed by a runner. The difference is, of course, that the bungee does not run out of "puff," or trip over. On the other hand, *all* the controlling of the model, when it is on a Hi-start launch, has to be done by the pilot, whereas, with a towed model, the tow-man can slow down and "ease off" the tow, reducing the stresses on the model if required. Once the

Fig. 119



Hi-start has been released there is no stopping it until all its energy has been spent. Any reduction, or increase, in the model's angle of climb, therefore, must be effected by the pilot, using elevator control. Fig. 119 shows the overall set-up.

This brings us to another point, this time on the controlling of the model. Many people ask whether they should touch the elevator control at all during the launch. This rather depends upon the individual model, of course, but as a general rule, one should release the model holding in a little up-elevator, decreasing this if the model climbs *too* steeply (indicated by the wings beginning to flex too much for comfort). Then, as it nears the "top" of the launch, and begins to slow up, feed in more up-elevator to keep the line taut and maintain some climb. When the optimum point is reached, if the parachute does not pull off, the model will begin to sink (unless it is already in strong lift—lucky you!), so dip the nose *very briefly*, with a quick forward flick of the control stick, to release it. Try not to get caught unawares, pulling back on the stick, when the 'chute detaches or the model will stall and lose some of that valuable height, before you can flatten out its flight path.

We mentioned earlier, the running tow-man, towing a model and running out of breath. On dead calm days this can often happen, with the result that he slows down, the line sags and the model releases itself, actually flying at a greater speed than the person towing is able to run. (On days with some wind, of course, there is no problem, as there is no need to run so fast—in fact the tow-man will often have to stand still or even run back, towards the model.) It is on the calm, or near-calm, days that the bungee launch can come into its own, since the speed at which the model travels is, to quite a degree, governed by the amount of head-wind. It is, therefore, self-adjusting, to the conditions, and will always produce a launch.

So much for the basic operation of the system. Now let us look at the equipment required, the techniques used, and desirable model characteristics.

Equipment

The items required are (i) a secure anchorage for the bungee (elastic cord), (2) Bungee cord, (3) nylon monofilament line (fishing line), (4) drogue 'chute, (5) metal ring. Other accessories come under the heading of sophisticated refinements, and will be mentioned as the opportunity arises.

Dealing with the first item, then, a *secure anchorage* for the bungee cannot be over emphasised. A large old chisel or screwdriver *will not do!* These quickly work loose in the ground after a few consecutive launchings—and can be positively lethal when lifted out of the ground by a good "over the top" release. A short *screw stake* is far more safe and reliable, and I always use one. The steel tommy bar used to screw this into the ground doubles as a handle for my field box, so there is no fear of leaving it at home.

Screw stakes are available in several forms. At ships' chandlers, you can obtain a boat mooring stake, which is extremely substantial—if rather heavy—and usually has a galvanised finish. A lighter, more portable, and equally effective, screw stake is to be obtained at most pet stores, and is known as a tie-out stake—used for "round-the-pole" exercising of dogs, by lazy owners. It is a good idea to paint the above-ground portion of the stake—either bright red, or with black and yellow bands—to make it easily seen in the grass and help prevent anyone tripping over it.

To "lock" the bungee to the desired length, *never knot it.* This causes internal ruptures and localised over-stressing. Use either a fixed length of bungee with hooks at both ends, or a device known as a cam-cleat, as illustrated. This item, again, is obtainable at ships' chandlers—the sort of little marine suppliers one sees in most seaside or riverside towns. The action is to lock the rope—or, in our case, the bungee cord—without damaging it, so that it is firm in one direction but may be pulled in the other. A bracket can be easily made by the modeller, which allows the cam cleat to be clamped securely to the screw stake or, alternatively, if conditions permit, to the car bumper.

The bungee cord I use is the $\frac{1}{4}$in. diameter type, but many fliers seem to prefer the $\frac{3}{8}$in. diameter size. This appears to be sufficient for all but the heaviest and most highly-loaded sailplanes and, as a general rule, I reckon that if a model is too highly loaded

to be taken aloft by this bungee, then it isn't likely to perform at all well, even if you do get it up!

Why "bungee" as such, and not just any rubber strip or catapult elastic? The main reason is not so much one of efficiency, but of durability. Proper bungee will last many years, while bare rubber, used over rough terrain, or not properly stored, may not see a season out. Basically, the recommended bungee is composed of a number of very thin strands of rubber, covered by a woven cloth sheath. The cotton has each strand individually treated with PVC coating which imparts a fairly tough, abrasion-resistant, almost waterproof, covering.

The two alternatives are, first, the untreated cotton covered type, commonly used for luggage straps, and the PVC sheathed type. The main advantages of the former are that it gives a longer stretch and is marginally lighter—but it is less resistant to abrasion and not waterproof. The sheathed or shielded type is where the *completed* cotton sheathing is coated in PVC, producing a solid sheath. The main advantages of this are its extremely high abrasion-resistance and that it is completely waterproof. The disadvantages are considerably increased weight and insufficient stretch (with a positive deadstop!), together with the fact that it is more difficult to secure endhooks to it. The proper bungee described, therefore, is by far the best suited to our purpose.

We have seen that bungee should never be knotted, but that hooks should be fitted at each end. The bungee can then be hooked onto a clip on the monofilament line, and onto another hook or clip on the tie-out stake. Two or more lengths of bungee may be hooked together in this way, too, if required. What sort of hooks, then, should be used, and how are they secured to the bungee?

I used to use the "luggage hook" (à la car luggage rack cords) type of hook for the ends of the bungee, but have now abandoned this in favour of the "hook" type, which is an enlarged version of the "hook and eye" used to fasten ladies' bras! For the benefit of the unmarried or less adventurous, the sketch (Fig. 120) may be helpful, as the item is very easy to produce from 20 or 22 swg piano wire.

Fig. 120

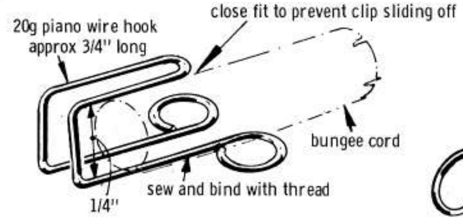
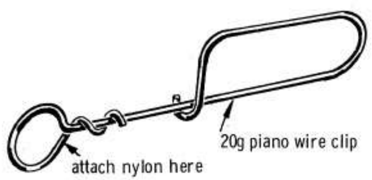


Fig. 121



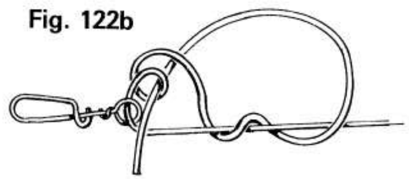
This hook, then, is simply sewn and bound to the end of the bungee, using two yards (approximately) of ordinary sewing thread as used in all kinds of binding, and passing the needle *through* the bungee a few times. The binding is then coated with contact adhesive and allowed to dry. If a neat job is made of this hook, it will pass easily through the staple of the cam-cleat. Although I have never known a hook fitted in this manner to fail, I always attach one to *each* end of the bungee, working on the assumption that, of one *were* to fail, it would be on the first flight of the day and far from home.

The breaking strain of the nylon monofilament line that I now use is 55lb. This is a heavier type than I have previously recommended (and, indeed, may seem ridiculously thick to those used to hand towing their models), but it is very helpful for crosswind launches, as it aids the directional stability of the model. For models with less than 600sq. in. or so of lifting surfaces, however, the 40lb. line is, in my opinion, the optimum, though many people use a 30lb. line and $\frac{3}{16}$ in. dia. bungee with success.

As to the maximum size/weight of models capable of being launched efficiently, I can

Fig. 122a

Fig. 122b



say that models of up to 5lb. weight and some 12sq. ft. wing area have performed well (using ¼in. diameter bungee). In fact, the *smaller* models (say, under 5ft. span) tend to be the most inefficient, since the weight of line and bungee will tend to affect the height they can attain, more so than with models of greater wing area.

To join lengths of nylon monofilament line so as to provide the desired length of launch (I normally carry two 100yd., one 66yd., and one 33yd. length) I equip each end of my lines with a simple wire coupling, bent up from 20 swg wire, as shown in Fig. 121. Tying knots in nylon line is difficult, but there are some special knots which have been developed for the purpose. I invariably use the knot shown in Fig. 122a, this being well tried by fishermen for joining two pieces of nylon. The knot for fastening nylon line to metal fasteners and hooks is shown in Fig. 122b.

For the drogue parachute, you could try making your own but, quite frankly, I don't believe it is worth the effort. There are commercial ones on the market—the K.D.H. and the Graupner No. 55—but, of course, the availability varies, as these come from abroad, and you may have to shop around a little.

Now here is a point that far too many people fail to realise. *The drogue parachute is incorporated as part of the line.* Let me explain. When told that there is a parachute on the line, the uninitiated always ask "Won't it slow the model down too much as it goes up?" The answer is no, because the parachute does not just hang from the line—it becomes part of it, with its lines continuing a couple of inches beyond the top of the 'chute and terminating in the metal towing ring. Thus, when the bungee is in tension (prior to, and during, the launch) the parachute is pulled tightly closed and produces very little drag. When the bungee slacks off, however, so do the chute's lines, allowing it to open and help pull the line off the hook, to release the model. Fig. 123 shows what happens, with the line in tension, and then released.

Between the nylon line and the drogue, I fit a fishing swivel. By choice, I use a steel (grey-black finish) one in preference to the brass type as it is stronger and, like nylon line can be bought in various breaking strains. Needless to say, these are to be purchased at fishing tackle shops. The swivel must be securely tied to the nylon cord lines at the bottom of the parachute and the knots may be secured by a liberal application of balsa cement. Fitted at this position, the swivel reduces the chance of the parachute entering a "Roman candle" (failing to deploy correctly). I have only had four Roman candles on more than four hundred launches, using the swivel arrangement.

For the metal ring, I use a split ring (key ring). The top of the parachute is already well

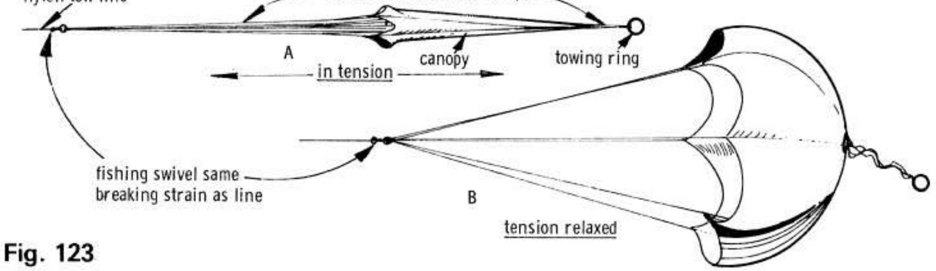
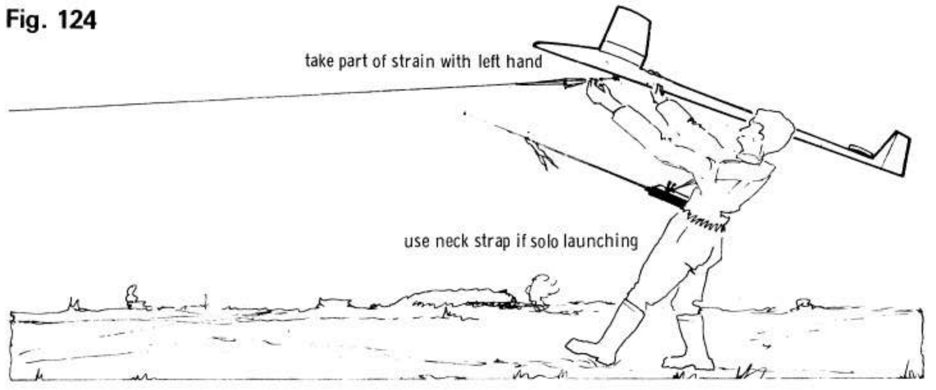


Fig. 123

Fig. 124



knotted, requiring only a smearing of balsa cement; the ring may then be slipped on, and the Hi-start outfit is ready for use.

Launch techniques.

The basic operation has already been explained. It must be borne in mind that the whole object is to attain the maximum possible height before the model releases itself, or you release it. After the launch (*i.e.*, after the model leaves the launcher's hand), the angle of climb will control the rate of return of the bungee. This angle should not, of course, be excessive. As a rough guide, from the launch position, you should just be able to see the top surfaces of the wing. But only just. See Fig. 124.

Using elevator, as the model goes up, it is a simple matter to increase or reduce the model's angle of climb, as is felt to be necessary. The best use of elevator, to attain the best height at launch, with a particular model, will only come with practice, and one cannot lay down any rule-of-thumb laws. The modeller's renowned "feel" for what is right and what is not, has to come into play here, as well as in designing his models!

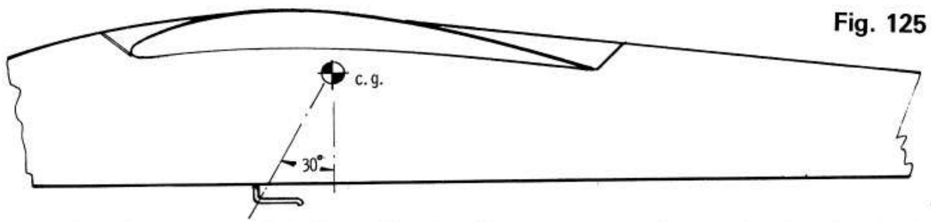
On a model of the rudder-only type—not equipped with elevator—a quick left-and-right of the rudder will effectively reduce the angle of climb. Try to avoid any jerky motions which may release the line prematurely. Mild weaving is not dangerous, provided the rudder is effective in all attitudes; towards the top of the launch, in fact, weaving has the beneficial effect of partially tensioning the bungee, thus allowing a higher release. Generally, however, weaving should be avoided as far as possible during the initial climb, as it places undue stress on the model, as does a jerky transition from the release through the initial climb.

With the foregoing points in mind, it will be seen that some attention to the position of the tow-hook will pay off in achieving a smooth, safe and optimum launch. Moving the tow-hook rearwards from its initial position will cause the model to climb faster, but lose some directional stability (though you can cope with this from the transmitter end) and is generally of more use as the wind speed decreases. Moving the tow-hook forwards of its initial position has the opposite effect, but a tow-hook positioned excessively far forward will again cause the model to lose directional stability.

You may not feel that your tow-hook was in the right position in the first instance, so it is best to check this before making any drastic alterations one way or another. To arrive at the basic tow-hook position—assuming the c.g. is in the correct place—balance the model under the wing root and, from the vertical, mark a line 30° forward from the balance point. This is shown in Fig. 125. As an example; with a depth of fuselage under the wing in the region of 3in., movement of the tow-hook by ½in. would not be excessive, either side of the indicated optimum position.

Cross-wind launches, when the wind is in the region of 90° out of the launch direction,

Fig. 125



are quite safe. Feed in a little bias, either by aileron or rudder trim, so that the wing that is into wind is kept low. On launch, take a couple of sharp paces forward to increase control effectiveness. It would be best, if conditions permit, to work your way gradually round to the full cross-wind launch, particularly if the wind is around 15 m.p.h. or gusty. This is a useful technique for narrow flying fields, but remember that the line will be blown down wind after the release.

Down-wind launches are handy for launching in front of low slopes which, because of their vegetation or inaccessibility, are impossible to use for ordinary slope soaring. Another example is sandhills, with a relatively short beach. The technique here is quite simply to move the tow-hook back to, perhaps, the optimum still-air position and launch the model, forgetting—if you can—that the wind is on your back. The release is best achieved actually cross-wind. I have used this technique to particularly good effect on various locations on the Dutch North Sea coast, where some excellent dune soaring is to be enjoyed.

The final item to be discussed, in the matter of technique, is the question of *line tension* and the *ratio of line-to-bungee*. Both these can vary to quite an extent, depending upon the models and the individuals flying them, and tend to be largely a matter of experience. This is, of course, no help whatever to the tyro, so let us again go back to basics.

Assuming that your first experience of Hi-start launching is in reasonably calm conditions (wind, say, up to a maximum of 10 m.p.h.), the bungee length should be about one-third of that of the nylon line. The tension applied by stretching would be in the region of 30lb. If you are nervous, or not sure of the model's suitability, this could be reduced to about 20lb., but, under these circumstances, I would recommend an absolute minimum of 100 yards of monofilament line, and 35 yards of bungee. This would allow a release at a reasonable altitude, affording you a better chance to observe the model's behaviour, both on and off the line. This tension may be progressively increased, on subsequent launches, to perhaps 45lb. or thereabouts.

True line tension is difficult to define exactly, as the type of terrain affects the tension/extension. Over a clean runway, little drag is felt and the *true* line tension is as much as you actually feel. Over a field, however, with the bungee and line going through long grass, thistle and nettles, the drag you feel is very high—probably the highest you are likely to encounter—but the true line tension is now actually much lower than it seems, so you can still happily step back a few more paces.

Don't be alarmed about line tension. I never carry a spring balance with me, as I think that this is being over-exacting. One quickly gets into the feel of it, particularly if one notes how far back one walks for a good launch with a particular model on a particular day and, if necessary, mark the spot, by dropping one's hat or handkerchief! My own golden rule is that it is better to have too much tension than too little, as it is easier to extricate a model from any trouble at a higher altitude, or with a little extra speed in hand—provided one has the correct reactions at the transmitter end.

The model

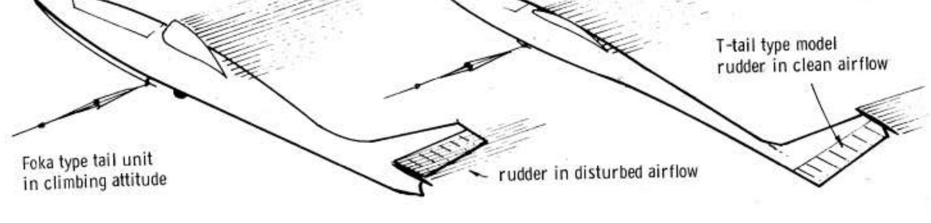
From the design standpoint very little can be said. From my examination of various models performing, very few could be described as really "dodgy" on the Hi-start. Those that *are* difficult fall into two categories: those with unsuitable aerodynamic layout, and those with bad (for want of a better phrase) force arrangements. Aerodynamically, provided the model is reasonably stable in flight and capable of fairly

rapid recovery from upsets, stalls, etc., the normal fault is that of the *blanketing* of flying and control surfaces while in a climbing attitude. A good example of this is the *Foka*—both full-size and model. The position of the fin and rudder makes them subject to the combined blanketing effect of the fuselage and tailplane. This blanketing effect is shown in Fig. 126 in comparison with a T-tail model in the same attitude.

In all fairness, I should state that the *Foka* is *not* dangerous, but it does demonstrate these tendencies, particularly if the rudder linkage is unduly sloppy. For this reason, one should make a careful examination of proposed designs, before deciding on a model for Hi-start launching. As a rough rule, the *Foka* has the very maximum acceptable blanketing, in the climbing attitude. Models with high-mounted tailplanes, or T-tails, are, of course, the best behaved in this respect, as the rudder is never blanketed by the tailplane.

With "force arrangements," most of the problems arise from faulty positioning of the tow-hook, in the main, and this has already been dealt with earlier on (Fig. 125). In addition, models should be aerodynamically "clean," paying particular attention to a clean "exit" (*i.e.* wake) free of turbulence. This also pays dividends during the launch as, properly applied, it reduces blanketing of flying surfaces and controls.

Fig. 126



For ultra-light types

The rudder-only model was mentioned early in this chapter, and the flier of this type of model may feel that, for him, with his usually very light model, the pukka bungee set-up is not required. Whilst what has already been said about the transient nature of unsheathed rubber strip still stands, there is here, perhaps, a case for its adoption, especially if it is felt that the initial outlay for bungee outweighs its long-term saving.

With a lightly loaded model, especially in near-calm conditions, success has been achieved by employing a very light Hi-start comprising about 50 yards of ¼in. flat rubber strip (the type used to power rubber driven models) and 100 yards of 6-7lb. b.s. nylon monofilament line. This gives a very slow pull up, with the rubber's energy expending itself at about half of the full stretch potential.

The trick now is to turn the model either left or right, on the line, causing the rubber to stretch before turning back into wind. This utilises the re-stored energy and enables more height to be gained. The process may be repeated a number of times, to good effect. To avoid pilot disorientation, with the model weaving all over the sky in this manner, it is advisable to have a very eye-catching marker at the anchorage position. The model should be very responsive to rudder for this technique to be fully effective.

Whichever method is used to get the models up, the prime aim is maximum height gain. Once off the line, then flying them is like flying any other models. With the Hi-start launch, it is the correct approach, and the technique on the line, that count.

CHAPTER 17

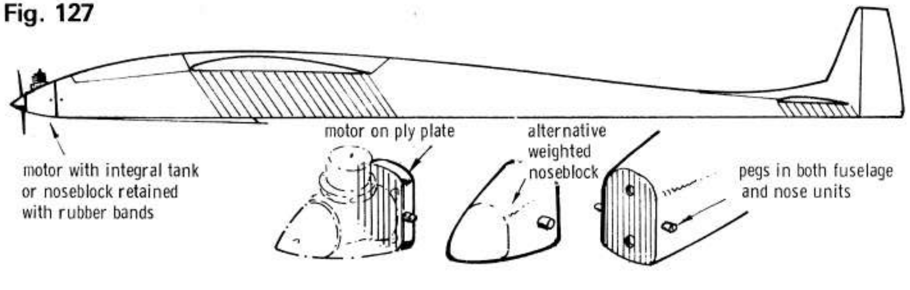
THE POWER-ASSISTED GLIDER

ALTHOUGH the sport of soaring—be it slope or thermal—is really one for the purist, there does exist an interest in the power-assisted glider. For obvious reasons, this interest is usually centred in areas with no hills. It is also favoured by the lone hand, with no one to tow up his model for him and who, for some reason, is not very happy about a bungee launch. (Perhaps he cannot be bothered with the "paraphernalia," such as it is, of reel, line, bungee and stake, described in the previous chapter.) For whatever reason, this group of modellers prefer the power-assist—despite getting oil on their models!

How much power?

First and foremost, it must be borne in mind that the power used should be just sufficient to take the model in a *very* gentle climb. We do not want our elegant, peaceful gliders to turn into "power duration" models, with screaming vertical climbs. An ·049 motor is ample for all small and medium sized models, up to about *Amigo* size,* with an ·09 or ·10 motor for anything larger. (The 8ft. span RM *Diphda* goes up nicely on ·09 power.) We would not recommend higher power for any glider—unless, of course, the wing loading is so ridiculously high as to make it necessary—but then it will, in effect, become just a "power model" and not a power-assisted glider at all!

Fig. 127



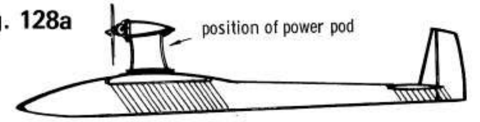
Location of engine

There are a number of different ways of mounting the engine on a power-assisted glider. Some designs feature a clip-on motor mount which goes on the nose, making the model look more like a conventional power model, as shown in Fig. 127, but this is not greatly favoured, as the motor can come in for some knocks, or easily get dirt in it, when landing in rough fields.

The most popular method, and one which keeps the motor well out of harm's way, is a power-pod, as shown in Fig. 128. This is mounted above the wing, on a pylon, in such a

* The *Amigo* is an old-established kit model, of some 79in. span, which has become something of a yardstick among r/c gliders. It is a general purpose model, being suited either to tow-launched thermal soaring, or to slope soaring in light winds. In fact, it has come to be regarded as the ideal model for "marginal" lift conditions at the slope, when it remains aloft while most other models are grounded for lack of lift.

Fig. 128a



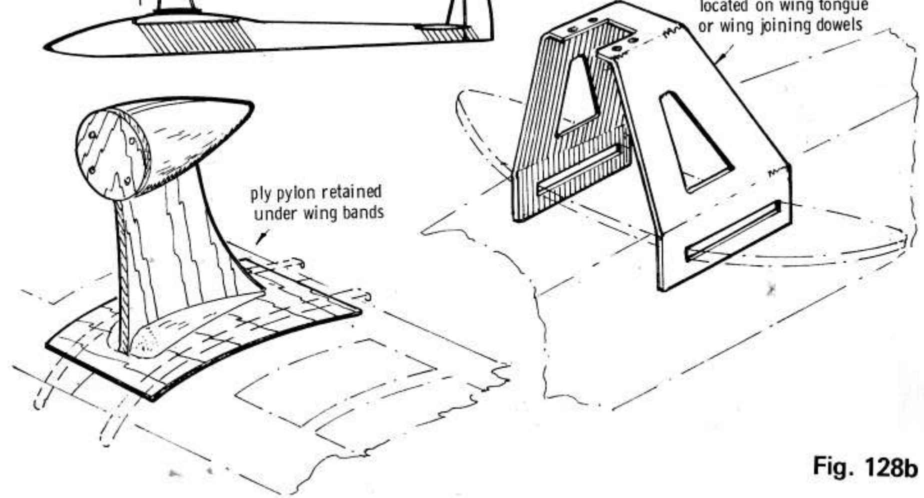


Fig. 128b

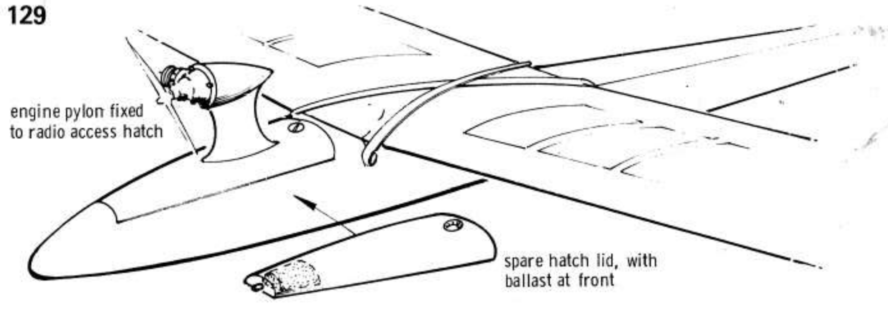
manner that it does not disturb the model's trim (that is, over the centre of gravity of the model). Very often the mount is devised so as to slip under the wing bands or between the wing-joining dowels or tongues, and locate between the wing roots and the fuselage (Fig. 128a and b). A variation on the "pylon" mount theme is that built onto the nose hatch of the model, as shown in Fig. 129. Thus, a plain hatch (plus an ounce or two of ballast) may be substituted for the pylon hatch whenever the model is to be used for pure gliding.

The question of thrust lines is one that is often raised in this connection but, in practice, there really do not seem to be any problems here. Theoretically, with the motor mounted some distance above the wing—and the centre of drag—its thrust should tend to produce a nose-down couple, as shown in Fig. 130. To counteract this effect, if it is noticed in practice, a degree or two of up-thrust is given to the engine.

In every day, out-in-the-field practice, however, most modellers find that with power-assisted gliders, using relatively low power, this downward-couple effect is not noticeable, and are quite happy with zero or neutral thrustlines. It is only when more powerful motors are used—*overpowering* the model, in fact—that the effect of offset thrustlines, or the need for them, is going to be felt to any degree.

"Extreme" locations of the engine, when designed into a model, can be interesting. That is to say, if the model is actually designed as a power-assisted glider, instead of merely

Fig. 129



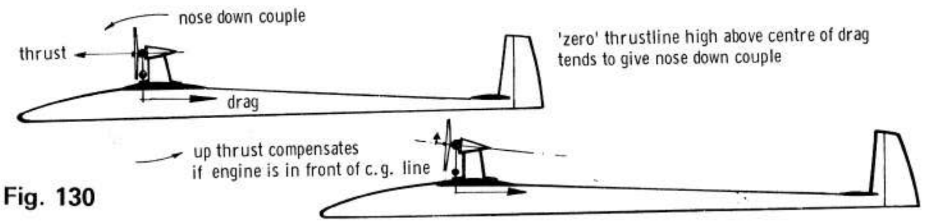
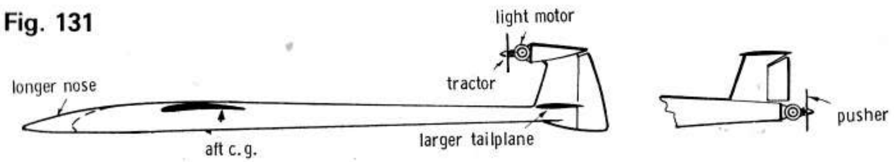


Fig. 130

being adapted to serve as such. For instance, on certain layouts—especially these featuring swept-back wings—it is possible to locate the motor at the tail end. (Apart from anything else, this means there will be no messy fuel on the rest of the model!) If the designer can come to terms with having weight still further aft, then even a pusher version is possible. Fig. 131 shows the configurations.

Fig. 131



Gondolas—the drop-off engines!

A rather different concept is that of the motor-gondola. Here the pylon is, in fact, suspended *beneath* the model's c.g. instead of being mounted above it. The motor-pylon becomes a "gondola" when so positioned. The device is plugged into the fuselage in such a way that it is actually held in place only by its own thrust. When the motor stops, the whole assembly slides out and drops clear of the model, leaving it a "pure" glider in every sense. A parachute or streamer is used to slow the gondola's descent and to mark its position on the ground. Fig. 132 shows the set-up.

The idea is certainly an appealing one, from the point of view of dispensing with what, after it has served its purpose, is only a drag-producing appendage. In practice, however, there are sometimes problems connected with locating the fallen gondola (and also of its premature release—with motor still running!) which could tend to make one think that the carrying of the motor on the model might, after all, be the lesser of two evils!

As with most systems, there are innumerable variations on the theme, and some can be quite sophisticated, like the streamlined version shown in Fig. 133. This has a moulded glassfibre body, shaped to follow the lines of the fuselage. It is not self-jettisoning but is operated by radio, so that the pilot can choose his own "dropping zone," depending on the wind drift. There is, of course, a shift of the centre of gravity when this forward fitted type is used—but no doubt some ingenious r/c modeller has already found the answer to that one! There is certainly a lot of room for individual experiment with motor-gondolas and, once

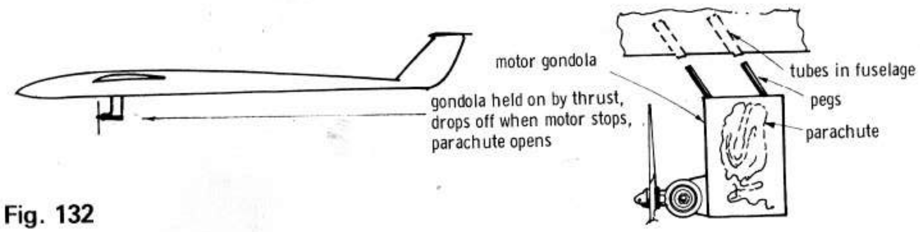
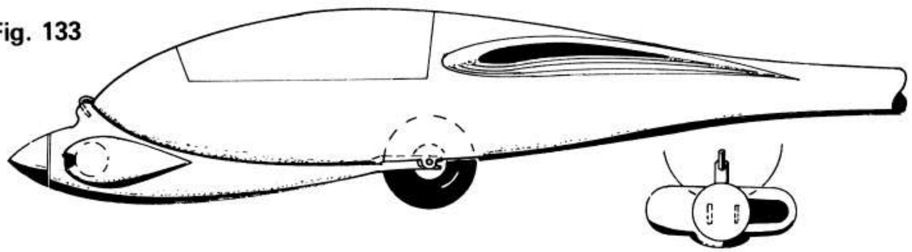


Fig. 132

Fig. 133



they have achieved a reasonable degree of reliability, in terms of the mechanics of actual fixing and release, they could quite possibly be the most satisfactory power-assist system of all.

All that height. . . .

Small engines run for several minutes on an ounce of fuel, so that slow, gradual climb is no disadvantage. The climb out, in calm weather, should be made in large circles, turning as flatly as possible. Do not start pointing the nose up, like an aerobatic model, or the glider will stall. Near the ground, this can be fatal. When a safe height has been reached, it will be in order to experiment, if desired, with some extremes of control, so as to determine just what are the safe limits of control which can be given. With practice, one becomes familiar with the model's handling characteristics, and the amount of fuel required for attaining a given height. Then the real thermal-hunting can begin.

If there is any amount of breeze, it is best to fly the powered glider in a manner rather similar to that in which slope soarers are flown in light winds. That is to say, after an initial into-wind launch and climb-out the model should not be flown directly into wind, but "tacked" to and fro in a crosswind direction. After a short trial period, it will soon be apparent which direction enables it to achieve the best height-gain. Once the motor has cut, it is probably best to fly in wide, flat circles, tightening them up if the model seems to be in lift. When it is lower once more, the pilot should be on the lookout for signs of thermal activity, as described in Chapter 14, so as to prolong the flight even further.

With a long motor run, of course, it is possible to fly the model much higher than with a tow-line or bungee launch and, at this sort of height, the problem, instead of being one of how to keep the model up, becomes one of how to get it down—or even how to keep it in sight! If you do not have spoilers fitted to your model, care must be taken how you go about bringing it down out of strong lift; too steep a dive could snap the wings. If the model will *spin*, then this is the safest way of bringing it down (not all the way, of course!) without over-stressing the flying surfaces. If it will not spin, then a series of stalls will often bring it down without too much strain. Simply ease the stick back gently until you are giving full "up." Let the model stall a few times and then, if it is becoming too violent, ease off until it levels out, then start over again, and so on. This method can be quite effective, where a dive (especially if the model is so high that you cannot see properly at what angle it is descending) could quickly result in debris raining from the blue.

It is necessary to know about such contingencies but, if you start with *small* amounts of fuel in the tank, and gradually increase them, you should be able to control the model all the time in such a manner that it does not get too high, in the first place.

On calm days or summer evenings, many happy and rewarding hours may be spent seeking lift and learning to recognise and use it, with a glider that has initially been helped aloft by that add-on motor, that "power-assist."

CHAPTER 18

AERO-TOWING

FULL-SIZE gliders are towed aloft by powered machines, so why not models? A few years ago it was thought this would be far too difficult, since the pilot of neither aircraft is *in* it, to fly "by the seat of the pants," as it were. However, modellers are a determined bunch, once they set themselves a goal, and quite a number of groups, in different parts of the country, have now brought methods of aero-towing with models to near-perfection. As a result, there are a number of different techniques—all of which work. Perhaps, as with model helicopters, once it is established that it *can* be done, then more and more people succeed.

Of course, aero-towing is an immensely elaborate way of getting a model glider into the air, and one would not normally think of it in this connection, in the way one does with full-size counterparts (which is why we have not included it under "Launching Techniques"!) It is, however, an interesting exercise and makes for useful co-operation between glider and power fliers. For demonstrations at shows and rallies, of course, it can be most impressive.

Early experiments

The experiences of one group, in the first stages of aero-towing, back in the 1960's gives an interesting insight into the sort of problems that arose and how these were overcome.

It was decided to attempt to tow a *Foka* glider with a *Taurus* as the tug. A release mechanism was devised, and strapped on top of the tug's fuselage. This had a special safety precaution built in, so that it would release the line if the glider were to "snatch" while on tow. If things went well, on the other hand, one could release both line and glider by giving "slow motor" command to the tug. The line, which was, in these early attempts, attached to the standard towing hook of the glider, would then drop away.

The launching procedure went like this: the glider and tug were attached by their line, and someone would hold the glider which, in turn, would hold back the tug. The engine on the tug would then be fully opened up and, at a given signal, the man who was holding the glider would gently run—just keeping the line taut—and launch it.

Although able to get the models airborne in this way, they found they were only able to make about half a circuit before having to release the glider, as it would, by then, be oscillating madly—and occasionally even barrel rolling!—behind the tug. Different hook positions and various lengths of line were then tried, but no real progress was made.

The breakthrough came when, almost in desperation, a very much greater line length was tried than previously—about 100ft. longer, in fact—making a total length of some 140ft. The line used was fishing line of 40lb. breaking strain. Everything went much more smoothly now and long, long, tows were achieved. They would release the *Foka* when tug and glider were mere specks in the sky, and glide durations of 20 minutes and more were regularly achieved. Once the tug had been landed, the two pilots would take it in turns to fly the glider.

The problem, at this stage, was that tow-lines were continually getting lost. As already mentioned, they were hooked onto the glider's normal tow-hook, and slipped off when the other end was released from the tug. So the attachment point was now moved up onto the top of the glider's nose, and a release mechanism devised so as to be able to release the line

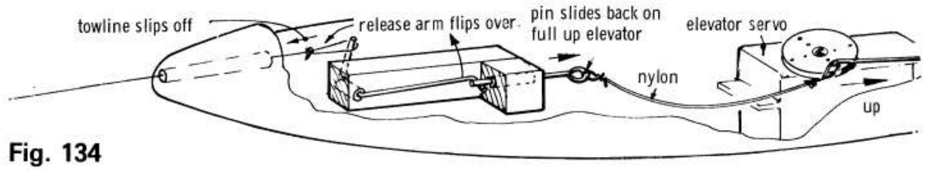


Fig. 134

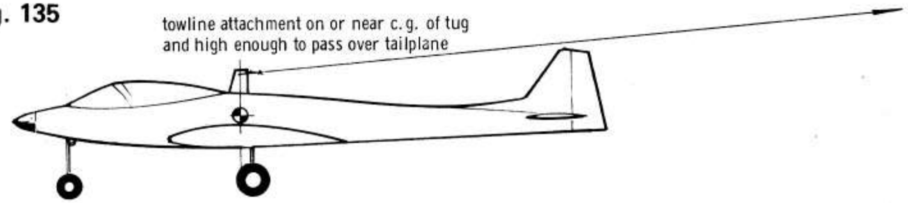
from the glider end, leaving it trailing behind the tug—as with full-size practice. The tug could then return with the line and, doing a low pass along the strip, drop it neatly in place for the next flight.

The release mechanism in the glider was quite simple and was actuated from the elevator servo. Ideally, of course, one would use an additional servo for this, and so avoid having to give up-elevator and "peel off" as it were. The release mechanism is shown in Fig. 134.

All the flights were made from a grass strip and, initially, the tug would make heavy going of attaining flying speed for take-off while towing the glider, which was already airborne and above the still earthbound tug. This problem was eventually overcome by the glider pilot applying a fair amount of down-elevator soon after the glider was launched, effectively taking the load off the tug for take-off, though not allowing the line to become slack enough to cause the glider to wallow.

Once airborne, the tug pilot would make very wide, gentle turns—especially the turn down wind on a windy day. The glider pilot generally seemed to apply slight down-elevator throughout the towed part of the flight, and maintained station slightly higher than the tug. All towing was conducted at full throttle. At times, the models were so high that any *precise* control could not possibly have been applied, yet the models still performed satisfactorily and did not get into any sort of pitching trouble.

Fig. 135

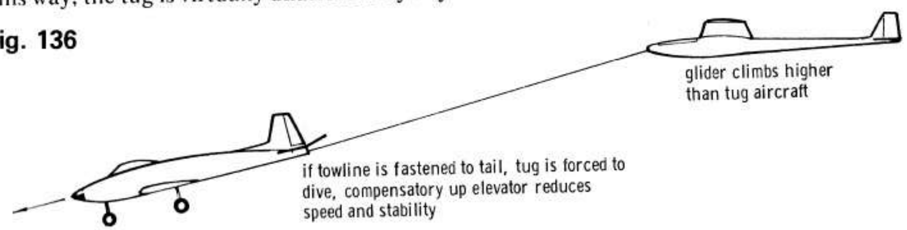


Recent pointers

Many groups of r/c fliers have since had success with their own variations of these methods and one, who have done a considerable amount of work on the subject, have come up with some fairly definitive pointers for those considering this rather off-beat branch of r/c gliding.

First, the attachment point on the tug is important, as it is critical in relation to the c.g. A line should be taken through the tug's c.g. and the attachment point (a small pylon or simply a hook) fitted to the point on the top deck of the fuselage where it emerges (Fig. 135). This way, the tug is virtually unaffected by any extra stresses and strains the glider attempts

Fig. 136



to put on it, by riding too high or too much to one side. A line attached to, or near, the tug's tail, however, will result in the tug becoming very difficult to handle. Fig. 136 shows how, with the glider riding in its normal position, slightly above the level of the tug, the tail attached line will pull the tail of the tug upwards. The pilot then applies a lot of up-elevator to the tug, to correct this, with the resultant loss of airspeed and general instability. The same sort of thing happens, as one can imagine, if the glider wanders too far either side. Too much to the left, and it pulls the tug's tail round and points it in the opposite direction, and so on. Keep the attachment fairly near the tug's c.g., therefore.

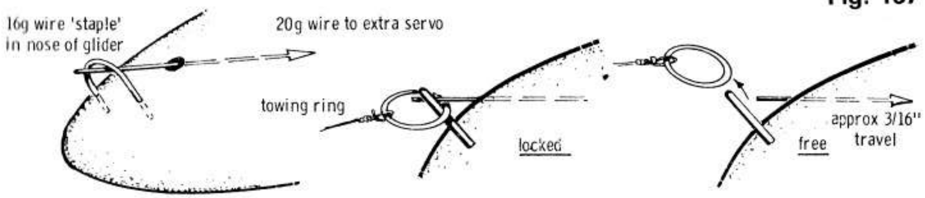
The attachment point on the glider is not, as we have seen, nearly so critical, but the optimum position is as high up on the nose as is possible. Various release mechanisms have been tried, the most satisfactory being a simple staple in the nose, with a rod from the servo going through a ring at the end of the line and holding it in place until withdrawn. This is shown in Fig. 137.

The towing line should *on no account* be of nylon monofilament, such as is used for ordinary tow-launches, as this has too much elasticity for aero-towing work and can cause snatch and oscillation in an otherwise satisfactory set-up. The recommended line is a shoe repairer's twine—linen thread, 7 cord, normal twist, WH&B. A "weak link" is used, to break in case of a bad "snatch," and is Keilkraft Terylene thread (as used for small control-line models). A length of rubber has been tried, to act as a kind of weak link, but only resulted in oscillation.

The length of the towing line should be 100-120ft. Longer lines are quite safe but do lead to weaving, and make it harder for the glider pilot to follow round turns.

The glider used should, for preference, have aileron control. The rudder steered model has to yaw before it can turn, and this can tend to build up into an oscillation, whereas the aileron controlled glider will follow quite smoothly. The rudder steered glider *can* be used, of course (as we have already seen) but more acquired technique is needed to ensure this yaw-swing remains at a minimum.

Fig. 137



Flying

With aileron controlled gliders, it is not necessary that they be hand launched, and it has proved surprisingly easy for them to be towed off the ground, without even the initial support at the wingtip that full-size gliders require, provided the grass of the strip is close cropped.

The glider is first taken to the extreme downwind end of the take-off strip, and the tow-line attached and laid out up wind. The tug then attaches to the up wind end, motor idling. At a given signal, the tug pilot opens up a little, and moves forward very slowly to take up the slack in the line then, at another signal from the glider pilot, he opens up the engine to full throttle—*not* looking at the glider any more—and starts the take-off. The climb-out should be very gentle, the tug pilot holding his model in as shallow a climb as possible, and straight into wind. The glider will take up a natural position some 20-30ft. higher than the tug.

Turns should be wide and flat, and the glider's nose should be kept pointing just slightly "out" of the turn, to maintain the line tension. If the line slackens due to the glider cutting across the inside of the turn, "snatching" will result, probably breaking the weak link.

Take-offs with rudder/elevator gliders are best done as described at the beginning of this chapter, with the glider being hand-launched, since, without aileron, it is not at all easy to keep the wings level, in the first few feet. As has been said, however, aileron control is infinitely preferable.

Weights and power

Gliders weighing between 2½ and 3½lb. can be towed quite adequately by ·40 powered models, it has been found. For towing gliders weighing between 3½ and 5lb. a ·61 powered tug is required, the figure of 5lb. having been found to be maximum weight for the glider, for reasonable and safe towing (the model in this particular case being a *Big Eagle).*

SECTION THREE

SOARING AERODYNAMICS

By FRED DEUDNEY

" Now that's what I call slope lift. "

CHAPTER 19

DOWNHILL ALL THE WAY

THE twenty years I spent in professional aerodynamic research have left me with the overriding impression that one uncovers new and harder questions at a greater rate than one finds answers to the old ones. I've got problems you've never even heard of. So, take my tip, acquaint yourself with some of the fundamental principles—if only to save chasing unattainable goals equivalent to perpetual motion. But don't try to dig too deeply, because you will never reduce it all to logic!

Who needs "Theory"?

Ours is a practical hobby. To be an expert needs no formal qualifications, and there are no lessons to be had. You learn piece-meal as you go, but the snag is that you pick things up in a random order, and the understanding of it is also hampered by encountering the innumerable handed-down half truths with which the folklore of our hobby is well supplied. Small wonder that so few persevere with trying to get their ideas on a sounder basis.

Take a look at a selection of the most advanced designs in all the fields of performance, gliding and powered, duration and aerobatics. You'll find always that the designer has quite a background of experience, and you'll often find that the model is the latest of a progressively developed series. But you'll seldom find that the designer will admit to knowing anything formally about aerodynamics (though intuitively he's done the right things), and you'll *never* find that the design was "theoretically calculated." The case for theory appears, to coin a phrase, underwhelming.

The most indisputable proven fact in the whole of modelling is that the design of (model) planes is so uncritical that no mathematical processes are needed. Also, from the sheer weight of evidence, it would seem unlikely that resorting to calculations would put your "solution" anywhere but in the middle of a broad tolerance band, at best. What is particularly discouraging to anybody who prefers not to leave it all to intuition, is that whilst there's no difficulty in using equations, the calculated result will be no more reliable than the aerodynamic data fed in, and this for models is likely to be very poor indeed. So, it isn't necessary, it isn't likely to offer advantages, and it's just as likely to be worse.

That concept of "theory" is not what I'm selling!

What, then?

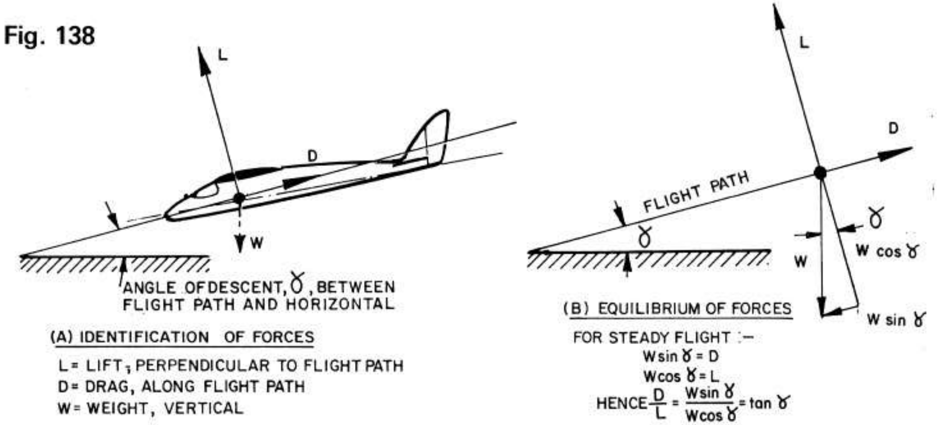
A professional engineer's approach to studying design requirements would be in three stages. First, to identify the main factors involved, secondly by theory and experiment to relate them in a mathematical sense, then finally to make an appraisal of the relative importance of each, in his particular application, by putting some figures in. Now, in our case, there's not much we can do in the latter respect, lacking good data. This is often taken as an excuse for ignoring the principles as well, and this is where the big mistake is made in the common dismissal of "theory."

The *principles* of flight, and of aerodynamics, are well established, without reference to the dimensions, which merely determine the quantities. You may be the pilot, but the laws of physics exercise an unseen control over what is possible in the way of performance. Better to have them working for you. What I offer is a very basic guide to the main principles, as something on which to build your own understanding. It's not a substitute for experience, talent and inspiration—you'll need those as well.

See me after school

If you found school algebra to be baffling, boring, and totally irrelevant to real life, then you're in the majority and I'm just an eccentric. But there's no other way to present a coherent account of a technical subject, so we have a problem of communication. At least we have a common interest—shedding a bit of light on model behaviour, something we see and experiment with for ourselves. As an incentive, tackling the "rules" is an economical alternative to building a hundred different models and trying to figure out why some are better than others, or why you can't get that elusive bit "more lift."

Fig. 138



Classical jazz

Back in school, they used to try to interest us in unrealistic problems involving inertialess masses connected by weightless string over frictionless pulleys. If you pursue book-learning, you do eventually find that you can progressively introduce all the tiresome realities and solve "real" problems: to have started this way would have been very off-putting. This "Classical" approach is the way to start thinking about gliding but because we don't need to simplify to the point of unrealism (a "frictionless" glider wouldn't come down), we don't need to go on to any difficult stuff. The only thing which we do, from convenience rather than necessity, is to start our considerations with a glider in still air over level ground.

(a) Glide angle. As a start we take a glider in steady flight at airspeed v, descending on a straight flight path at angle γ to the horizontal. The relation between the aerodynamic and gravitational forces can be deduced without knowing anything about the aeroplane. An overall aerodynamic force will be acting, which can be represented by two components; the major one is defined as the Lift, acting perpendicular to the flight path (not vertically), and the minor force acting along the flight path is defined as the Drag. See Fig. 138a. Similarly the weight can be represented as two components, as in Fig. 138b. The propulsive force is the component of weight acting forwards along the flight path, which is W $\sin\gamma$. Now, because the plane is in steady flight, the propulsive force must be exactly balanced by the Drag; if it were not, the plane would be getting faster or slower, because any unbalanced force produces an acceleration. So we can write $D = W \sin\gamma$. Similarly, the Lift must be equal and opposite to W $\cos\gamma$ or the plane will deviate from the flight path. Hence $L = W \cos\gamma$. Dividing, we get: $\frac{D}{L} = \frac{W \sin\gamma}{W \cos} = \tan\gamma$

So the first thing to emerge is that the *Drag/Lift ratio is a direct measure of the angle of descent.* As an example, a Lift/Drag ratio of 15 gives a glide slope of 1 in 15, or just under 4 degrees.

Two points to mention before proceeding. The first is that the glide angle is *not* the incidence angle of wing to fuselage, nor the operating incidence of wing to airflow, nor the observed angle of the fuselage to the horizontal when in steady flight. It *could* be equal to any or all of these, by accident or design, but as anyone who has seen gliders descending in a nose-up attitude will confirm, it isn't necessarily so. The second point is that for straight steady flight, we can always say that the Lift is just about equal to the weight. For our example with a glide angle of 1 in 15, the exact figure is $L = 0.998$ W, a discrepancy of one part in five hundred. The glide angle would have to be as bad as 1 in 7 for the error to be as much as 1%. So, for all practical purposes, Lift equals weight, and the reason for your plane descending is not a shortage of lift! If you learn nothing else, learn that.

(b) Rate of Descent. This is apparent from the triangle of velocities. If the plane flies at v ft./sec. along its flight path, then it covers the ground at v $\cos\gamma$ and descends at v $\sin\gamma$, Fig. 139a. As we've seen already, the glide angle is governed only by L/D, so for reasonably flat glide angles the rate of descent is $v \div L/D$. As an example, a model flying at 30ft./sec. with a L/D of 15 descends at 1/15th of 30, or 2ft./sec. Thus the D/L ratio represents the rate of descent as a fraction of the forward speed.

(c) Range. From a given height, the distance to touchdown in still air is the range. The same shape of triangle relates the starting height, horizontal range, and flight path, so that the ratio range/height is the same as the ratio Lift/Drag. As shown in Fig. 139b.

$$s_o = h \times L/D$$

The third result, then, is that the distance covered in still air is proportional to the L/D ratio, without reference to speed, weight, etc. As an example, from a height of 100ft., a model descending with a L/D ratio of 15 covers 1500ft. horizontally (1503ft. along its flight path).

(d) Duration. The time taken to descend will be the height divided by the rate of descent. Alternatively it may be derived from the slant range along the flight path, divided by the flying speed.

$$t = \frac{h}{v_s} \quad \text{and } v_s = v\frac{D}{L} \quad \text{hence } t = \frac{h}{v}\frac{L}{D}$$

As an example, from a height h = 100ft., at a flying speed v = 30ft./sec. and L/D = 15, the time of descent is $t = \frac{100}{30} \times 15 = 50$ secs.

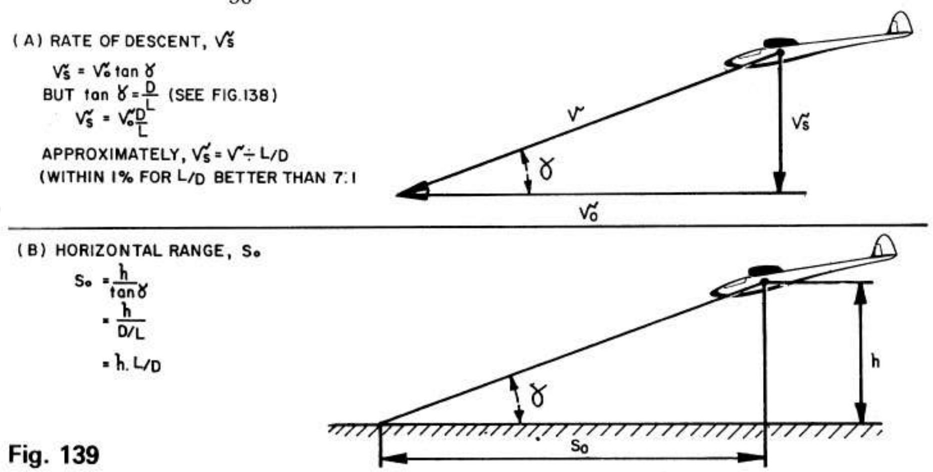


Fig. 139

(e) Energy considerations. The whole business of gliding is bound up with energy. If you take a plane at rest on the ground and haul it up to a height h, you give it a potential energy W ×h ft.lbs. This store of energy is used up on the descent by doing work against drag, and whether there is a high drag and short steep descent, or a low drag and a long shallow descent, the total work done is neither more nor less than the energy put in to the plane. This proves to be so, from the foregoing relationships. The distance covered along the flight path is h/sinγ and the drag force is W × sinγ; the work done is force × distance, which is W × h. It all ties up!

Pause to take stock

At this stage, what stands out is that the property of a plane known as its Lift/Drag ratio is of primary importance in every aspect of its performance.

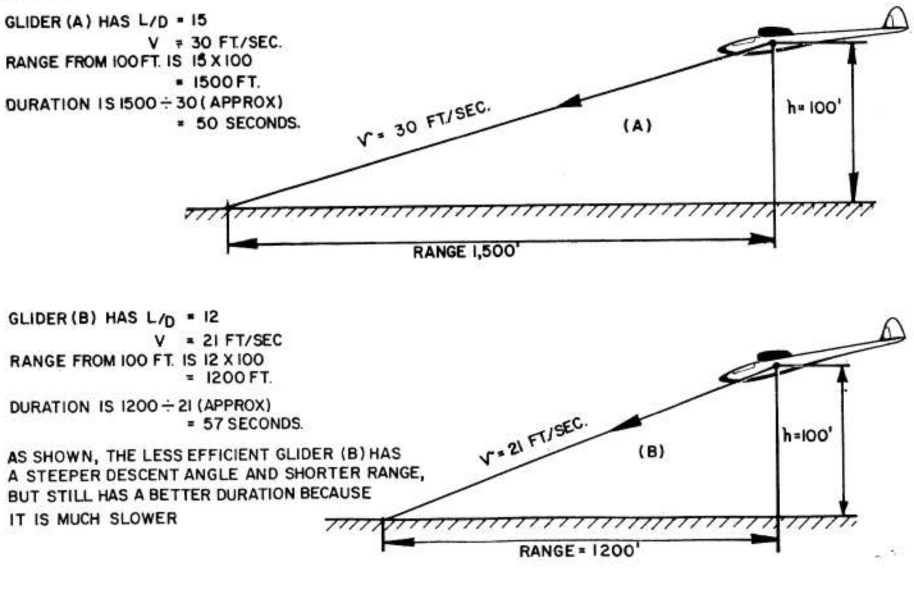
(a) Glide angle decreases with L/D.
(b) Rate of descent decreases with L/D; increases with speed.
(c) Range increases with L/D and height.
(d) Duration increases with L/D and height; decreases with speed.

Obviously L/D is a measure of what may be termed "efficiency," without needing to define what we mean, but it should be noted from *(d)* that where duration is the objective, both L/D and flight speed are equally important. It would seem that, in principle, we might trade L/D for reduced flight speed, to get a better duration if the rate of exchange is good.

As an example, our standard case in earlier illustrations has L/D = 15 and Speed 30ft./sec.; from a height of 100ft., it covers 1500ft. along the glide path, and the duration is thus 1500/30, or 50 secs. If we take another design where the L/D is less, having a value of 12, and where the flight speed is also less, at 21ft./sec., we get a glide distance of 1200ft. and a duration of 1200/21, or 57 secs. So the second example, though less "efficient," has a better duration, though its range is less, see Fig. 140.

So far, we've made some progress in isolating the main factors and relating them to performance; what we now have to do is to resort to some principles of *aerodynamics,* to see what governs the values of flight speed and the all-important Lift/Drag ratio.

Fig. 140



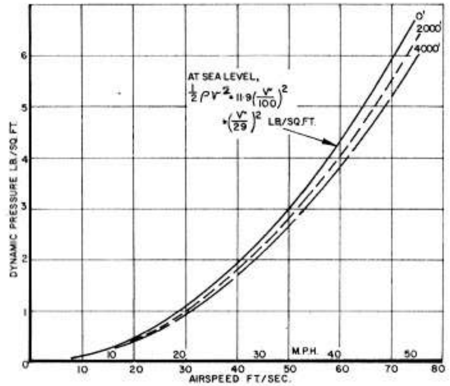


Fig. 141

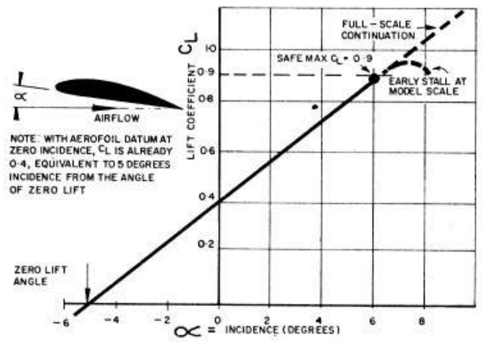


Fig. 142

Wings an' things

That "The lift is proportional to the square of the speed" is the first and often the only bit of aerodynamics that every modeller knows. It is possible to put it in terms which are more readily visualised, however, and as a start we have to accept that whenever air moves past an object, the motion generates what is called "Dynamic Pressure." Any solid object which slows or stops the air is then subjected to a force due to this pressure—this is the "wind in your face" effect. The dynamic pressure is the thing which varies with the square of the speed, and also depends on the air density, though the latter effect is only of concern to the really Alpine fliers. It is written $\frac{1}{2}\rho v^2$ and called "Half Rho Vee Squared," in spite of the printers' usual habit of putting a letter p where there should be a Greek symbol ρ, if you follow me. The value (in ft., lb. units, the only fit ones for an English-speaking gentleman) is $0.00119\ v^2$, or $\left(\frac{v}{29}\right)^2$, lbs. per sq.ft. at sea level, see Fig. 141. Air density is expressed in Slugs/cu.ft.—rather agricultural. It is self-evident that the lift produced by a wing will depend on its area, and the effectiveness of a wing (at incidence) in converting the available dynamic pressure into a Lift force, per sq.ft. of wing, is known as the Lift Coefficient C_L.

Thus Lift (lbs.) = Dynamic Pressure (lb./ft.²) × Area (ft.²) × C_L.

In the same way, Drag depends on a coefficient, C_D.

The equations are: $L = \frac{1}{2}\rho v^2\ S\ C_L$ and $D = \frac{1}{2}\rho v^2\ S\ C_D$.

The lift coefficient of a wing increases steadily with incidence angle, until the point is reached where the flow breaks down. This is the "stall," dependent on incidence, not speed, Fig. 142 and later chapters illustrate. For a complete aeroplane, it is a commonly accepted simplification to ignore tail and body contributions to the total lift, as they are normally only a few per cent. One can't do so for drag, however.

The foregoing shows what I mean by a useful principle; you may never want to use the equations to calculate quantities, but they do show what the parameters are, and as will be seen, enable us to get at what we want to know about the lift-drag-speed picture. First, however, we need an idea of what determines the incidence of a wing in flight, and what keeps it to a particular value. There's more to it than drawing the wing at a particular angle to the fuselage datum and hoping that's what it will fly at.

Stability and trim

The purpose of a wing is to provide lift; if it operated at zero incidence, the plane would follow a ballistic trajectory into the ground. The purpose of the tailplane is to provide a steady load to hold the wing at incidence, and to be capable of providing a change of load, as a result of any disturbance of the incidence, such as to restore the plane to its trimmed incidence. Digest that carefully, because the two functions of the tailplane are frequently confused. *The trimmed incidence* of the plane depends on the tail setting angle, or elevator angle, in relation to the wing setting angle; in other words, the *difference* between wing and tail incidence. The *stability* of the system does not depend on the rigging incidences, but on the tail size, moment arm, and c.g. position of the whole plane.

This latter state of affairs is invariably turned back-to-front by every modeller and every magazine article (and probably even by someone else in this book). The incidence difference does *not* govern longitudinal stability; it is governed *by* it! Anybody wanting to insist otherwise is taking on the world's entire missile/aircraft industry and denying the evidence of a prodigious number of measurements—including mine.

In Fig. 143a we show a symmetrical sectioned and symmetrically laid out design at zero incidence to the airflow. There is no lift from wing or tail, and no moment to change the incidence. In Fig. 143b, we've shown the same aeroplane at some incidence, say 3 deg. The *total* Lift (perhaps 90% wing and 10% tail) acts behind the c.g. and the result is a nose-down pitching moment tending to reduce the incidence. This is a *stable* aeroplane, but untrimmed; the incidence-reducing moment will not vanish until the lift and incidence are zero. The trimmed incidence is zero, and (like a weathercock on its side) any change of incidence, positive or negative, produces a stable moment restoring it to zero. In Fig. 143c, however, the same aeroplane is shown with the tail set negative to the datum at say −2 deg. At 3 deg. body incidence, the tail lift is then less, and the total lift will have moved closer to the wing c.p. As shown, it acts through the c.g., so there is no moment acting to change the incidence; the plane is now *trimmed* to fly at 3 deg. incidence. To examine whether it is still stable, imagine another 3 deg. added to the body incidence. The *increment* of lift added to wing and tail will be the same as case *(b)* experienced in going from 0 deg. to 3 deg., and the position of this added lift will be the same, so the restoring moment will be the same. This time, the restoring moment will vanish on returning to the trim at 3 deg. incidence. Thus, the plane is not only stable, but has the *same* stability as the zero-rigged one, *i.e.* it experiences the same restoring moment for any given displacement *from its steady trim.*

It needs a chapter rather than a paragraph, but that's the essence of it. How it applies in practice is as follows: if the c.g. were moved aft in Fig. 143b, the restoring moment about it would be less. This is a reduction in stability. At the same time, the tail setting would have to be reduced if you want to retain the trim at 3 deg. as in Fig. 143c. The two factors are inseparable; the lower the stability (aft c.g.), the less the negative tail angle required to trim the plane to any given incidence or lift, *i.e.* the more responsive the plane becomes. But it isn't the reduction of tail setting that reduces the stability; the point is that if you *rig* a plane in this way, you will *then* have to move the c.g. aft in order to avoid an excessively nose-heavy (low incidence) trim.

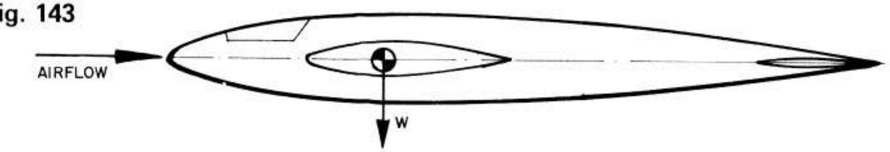
The first requirement of a model is *some* measure of stability, without which it becomes unflyable whatever the tail setting. This means in practical terms that the tail and its moment arm must be large enough and that the c.g. must be far enough forward; these three variables may be juggled to get the desired characteristic, and it's all done by trial and error! Having ensured stability, the question of trimming the model is obviously then a matter of how much tail incidence is built in, and how much is left to be set up in flight by shifting the elevator angle.

In practice, a high wing position, and the presence of the fin, may contribute a built-in nose-up moment, so that even with zero incidence wing and tail settings, it is not necessary to apply "up" elevator to trim at positive lift. All that we can say is that, provided the plane is stable, it can be flown continuously at any incidence within its range by adjustment of its tail setting or elevator. We can't predict how much incidence for how much elevator, and don't really need to. It could be done with reliable data, of course, but we don't believe in mathematical design, do we?

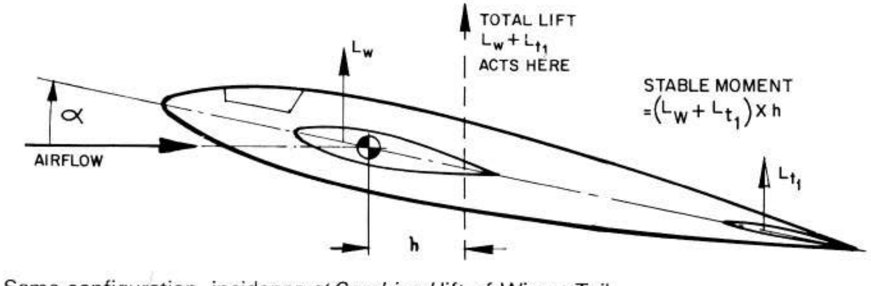
Back to the equations, men

After that digression, we now know that incidence, and hence the Lift coefficient C_L, is something that can be varied or held, in flight, by altering the tail setting. We know also that whether it takes a lot of up-elevator or only a little is governed by whether we've balanced the plane to have a well forward c.g. or a more aft one, and whether we've used generous tail

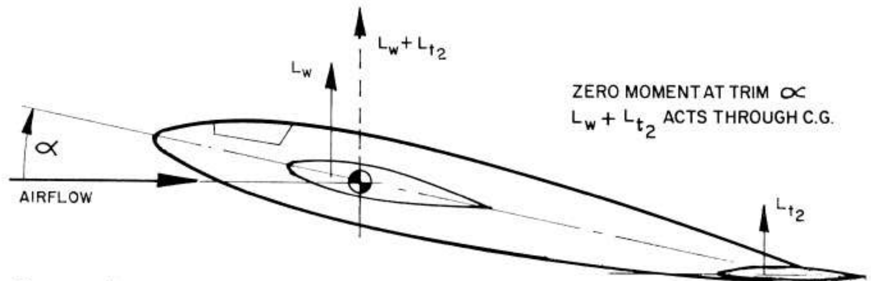
Fig. 143



(a) Symmetrical wing and tail aerofoils set at 0 deg. on fuselage axis. At zero incidence, no force or moment acts to change incidence α ∴ This is *trimmed* to zero lift. We cannot say whether it is stable till we examine the effect of body incidence.



(b) Same configuration, incidence α *Combined* lift of Wing + Tail acts aft of wing C.P. If, as shown, this is aft of c.g., then a nose-down moment results, tending to reduce incidence. Thus, config. (a) is *stable,* but trimmed to zero lift. It won't fly in this state!



(c) Same as (b) but with tail set negative to fuselage datum. At the same α, the tail lift is less, and total lift $L_w + L_{t_2}$ acts closer to the wing C.P. If, as shown, it acts through c.g., then there is no moment, and model is *trimmed* at α.

BUT: adding further incidence produces *extra* lift on both wing and tail, acting at h behind c.g. as in (b). Model is therefore *stable* about its trimmed α.

(d) This one was *unstable.* We moved the c.g. in case (b) to behind where $L_w + L_t$ acts. Model went both ways simultaneously and disappeared up its own antenna.

Moral: move the c.g. back in steps. The safe aft limit is then the step before the one at which it crashed.

surfaces or not. We can't tell from the drawings what C_L the plane will settle to, but by rigging and trimming, we can get what we want in flight.

Reverting to the equation relating lift, speed, and wing area, we have $L=C_L\ \frac{1}{2}\rho v^2\ S$, and now know two of the three things which we need, namely C_L and S. Also, we can say that after time to settle to a steady glide, the Lift L is equal to the Weight W.

$$\text{Hence } W=C_L\ \tfrac{1}{2}\rho v^2\ S$$

This is the flight speed equation, in which the only unknown is $\frac{1}{2}\rho v^2$. Rearranged, it becomes: $v=\sqrt{\frac{W}{\frac{1}{2}\rho S C_L}}=29\sqrt{\frac{W}{S\ C_L}}$ ft./sec.

Thus, in flight, the only thing governing the speed of any given glider is the Lift coefficient C_L, provided that we allow time to settle. A glider is a self-regulating device as regards speed, and if we change the trim in flight to a different incidence and C_L, then the speed will adjust itself in accordance with the above relationship. It's as easy as that. It follows that the elevator is the speed regulator; if you ease in "up" elevator trim gently, the plane will get slower, and vice-versa. A high C_L dictates a low speed, low C_L demands high speed. Unless your plane flies around shedding radio gear or wings, the weight and area are fixed, and all that the pilot can do is to trade speed for incidence, where steady flight is concerned, because the outcome of each elevator change is the same result, Lift equals Weight, after the appropriate settling time. The limits of this are the "too much elevator" case where the plane stalls, and the opposite where it comes straight down—no lift at all!

Weight, drag, and speed

So far, we've concentrated on sorting out the relationship between Lift, Weight, and Speed, and with the use of one more parameter, the Wing Area, we've got the whole story. We can now dispose of a widely held belief concerning the part played by the Drag.

The equation: $v=29\sqrt{\frac{W}{S\ C_L}}$ may be simplified, if we note that $\frac{W}{S}$ is Total Weight divided by Wing Area, i.e. the Wing Loading in lb./sq.ft. Writing "w" for wing loading, we then have:—

$$v=29\sqrt{\frac{w}{C_L}}$$

Thus it is not necessary to know separately the Weight and Area, and the wing loading is a useful criterion for judging a model's potential speed. The point to note, however, is that the speed depends only on the *two* parameters, wing loading and lift coefficient. It may seem intuitively "obvious" that cleaning up a design to reduce the Drag will make it go faster. Not so! Drag governs the *Angle of Descent*, and any reduction of drag will result in a shallower glide path at the *same* forward speed. The only speed change that results is in the rate of descent, which gets *less*.

The background to this common misinterpretation of evidence may become clearer (or possibly foggier) if you read my other bit. If you use a particularly thin aerofoil to reduce Drag, it will stall at a lower incidence, or C_L, so it will not then be possible to fly the plane as slowly as the *minimum* speed of its thick-winged counterpart. But if the thin-winged model is retrimmed, by under-elevating, to *make* it descend as steeply as the other, *then* it will fly faster. The drag reduction *permits* faster flight, if you throw away the primary effect of a reduction of glide angle.

There is one exception—straight down at zero lift. The plane will accelerate under gravity until the Drag equals the Weight, at some fearful Terminal Velocity. If you persist in this sort of thing, it would be more appropriate to study excavation than Aerodynamics.

Up, up and away

That tempting carrot before the donkey, the notion of getting "more lift," should by now be losing its allure.

The equation was: $L=C_L\times\frac{1}{2}\rho v^2\times S$.

Can't we fiddle one of those three things on the right hand side, just to squeeze a bit more

lift out of our plane? The answer, to your regret and mine, is an unqualified No. Return to the beginning of all this rigmarole and you'll see that the vital "Lift = Weight" principle was established purely as a consequence of the steady flight condition, without needing to know the value of either, and without needing to know anything about aerodynamic behaviour. Old Isaac Newton himself would have told you that. If your plane seems to come down too fast, it's not a bit of good treating it as a case of shortage of lift, and resorting to "high lift" sections" and grafted-on wing extensions. What you need is less drag.

Of course, if you increase wing area, or change to an aerofoil which can achieve a higher C_L, the self-adjusting property of the stable aeroplane will ensure that the final outcome is $L=W$, as always, and this implies a reduction in speed. So although your plane may descend just as steeply, it will do so more slowly. If you could "get more lift," the logical outcome would be the plane that just got up and flew away. And don't ring us, we'll ring you.

The price of flight

The Lift/Drag ratio is a direct factor in every aspect of measurable performance. A scale model would have exactly the same L/D as the prototype, if it were not for the deterioration in aerodynamic characteristics, called "Scale Effect," which occurs somewhere between "their" conditions and ours. The point I'm making is that, if we stick to models, then the L/D ratio of a given design is a property of the layout, its proportions and sections, and not dependent on the scale to which it is built, or the weight at which it is flown. Remember that L/D is the same as C_L/C_D, so forget the *forces* and think of coefficients which depend on the geometry.

Just as C_L is a measure of the lifting effectiveness, so the C_D value is a measure of the bluffness of the aeroplane; a well streamlined plane has a low C_D. For a plane with elevator control, the incidence and C_L can be varied in flight, so that a whole range of values of C_L/C_D must be possible. At $C_L=0$, the value of C_L/C_D must be zero, and one may infer that increases of C_L to normal flying values, say 0.2 to 0.9, will lead to respectable values of C_L/C_D. Without knowing anything about the behaviour of the Drag Coefficient with incidence, we may still safely infer that L/D will tend to deteriorate whenever the incidence and C_L are reduced to build up speed.

An aeroplane needs lift, however, and associated with the generation of this lift is a penalty known as "Induced Drag." Even if a designer were clever enough to make a perfectly streamlined plane having zero profile drag, it would still have this lift-dependent drag. This is what I call the "Price of Flight," because it's still there for the perfect plane, but wouldn't be there for a buoyant thing such as an airship. The importance of induced drag to model gliders is illustrated in a later numerical example, but at present we should mention that the Induced Drag Coefficient increases with the square of C_L, and decreases with aspect ratio. If we write C_{Di} for it, and say that the rest of the drag is independent of incidence and is called C_{Dp} (Profile drag), then:—

Total $C_D=C_{Dp}+C_{Di}=C_{Dp}+(C_L^2\ /3{\cdot}14A)$, where A=Aspect Ratio.*

Thus the least value of total drag coefficient occurs at zero C_L, where L/D must also be zero, and the rapid rise of C_{Di} with C_L^2 suggests that the total drag may reach an excessive value at particularly large values of C_L, prohibiting the attainment of a high value of L/D. An optimum should exist somewhere, at an intermediate C_L, before the induced drag has risen to an excessive amount. This is the case, and in fact it follows mathematically that the *maximum* value of L/D will occur at a C_L where C_{Di} is equal to C_{Dp}. In practical terms, this is invariably at quite a high value of C_L.

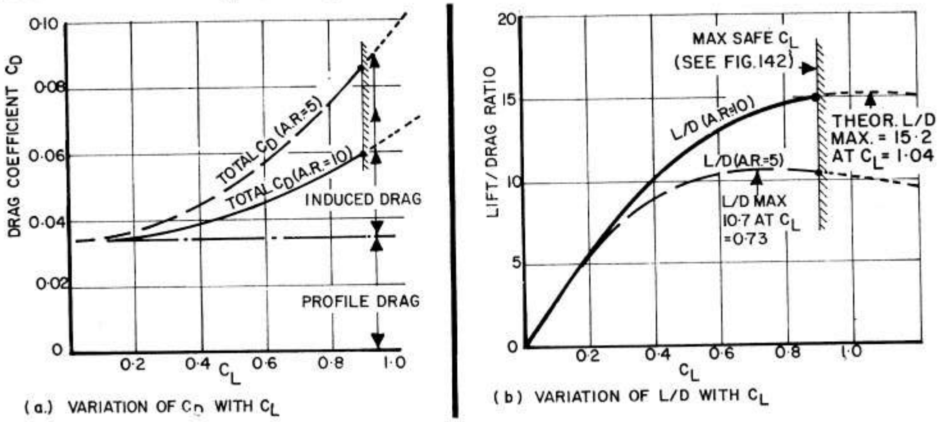
Under model conditions, of small chords and low speeds compared with full scale, there is always a premature breakdown of lift at a lower incidence and C_L than that attainable full-size, and in practice this may occur before reaching the incidence at which the theoretical L/D max. occurs. Under these circumstances, the best L/D obtainable is found at the

* The Aspect Ratio of a wing is the ratio of Gross Span to Average Chord. There is no need to calculate the Av. Chord for an awkward planform, provided that the Gross Area (including the part of the wing 'covered' by the fuselage) is known. The universal definition for all planforms is:—

A.R. = Span^2 ÷ Gross Area

highest C_L to which the model can be trimmed, and the standard duration-flying practice of trimming the plane to fly right on the brink of stalling is then the right one to get the best L/D, or flattest glide angle. It isn't always so for all models, especially where the aspect ratio is particularly low, when the best L/D may occur at an intermediate C_L which is well below the stall. Likewise, a model having low profile drag, *i.e.* good streamlining and slender cross-sections, may have its best L/D at a middling C_L.

Without measured evidence from a range of models, it is not possible to make forecasts, but one's eyes may be kept open for evidence of a visual nature, in the light of the above account of the workings of things. By way of an example, Fig. 144 illustrates the sort of



(a.) VARIATION OF C_D WITH C_L

(b) VARIATION OF L/D WITH C_L

Fig. 144

characteristics which our earlier specimen would have, given the additional information that the quoted L/D = 15 occurred at C_L=0·9, and the wing aspect ratio was 10. It may be seen that the theoretical max. L/D is 15·15, occurring at C_L = 1·04, beyond the safe incidence of the aerofoil. Also indicated is the result of changing the planform to an aspect ratio of 5; the L/D is inevitably worse, and its maximum occurs well below the stall region. The peak L/D region is pretty flat, however, so the penalties are not large if you don't hit the ideal trim.

Sinking speed is a somewhat different matter, as it results from the simultaneous combination of L/D (which ensures a shallow descent angle), and forward speed. For models, it always pays to trim to the slowest possible forward speed (high C_L), as the saving in speed outweighs any changes in L/D near the peak.

To sum up, Drag is your enemy; you can't eliminate it but you can minimise it by commonsense clean design. Induced Drag may be 50% or more of the total, so high aspect ratio benefits "floaters."

Crazy, man

There's no denying the joy of silent aerobatics, but the design of models for it is a fine example of the art of compromise. Aerodynamic efficiency in terms of L/D demands high aspect ratios and thin, cambered wings. Rapid responses, especially in roll, demand short wing spans; strength demands thick wings, and matched looping ability upright and inverted demands a symmetrical uncambered section. I'll leave the recommendations to the experts.

The unseen penalty of every turn and every loop is that they all require *extra lift* to accelerate the model away from its steady-state straight path, and so there is a rise in induced drag, which is in any case a high proportion of the total at high C_L. So the combination of low aspect ratio with high-g turns and loops is unfavourable to the aim of keeping the thing moving. Doesn't stop people making very effective aerobatic gliders though.

Never do it into wind

The "ideal" environment used in our analysis was adopted to avoid the added complication which would arise when considering range, glide angle, etc., in the presence of a wind. The speed referred to throughout is that of the model in relation to the air; if you want to know what progress is being made in relation to the pilot on the ground, you must add or subtract wind speed. Our example flying at 30 ft./sec. airspeed would literally hover if it was heading into a steady wind of 30ft./sec., and its glide angle would be 90 degrees in relation to the ground. Down-wind flying would result in a disappearance rate of 60ft./sec. Nothing more needs saying; if the trim is unchanged, the airspeed is independent of whether it flies downwind or upwind, once it has settled down. What is *visually* confusing, however, is the *transient* effect of any quick change of direction. A fast-flying model going downwind at say 60ft./sec., turned *rapidly* into wind without any change of trim, has an excessive airspeed momentarily, which will cause it to "balloon" upwards; eventually all the excess energy will be used up and the steady state, in our example, will be a descent at the normal sinking speed, and at zero rate of progress relative to the ground. Similarly, real-life winds aren't steady, and a sudden gust will subject the model to a gratuitous bonus of "$\frac{1}{2}\rho v^2$": because of its momentum, the model can't lose speed instantaneously, and the result is that bit more lift than you wanted. On the other hand, when a sudden lack of blow appears, the model acts as if somebody pulled the air from under it. These effects are reversed for a model flying downwind, of course, and what appears to be a downwind stall may often be due to a gust "catching up" with the plane and reducing the lift to a value well below the weight.

Slope soaring must have wind, to prevent the model straying from the flying site, and that wind must be an uphill one to compensate for the rate of descent of the model relative to the air. These are essential conditions, and the arts of designing and flying the special breed of model to suit this particular environment will be found elsewhere. I do have something to say later about ballasting, however.

At last he's finishing

What I've written is no more than a distillation—a simplified exposition of the mechanics of gliding flight, restricted to the aspects of most relevance to modelling. If you're a newcomer, it won't have meant much to you. It never will until you've sampled the realities, got in some flying hours, seen it all happening, and made a few mistakes, because you don't need the answers before you've found the questions! When you come down to earth after the exhilarating landmarks of progress from the first "surviving" flight to the first "Own-design" success, then is the stage where my contribution may help you to interpret the confusion of visual evidence which you have acquired *en route*. Don't reject it as beyond your understanding; it's only what's in your head already, but re-arranged and disentangled from the fluff.