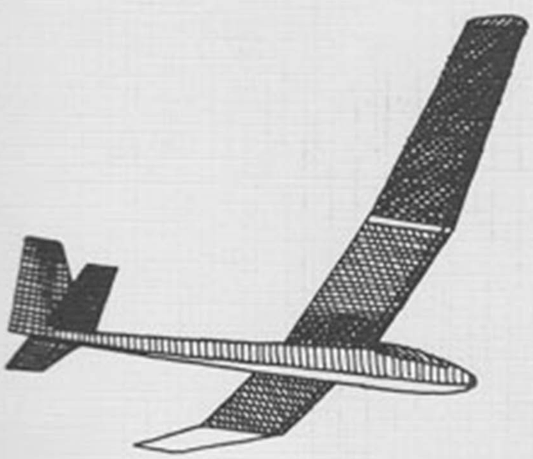
SFVSF

TECHNICAL ANTHOLOGY
1978 - 1982



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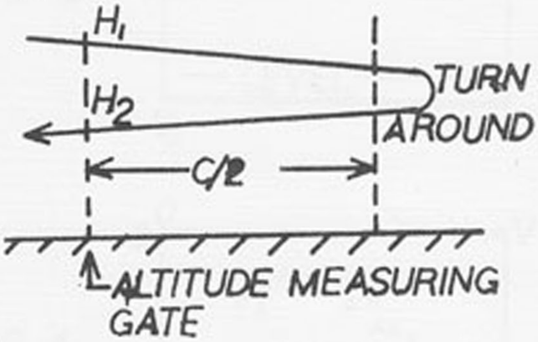
PRELIMINARY REPORT ON L/D TRIALS

Blaine Rawdon

On December 4, 1977, from dawn 'till 9:00 a.m., a number of us ran an experiment to measure the performance of several R.C. sailplanes. The data obtained is too incomplete to publish now, but with further trials I am confident that reasonably accurate information will be obtained. Typically, though, best performance might be $V = 20$ ft/sec, $V_{sink} = 1.3$ ft/sec, $L/D = 15$.

How the Measurements are Made:

FIG I



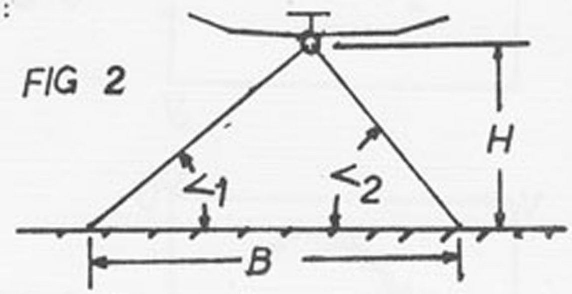
The plane is flown steadily between two vertical planes. The altitude is measured as it enters and exits the course. The total time on course, as well as the time spent turning, is measured.

Altitude is measured with 2 inclinometers:

$$H = \frac{B \; \text{SIN} \angle_1 \; \text{SIN} \angle_2}{\text{SIN} \; (\angle_1 + \angle_2)}$$

We used B = 700'

FIG 2



Airplane Velocity:

$$V = \frac{C}{T_{Total} - T_{Turn}}$$

Where C = 2(Distance Between Planes)

T = Time

We used C = 800'

Total Distance Flown:

$$D_{Total} = V \; T_{Total}$$

Sink Rate:

$$V_{Sink} = \frac{H_1 - H_2}{T_{Total}}$$

Where H_1 is entering altitude

H_2 is exiting altitude

$$\frac{L/D}{L/D} = \frac{V}{V_{Sink}}$$

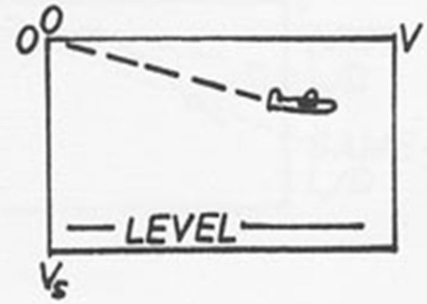
Why Do This?

Information about sailplane performance is generally shown in a graphic form called a Polar. This is a graph which relates sink rate to forward speed. This graph can be an amazingly rich source of information about how to fly the airplane.

The following illustrates the concept of a polar graph:

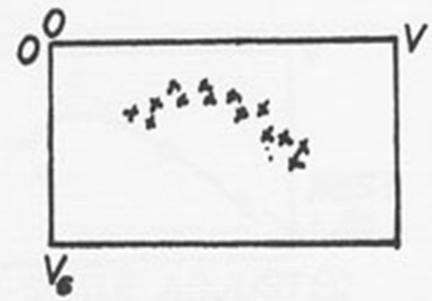
Imagine photographing a sailplane one second after it enters the corner of the frame (the plane flies parallel to the plane of the film). We could probably devise some way to measure off the photograph to determine how far the plane flew in that one second, and how far it sank.

FIG 3



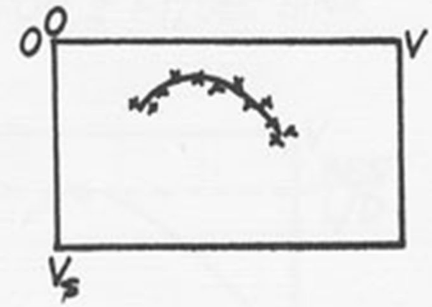
If we perform the experiment many times more and record the data on one sheet, we might get something like this:

FIG 4



We can see that the data jumps around a bit, due perhaps to measurement variations, errors in flying, or lift and sink on the course. If we assume that the performance is actually continuous, we can sort of average the data and represent it with a line, leaving the data points to indicate the roughness of the data. One can imagine that more data points will give greater confidence in the line chosen. The line represents the polar.

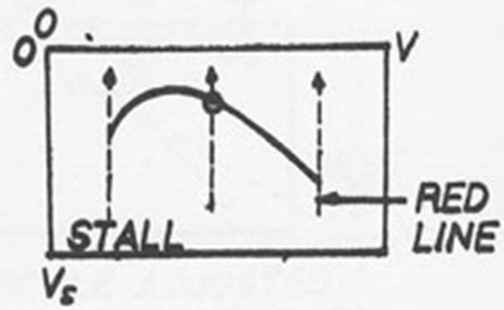
FIG 5



Given a polar, we can learn many interesting things about the plane:

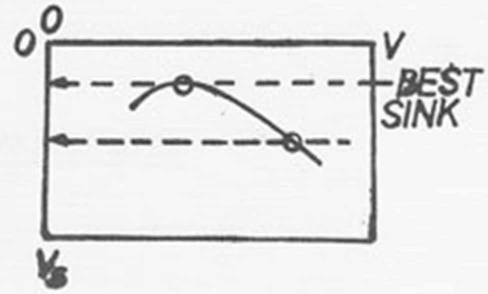
Speed: Just compare the point of interest to the speed axis.

FIG 6



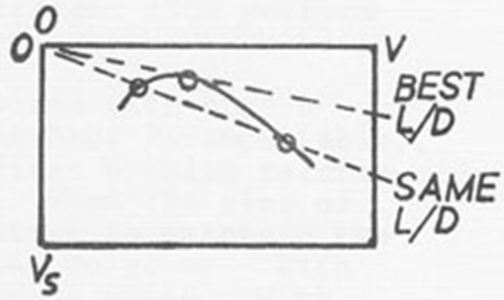
Sink Rate: Just compare the point of interest to the sink axis.

FIG 7



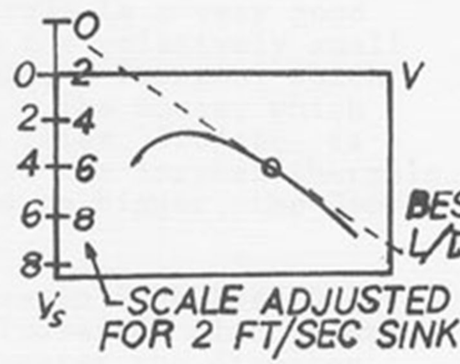
L/D (Still air): The ratio of V to V_s of the point gives the L/D at that point. A line swept from the origin has the same L/D along its length.

FIG 8



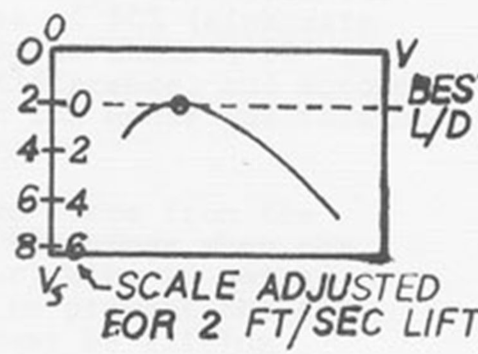
L/D in Sink: Move the origin according to the sink rate, then proceed as above. Note: best L/D in sink is at a higher V than in still air.

FIG 9



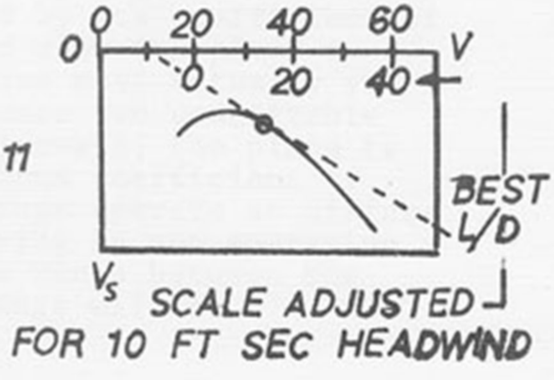
L/D in Lift: Ditto above. Note: best L/D in lift is at a lower V than in still air.

FIG 10



L/D in Wind: Similar to above; just move the V axis scale to simulate the effect of wind.

FIG 11



GRAPHS CONCERNING OPTIMUM SAILPLANE SIZE

Blaine Rawdon

Have you ever wondered how a 20' span Paragon would fly? I have been wondering a lot lately since the L/D trials show clearly that greater spans give better straight line performance.

There seems to be at least two basic problems with such a plane. They may not be insurmountable (perhaps Paramountable), but they are problems nonetheless. The first problem relates to wing loading and thereby flying speed. When the size of an airplane is increased, the extra structure to maintain the equivalent strength causes the wing loading to go up. With increased wing loading comes increased flying speed. With increased flying speed comes increased minimum circling diameter. How tight an airplane will circle is a very good measure of how well it will thermal. In the relatively small thermals in which we fly at Pierce College, a Paragon, which flies about 20ft/sec, thermals very well. The Goose, which has almost the same sink rate, but which flies 30ft/sec, is a very difficult plane to thermal in any but the largest thermals. In the desert, where the thermals tend to be bigger, the Goose really comes into its own.

If you look at the graph labeled "Increase in Sink Rate Due to Circling" you can see how the sink rate increases with tighter circles. The faster the airplane, the greater the diameter of the circle at any given sink rate increase. Note from our example above that at a sink rate increase of 50% (sink rate factor equals 1.5) the Paragon will circle at about a 19' radius, or 38' diameter. This is a big difference, and accounts, I believe, for the big difference between the Goose and Paragon in thermalling ability.

The other problem a 20' Paragon would have stems from the difference in airspeed which occurs over the wings when the plane is circling. The outside (or higher) wing is going faster than the inside wing, so in order to prevent the airplane from rolling in, the outside wing must be lifting relatively less than the inside wing. The degree to which a wing is lifting is partially determined by its coefficient of lift, or C_L. In order for a rudder and elevator plane to lift more on the inside wing, the plane must actually yaw to the <u>outside</u> of the circle. This causes two undesirable things to happen. First, when going sideways, the plane is less clean. Second, wings have an optimum coefficient of lift, so when the outside and inside wings operate at different coefficients it is clear that the wing is not operating in an optimum fashion. The greater the range between the inside and outside wings, the worse things will be.

Let us look at the other graph. The lines on the graph are grouped by plane flying speed and by plane span. If we take our imaginary 20' Paragon, which is presumed to fly at 20ft/sec, we see that the coefficient ratio between the wings can be as high as 2.6 when the plane is flying at an 18' radius. 2.6 is hopelessly high--no wing operates over that kind of range very well. If we take as a limit 1.5 (which seems to be reasonable) and we trace down that high 20' span line, we don't bump into the 1.5 ratio line until the circle radius is 56 ft. This means that a 20' Paragon which flies 20ft/sec would be a real turkey since it couldn't circle tight to save its life!

There would be two ways to fix this airplane. One way would be to add ballast to the plane so that it flew faster, say 30ft/sec. Now, back at the graph, if we look at the group of lines for 30ft/sec, we see that a 20' span plane peaks out at 1.5 C_L ratio at about a 40' radius increases its sinkrate by a factor of 1.66, which is a bit radical.

Another solution would be to chop the tips off so that the span was only 10 ft. Assuming the plane still flew 20ft/sec, we look back at the complicated graph to the missing 10' span line in the 20ft/sec group. We see that this imaginery line crosses the 1.5 ratio line at about 25' radius. Now this is a real improvement. Checking back to the other graph, we see that a 25' radius will only increase the sink rate factor to 1.24, which isn't bad at all. It seems that a 10' Paragon which flies 20ft/sec might be a pretty good plane. Imagine that!

Another example. Let us figure out the minimum circling radius for a Sailaire which has a span of a shade over 12' and a flying speed of about 20ft/sec. Just trace along a bit above the 12' span line in the 20ft/sec group until you get to the 1.5 C_L ratio line, and then go down to the circle radius scale at the edge of the graph, and you get about 35'. The bank angle for that speed and radius is about 20.9°. Checking back to the other graph we find that the sink rate factor would be only 1.1, which is no problem at all.

Clarifications, Comments, and Conclusions

The two graphs operate together to give some indication of a plane's circling ability. The simple graph ignores the effect of the complicated graph. The second graph has really nothing to do with the first, except that the end result is the same, namely, increased sink rate while circling.

The basic implication is that small planes circle better. This must be balanced by the fact that big planes go better in straight lines.

Big planes circle more cleanly, and tighter, if they go faster, but there may be an increase in sink rate due to bank angle.

The 1.5 C_L ratio limit seems about right for 12% thick flat bottom sections. I would imagine that undercambered and thinner sections with less speed range might be limited to about 1.3. Semi-symmetrical sections of about 12% thickness should be okay up to about 1.7. This means that undercambered airplanes must be circled relatively flat, whereas semi-symmetrical jobs can be banked right up there.

The trick with a large, slow thermal plane is to get the wing to operate over a wide C_L range, without yawing too much. A first step would be to increase the dihedral to lessen yaw. A better step might be to use ailerons, which would act as a flap on the inside panel, and as a reflexed section on the outside panel.

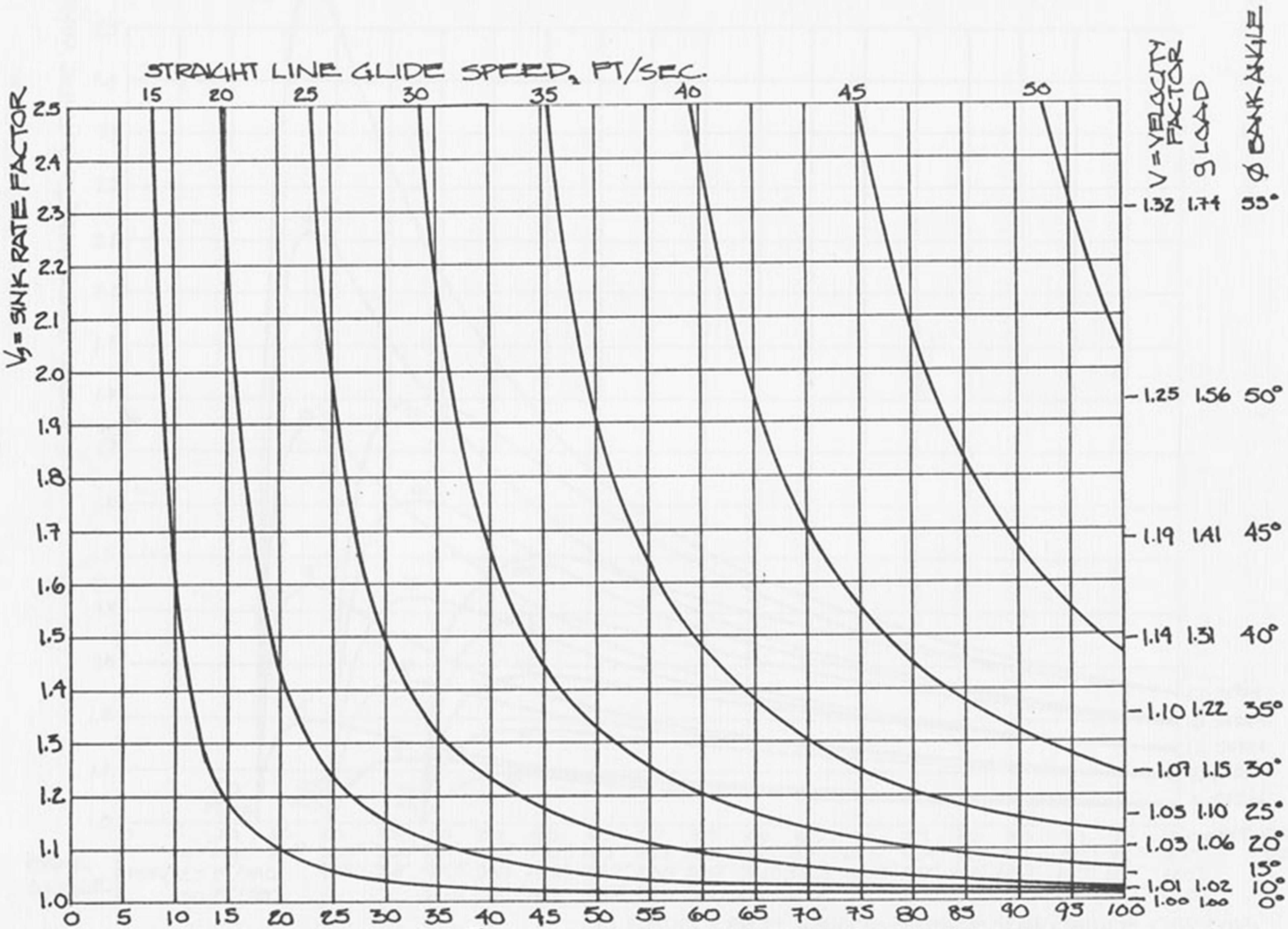
If you fly where there are big thermals, then you can fly big airplanes.

If you fly fast airplanes, they might just as well be big ones.

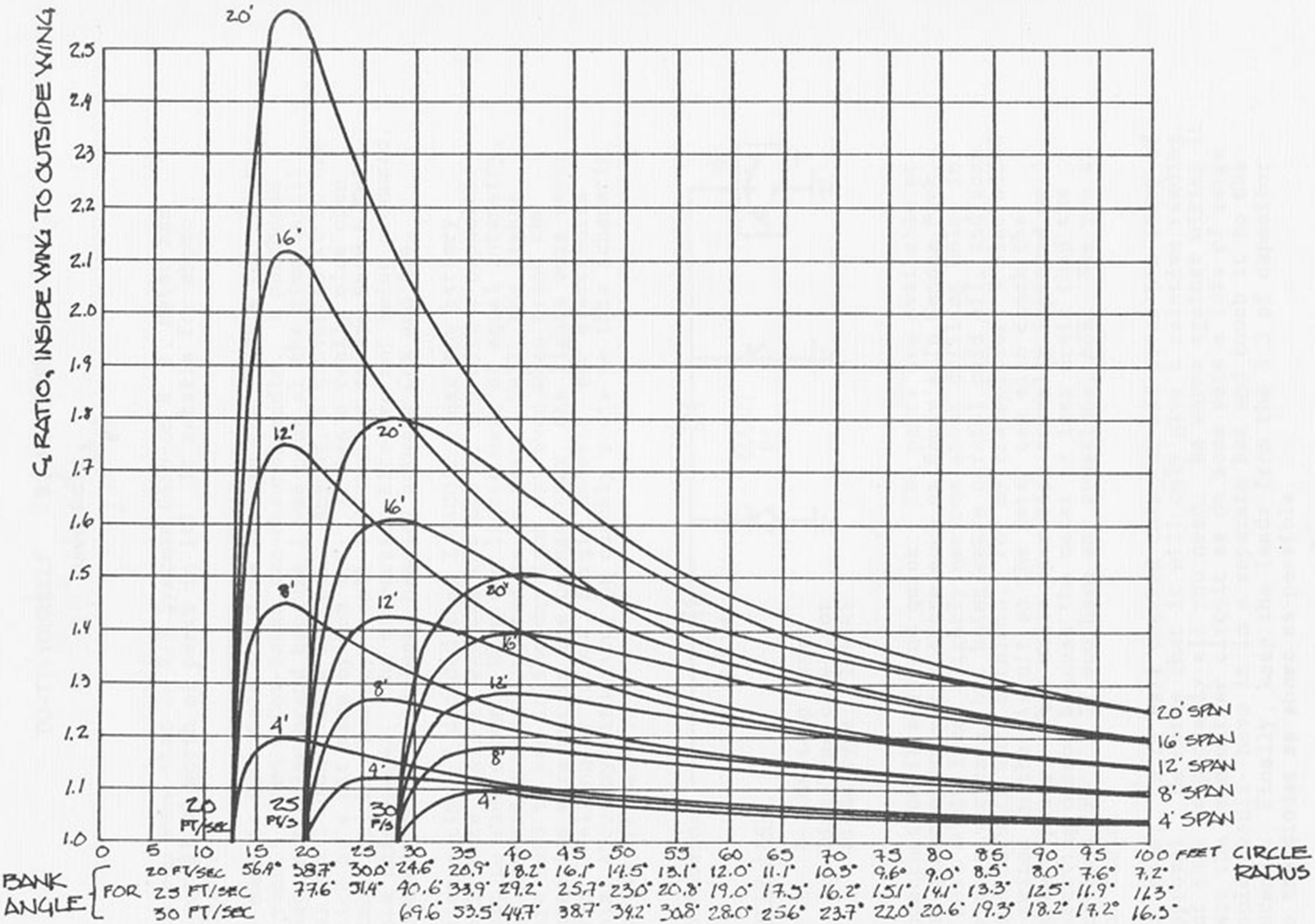
If you fly small airplanes in calm conditions, they may as well fly very slowly.

All of this is a matter of degree. Thermals are a matter of degree. Some are stronger in the center and taper off quickly away from the core. Others are big and even.

You pays your money and you makes your choice.



INCREASE IN SINK RATE DUE TO CIRCLING



C_L RATIO, INSIDE WING TO OUTSIDE WING, WHILE CIRCLING, AS A FUNCTION OF LEVEL FLYING SPEED, AIRPLANE SPAN, CIRCLE RADIUS, AND BANK ANGLE.

DO-IT-YOURSELF R. F. METER

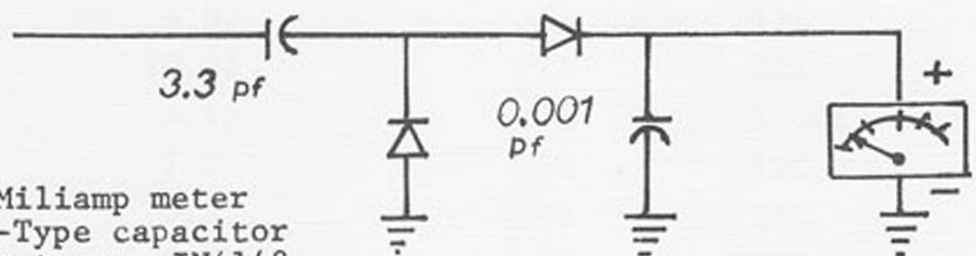
Dave Gold

Did you know that an R/S Systems Clip-on R. F. Meter has about $5.00 worth of parts in it? It retails for about $23.00.

My name is Dave Gold and I've been in the SFVSF's for about a year. I own a Cox-Sanwa two-channel radio. I purchased that particular brand because I was poor at the time (still am) and I didn't know better. Anyway, I converted it to one stick by a kit made by Cox R.C. It has a really nice open gimbal stick. You may recall I discussed it for Show & Tell once this summer. The conversion kits are not being produced, however, because of legal hassles between Cox and Ace.

After a time, I decided that I didn't trust the battery indicators. All it was was two LED's, one with a capacitor, next to each other. When the lights were of equal intensity, the batteries were supposed to be okay. Well, the lights were hard to see in the daylight and even when brand new batteries were put in the transmitter, the lights were never even. Telling my friend, Sergio Henerik, our electronics whiz, about my situation, he quickly wrote me this schematic for an R/F Meter:

To Antenna



Parts List:

1. 0-1 Miliamp meter
2. Disc-Type capacitor
3. Diode type: IN4148

Construction is easy and quick. The parts are available at any electronics parts store such as Sandy's in Canoga Park. I must admit I was slightly nervous about drilling holes in my receiver case, but being extra careful paid off, and soon good results were obtained. For my transmitter, I also added a switch in the circuit so the meter can also check the battery power. This whole operation actually improved my receiving output because the meter is less drain than the previous LED's. If you have any questions, ASK. See you at the field.

Ed. note: Terry Hall checked this out and gives his stamp of approval. He notes that it will only give a relative reading, but that is probably all you need. He warns against wiring it into the transmitter circuit as on some sets a loss of range could result--have it in a separate box and touch it to the antenna. Finally, keep the leads from the 3.3 pf capacitor to the diodes as short as possible.

GLIDE POLARS OF SEVEN MODEL SAILPLANES

Blaine Rawdon

Plane	Owner	Span/Inches	
Pierce 970	Lorin Blewett	120	→ 1
Eagle 128	Ted Yee	128	→ 2
Goose	Bill Watson	135.5	→ 3
Mirage	Blaine Rawdon	114	→ 4
Paragon	Larry Pettyjohn	118	→ 5
Paragon	Dick Harty	118	→ 6
Sailaire	Lorin Blewett	150	→ 7

Area	OZ/FT^2	Approximate Camber	Approximate Thickness
970 in^2	10.09	3%	9%
1,243 in^2	6.02	6%	12%
1,127 in^2	10.22	2%	12%
923 in^2	5.15	3%	12.4%
1,080 in^2	7.2	4%	12%
1,080 in^2	6.8	4%	12%
1,643 in^2	8.24	4%	12%

AllData Points (Velocity, Sink)

Pierce 970 (35.56, 2.05) (29.09, 1.85) (42.11, 4.38)
(28.07, 2.24) (30.77, 1.80)

Eagle 128 (15.3, 1.0) (23.2, 1.91) (20.8, 1.30) (20.0, 1.03)
(26.67, 2.41) - Demolished

Paragon - Pettyjohn (23.4, 2.52)(17.9, 1.29)(17.4, 1.45)
(20.0, 1.19)(19.4, 1.34)(20.0,1.35)(30.19, 2.62)
(26.23, 1.47)(25.81, 1.92)(23.88, 1.69)(41.03, 6.57)
(29.09, 1.22)(34.04, 3.73)(42.44, 6.90)(46.38, 7.95)
(40.71, 7.26)

Paragon - Harty (23.9,2.2)(22.2,1.3)(23.0,1.58)(23.7,1.62)
(25.40,1.67)(23.19,1.46)(21.33,1.24)(21.92,1.36)
(30.19,2.66)(24.62,1.86)(28.57,1.80)(18.60,1.19)
(19.75,1.23)(20.65,1.43)(24.06,2.49)(23.36,1.30)
(22.38,2.46)(24.06,1.55)(29.63,4.37)

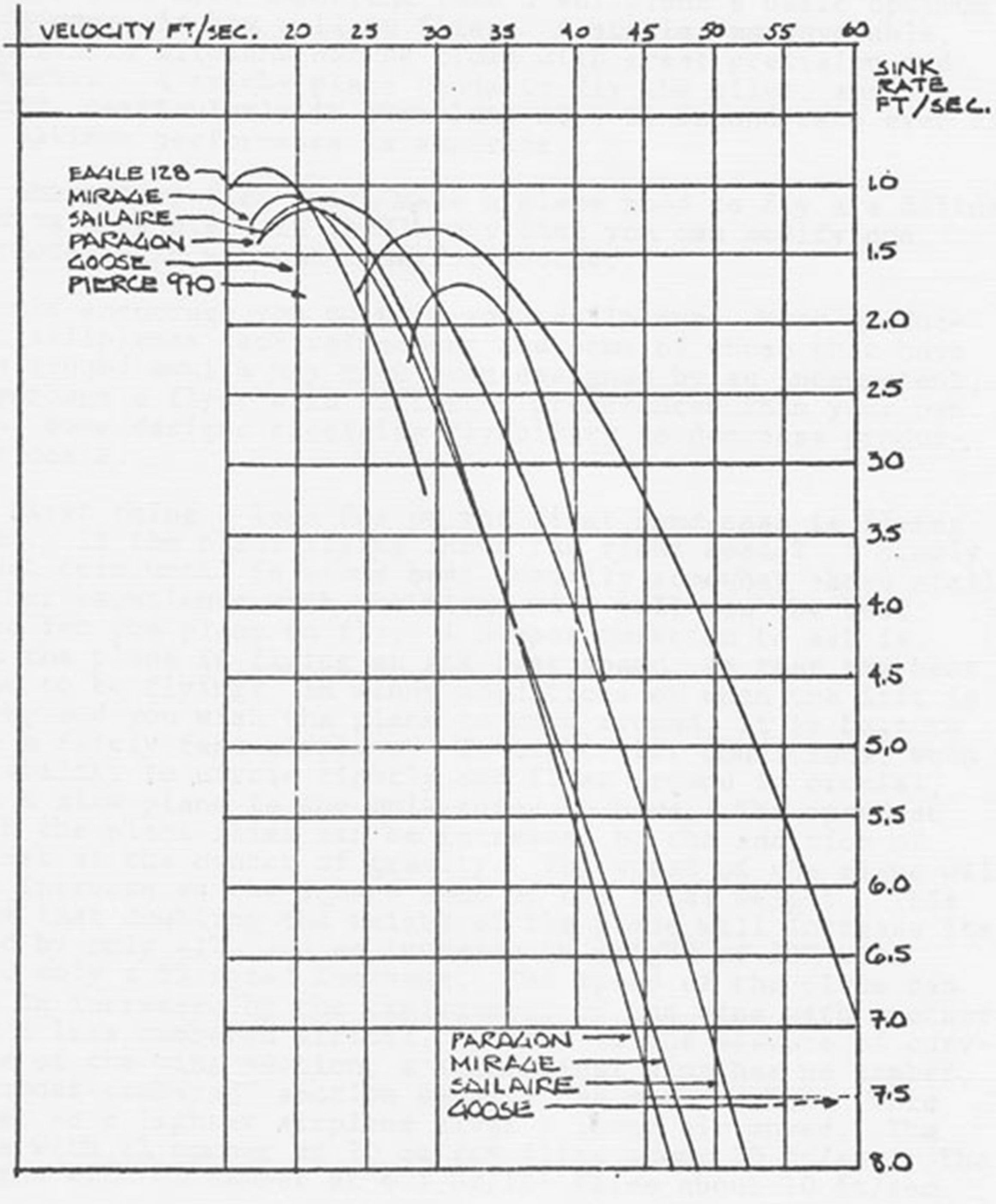
Goose (35.7,1.46)(30.5,2.22)(31.4,2.12)(36.4,2.63)(42.1,2.79)
(27.6,1.33)(32.65,1.92)(26.67,1.57)(26.67,1.40)(31.37,
1.78)(38.10,2.08)(48.48,3.90)(25.56,1.67)(24.39,1.76)
(28.57,1.43)(44.44,3.62)(66.67,8.97)

Mirage (17.98,1.18)(16.84,1.32)(18.39,1.26)(19.75,1.25)(18.39,
1.11)(18.56,1.38)(27.92,1.58)(40.00,5.76)(24.24,1.34)
(24.24,1.79)(23.67,2.30)(19.54,1.11)(20.51,1.33)
(19.39,1.68)(13.91,1.18)(13.36,0.96)(38.10,5.36)(20.13,
+1.14)(46.65,7.41)(26.19,1.85)(32.52,3.33)(21.68,1.23)
(26.58,2.09)(22.96,1.44)(22.47,2.18)(21.77,0.31)

Sailaire (21.33,1.04)(17.78,1.40)(21.92,1.34)(32.65,2.27)
(34.04,2.88)(32.65,2.13)(42.11,4.60)(24.54,1.33)
(25.20,1.12)(28.83,1.88)(23.70,2.81)(29.91,1.23)
(30.77,1.96)

Errors showing decreased sink rate: lift, measurement errors

Errors showing increased sink rate: sink, measurement errors, all flying mistakes, all wind


VELOCITY FT/SEC.
20
25
30
35
40
45
50
55
60
SINK RATE FT/SEC.
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
EAGLE 128
MIRAGE
SAILAIRE
PARAGON
GOOSE
PIERCE 970
PARAGON
MIRAGE
SAILAIRE
GOOSE

HOW TO TRIM A RUDDER AND ELEVATOR RC SAILPLANE

Blaine Rawdon

Perhaps even more important than a sailplane's basic optimum performance is how well it flies. A stable, maneuverable, predictable airplane can be flown with great precision and authority. A tricky plane tends to fly the pilot, and the result, particularly in turbulent air, is second-rate even if the optimum performance is superior.

The characteristics which make a plane good to fly are delineated in this piece in such a way that you can modify one characteristic without changing another.

I would encourage you to trim your sailplane. Many production sailplanes lack refinement and some of those that have been around awhile may have been designed by an incompetent, or perhaps a flyer with different preferences than your own. Also, some designs sacrifice flyability to decrease production costs.

The first thing I look for on the first hand-toss is flying speed. Is the plane flying about the right speed? I simply adjust trim until it seems best, usually somewhat above stall. Further experience with the plane will tell you the best speed for the plane to fly. A deeper question to ask is, when the plane is flying at its best speed, is that the best speed to be flying? In windy conditions or when the lift is strong and you wish the plane to move around, it is best to have a fairly fast airplane. In light lift conditions, when the ability to circle tightly and float around is crucial, then a slow plane is the only thing to have. The speed at which the plane flies can be increased by the addition of ballast at the center of gravity. The speed of the plane will then increase as the square root of the total weight. This means that doubling the weight of the plane will increase its speed by only 41%, and an increase in weight of 10% will yield only a 5% speed increase. The speed of the plane can also be increased by the replacement of the wing with another with a less cambered airfoil. Camber is the measure of curvature of the wing section; a symmetrical wing has no camber, an "under-cambered" section usually has much camber. More camber or a lighter airplane gives a lower air speed. The Goose with 2% camber at 10 oz/ft^2 flies about 30 ft/sec. The Paragon with 4% camber at 6.5 oz/ft^2 flies about 20 ft/sec.

Next, I look for pitch stability which is a measure of the quickness with which the plane returns to a trimmed setting from a pitch up or down situation. I test for this by putting the plane in a slight dive and releasing the stick. If the plane continues its dive, then it is not stable. If it tucks under, you are flying a monster. Someplace in the stable range is the place to be. If the plane is very stable then it will take large control movements to change pitch; the plane will not fly inverted and the plane will feel sluggish. If the plane is not stable enough, it will be sensitive to control inputs, and will constantly give you the feeling that it is about to get away from you. Set it to your preference. Performance-wise, I doubt that it makes much difference except that a stable airplane is easier to fly well.

A plane can be made more stable in three ways. The center of gravity can be moved forward by the addition of noseweight, the size of the stab can be increased, or the distance between the stab and the wing can be increased. Take your pick. As you might guess, planes with small stabs tend to use forward CG's more successfully.

Another quality easily confused with pitch stability is pitch damping. If you tap up-elevator and the plane moves one click up in pitch, then the plane is well damped in pitch. If you give a tap of up, and the plane continues to coast upward in pitch, then the plane is not highly damped in pitch. A plane which is not well damped in pitch must be flown with very smooth control inputs or else it will tend to porpoise all over the sky. At this time I believe that a plane cannot be overdamped in pitch, assuming that the means by which the damping is achieved doesn't mess up something else. Pitch damping is increased by increasing the size of the stab, lengthening the fuselage, or by lightening the fuselage and stab. The Aquila is an example of an under-damped airplane. The Mirage is highly damped. Bill Watson likes his airplanes with low stability but with good damping, so his Goose uses a great big stab for damping, and an aft CG (about 60%) to reduce stability.

As for turning the airplane, you can break it down into two basic aspects; changing direction, and constant circling. A plane will change direction quickly and smoothly if it has enough dihedral (or polyhedral, a more effective variety of dihedral), if the wingtips are light, and if there is enough rudder with enough throw. A plane with too little dihedral will tend to yaw for a bit before it rolls up into a turn. It may also tend to wallow around if not flown very smoothly. A plane with heavy tips will behave much like a plane with too little dihedral. You know your plane has too little rudder area or deflection if you find that you often use full rudder to control the plane. This is usually a matter of style and taste.

When circling the plane (hopefully in a thermal!) you should be holding a bit of bottom rudder and perhaps a bit of elevator. If you release the controls, the plane should straighten out all by itself. It may, however, tend to tighten up its turn and actually require top rudder in order to stay in the circle. This tendency can be fixed by several means including increasing dihedral, shrinking the rudder, or using an airfoil section with extra drag at lower angles of attack (such as undercambered sections--a poor solution). This can be overdone, however, resulting in an unstable plane which has the tendency to do dutch rolls (Hobie Hawks' favorite trick). Probably the best way to get it all right is to get the dihedral right for the transition maneuvers, and then adjust the rudder throw and proportion to get the rudder sensitivity right.

You will find that some airplanes (usually big slow ones) get a little weird if you try to bank them up steeply in order to circle tightly in a thermal. This has to do with the size of the plane relative to the circle size. If your plane doesn't circle tightly you might try adding ballast which will not make it circle much tighter, but it won't get weird when you bank it up. Other than that, you can decrease the wingspan, increase the dihedral, change the airfoil to one with a greater speed range, or use polyhedral instead of dihedral. Don't look for a plane which circles flat--any plane will circle flat if the circle is big enough--look for the plane that can circle tight banked right up there.

As nice as it would be to have a plane which could be halted in mid-air, it won't happen unless you have a skyhook. Lacking that, the plane stalls. And, they all stall. How they stall is something you can affect, however. A plane can stall suddenly or it can mush for a long time before it breaks. It can stall evenly on both wings and drop straight ahead, or it can stall on one tip and be on its back before you know it. In general, thick turbulated sections give a lot of warning before they stall, and then recover very, very quickly. Thick non-turbulated sections give less warning and take longer to recover. High aspect ratio designs tend to give less warning than low aspect ratio designs. Thin wings I can't say too much about except that they stall sooner. Tip stall problems can be made less severe by increasing tip chord, increasing tip thickness, using a section with a more forward high point at the tip; or simplest of all, and maybe the most effective, is to wash out the tip; that is, twist the wing so that the tip flies at a lower angle of attack. If you want to do this properly, you will also use a less cambered tip section so that it is cleaner at its lower angle of attack. Three degrees is a good place to start with the washout. This is about one-third inch on a six-inch chord.

Enough is enough. Good luck!

WHO THE HECK IS OSBORNE REYNOLDS?

Doug Ford

Osborne Reynolds conducted some experiments during the latter part of the 19th century which were designed to study the nature of fluid flow through pipes. These experiments led to a paper he authored in 1883 entitled "An Experimental Investigation of the Circumstances Which Determine Whether the Motion of Water Shall be Direct of Sinuous, and of the Laws of Resistance in Paralled Channels." He had absolutely nothing to do with aircraft, but his experiments led to the discovery of a parameter which has become important in all types of fluid flow, including aerodynamics.

Reynolds' experiments were conducted by drawing water through a small glass tube from a large glass sided tank (see Figure 1). The flow rate was adjusted by the opening or closing of a stop cock at the output end of the tube. A fine stream of colored water was allowed to enter the mouth of the glass tube so that a portion of the flow could be visualized. The diameter of the tube and the velocity of the flow were varied to determine their effects on the nature of the flow in the tube.

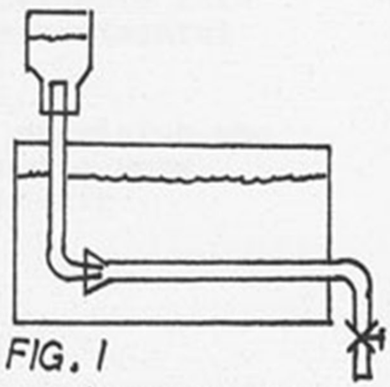


FIG. 1
REYNOLDS' EXPEIMENT

Reynolds discovered that when the velocity was low enough, or the diameter of the tube small enough, the stream of colored water appeared to be a straight line extending through the tube. As the rate of flow or the tube diameter was increased in small stages, a condition was obtained at which the fine stream of colored water suddenly broke up and mixed with the surrounding fluid. Reynolds reasoned that the intermingling of fluid particles in the flow was the cause of the breaking up of the colored stream. He further reasoned that as long as the colored stream remained unbroken no intermingling took place, and the fluid particles moved in parallel layers sliding over each other. This type of flow, where the fluid moves in layers with no intermingling, has become known as laminar flow. When the mixing of adjacent layers of fluid occurs, the flow is called turbulent. Reynolds identified a parameter which seemed to determine the type of flow which would occur under stated conditions. This parameter, , where is the diameter of the tube, is the velocity of the flow, and and are density and viscosity respectively, has become known as Reynolds' Number. This dimensionless number is actually the ratio of inertia forces to viscous forces. At small values of Reynolds' Numbers the viscous forces predominate, while at large values the inertia forces predominate.

Although flow past an object such as an airplane wing is not the same as flow in a pipe, the general laws governing fluid flow still apply. It has been discovered that at Reynolds' Numbers of from 200,000 to 2,000,000 (where in this case is the chord) the boundary layer over a wing changes from laminar to turbulent under subsonic conditions. Our model sailplanes fly in conditions where Reynolds' Numbers are generally in the 100,000 range. If turbulent flow is desired, therefore, it must be induced.

The lower skin friction drag associated with laminar flow is the feature which encourages designers to produce laminar flow wings. There is a trade-off, however, since at high angles of attack, or large flap angles, a laminar boundary layer is more apt to separate and/or stall. Transition from laminar to turbulent flow is sometimes induced, therefore, to reduce the possibility of separation. Little reliable data is available at our Reynolds' Numbers, so the experimental field is wide open.

We can now see why good 'ol Osborn, an English physicist who was interested in fluid flow in pipes, has become a very important individual to designers of modern aircraft.

WHAT MAKES 'EM TURN

Doug Ford

Most of the RC thermal sailplanes flying today are controlled using rudder and elevator. It's relatively easy to visualize how the elevator effects pitch and angle of attack. Changes in elevator angle cause a change in forces on the tail surfaces which, in turn, cause a change in pitch attitude of the aircraft. But what about the rudder? Just how does the rudder "steer" the airplane?

The rudder, contrary to popular belief, does not change the direction of flight--not directly anyway. A turn of the rudder causes the airplane to yaw or sideslip with respect to the direction of flight. Once the airplane is yawed by the rudder other rather interesting things happen.

First, a yawed airplane develops lateral forces on the fuselage, and any other surfaces that have "side" area, causing the airplane to veer in the direction that the nose is pointed. In our case this effect is relatively small compared with everything else, but it is one of the forces that occur.

The major turning forces result from the fact that a yawed airplane, if it has dihedral, will begin to roll. The roll is caused by what is known as yaw-roll coupling, usually referred to as (CEE-ELL-BETA). Basically, a yawed airplane rolls if it has dihedral because the angle of attack of the wing which is swept forward by the yaw is increased, while that of the aft swept wing is decreased. Thus, the lift of the "swept forward" wing is greater than that of the "swept aft" wing causing the airplane to roll. A left yaw causes a left roll. Once the aircraft is rolled it will turn providing the wing remains at a positive angle of attack. It turns because the "lifting" force generated by the wing, which is correctly referred to as the "normal" force, is no longer vertical but is angled in the direction of the intended turn. The lateral component of the normal force turns the aircraft.

Now none of this yaw-roll turning stuff would occur if the airplane had no dihedral (there is a yaw-roll effect due to wing sweep, but we really don't have many swept wings). Too little dihedral or polyhedral will result in a difficult to control sailplane--but too much can cause other problems which I won't go into right now.

Just remember that rudder causes yaw, yaw (with dihedral) causes roll, roll (with positive angle of attack) turns the airplane.

A REPORT ON LIGHT WEIGHT FOAM WINGS FOR RADIO CONTROL SAILPLANES

Michael Bame

The use of foam for model airplane wings is not new. Foam-cored wings sheeted with balsa or plywood have been used in power planes and slope gliders for years. However, sheeted foam wings have not generally been used for thermal gliders because of their higher weight as compared to built-up structures.

For the past year I have been experimenting with a lightweight, unsheeted foam wing. Perhaps the easiest way to describe the structure of this wing is that it is basically the same as a built-up wing except that the wood ribs have been replaced with a foam core. Wood is still used for leading and trailing edges and for the spar.

I will compare foam and built-up wings for the following qualities: (1) cost, (2) weight, (3) building ease and speed, (4) strength and durability, and (5) flying qualities. Comparison is based on experience that I have gained with my foam-wing Mirage, a foam 2-meter Mirage wing, and my observations of similar built-up wings of my own and others. Except as noted, comparisons are made using the Mirage wing.

COST: If you cut the foam cores yourself, the materials cost of a foam wing will generally be less than a built-up wing. A foam Mirage wing contains approximately \$4 of foam, \$7 of wood and \$6 of covering (Econokote) for a total of \$17. When they were available, Mirage rib kits sold for \$12 which I was told included about \$6 of wood. \$7 for additional wood and about \$9 for covering (Super Monokote) brought the total for a built-up Mirage wing using Blaine's rib-kit to \$28. If you chose to make the ribs and shear webs yourself you could save \$6 for a total of \$22.

WEIGHT: Weight will vary somewhat for both foam wings and for built-ups depending on the wood density and how much glue is used. My foam Mirage wing weighed 15 oz. ready-to-fly. This weight could probably be reduced 3/4 oz. by using less glue and by using only one layer of glass cloth on the center section below the rubber bands instead of two.

I have heard of built-up Mirage wings weighing anywhere from 11 oz. to 15 oz. Assuming an average built-up wing weight of 12.5 oz., the foam wing is about 20 percent heavier. I recently finished a built-up Mirage wing with a sheeted leading edge. Through careful wood selection, the finished weight came out to 15 oz. which is the same as the foam wing.

Overall, I think that the weight of the foam wing is about half-way between the light weight, turbulator spar, open structure wing and moderate weight, "D" tube sheeted, built-up wings.

BUILDING EASE AND SPEED: Building a foam wing is easier and faster than a built-up wing. This is due to the much lower parts count of the foam wing (52) as compared to the built-up wing (145). The fewer the parts, the fewer the glue joints, etc.

At this time I do not have any hard numbers on construction time. However, having made several built-up wings and a couple of foam wings, I would estimate that the foam wing takes only half the time to build. In addition, very little fitting of parts is required.

STRENGTH AND DURABILITY: Bending strength (or how long you can stand on the winch pedal) is at least as good for the foam wing as for the built-up wing, since the same spar is used in both.

In torsional (twisting) strength the foam wing is a little more flexible than the built-up wing. I think that this is due to the greater flexibility of the Econokote covering that is used over the foam since the foam wing and the built-up wing seem to be equally flexible before covering. The only time that the lower torsional strength is noticeable is when the plane is flying fast, as the flutter speed is a little lower.

For the purpose of this report, I will define durability as the ability of the structure to resist the minor impacts associated with handling, transport, storage, and normal flying as well as the major impacts of "mid-airs" and hard landings (crashes). In this area, I think that the foam wing has an advantage.

Even minor impacts can break turbulator spars and crack leading edges of built-up wings. Repairs usually require that the covering be removed over the damaged area. Minor impacts in foam wings usually do little more than dent the wood or foam a little bit. Dents in the foam are easily removed by passing a warm iron back and forth over the dent. The heat causes the foam to re-expand and simultaneously re-tightens the covering.

In major impacts, the foam absorbs and spreads the impact energy over a larger area than in the built-up wing. This generally results in less damage. An example will demonstrate this.

Earlier this year I was flying my foam wing Mirage in the same thermal as Doug Ford's Paragon. A mid-air collision followed in which both our left tip panels were damaged (we were circling clock-wise on different centers). Doug carefully landed his crippled Paragon whose Monokote covering was flapping away wildly. I landed my Mirage a minute or two later.

Damage to Doug's Paragon consisted of a broken leading edge and turbulator spars about 9" inboard of the wing tip, and shattered covering on one side of the panel. Damage to my Mirage consisted of three cracks in the leading edge about 12" outboard of the polyhedral break. One of the cracks was at the point of impact, the others were about 1" away on either side. I was able to continue flying my Mirage that day but Doug had to bring out his 2-meter ship or stop flying.

FLYING QUALITIES: Flying qualities of the foam wing seem to be the same as the built-up wings. The only difference noticed by all who flew both was a reduction in handling at low speed. This was probably due to the higher wing weight--especially the tips. Another possibility is that the turbulator spars of the open structure ship kept the boundary layer closer to the wing for more lift. Other than that, performance seemed to be the same for both types of wings.

SUMMARY: Overall, I think that foam is a good way to build a wing. The only disadvantages with foam is a somewhat heavier wing, and a slightly lower flutter speed. Ths advantages are easier and faster building, and a more durable structure.

LET'S TALK TECHNICAL

Doug Ford

I was asked some months ago to do some articles on aerodynamics for our newsletter, but up to now my available time has been minimal, to say the least. Anyhow, here we go. I'll try to start out with some basics (which will probably bore the other engineers in the crowd) then finish up with stuff that's a little more technical (which will probably upset others). With a little luck I will have alienated everyone by the end of the series.

You've all heard a lot about CL's, CD's, L/D's, etc., but many don't really know what they are. About the time of the Wright Brothers' early experiments, Wilber, Orville, and others figured out that the forces on a vehicle travelling through a medium such as air were a function of velocity, density, size, attitude, and shape. It followed that if two vehicles were of the same attitude at the same velocity in the same density air, that the forces induced on each should be identical.

Now, it turns out that the velocity and density effect the forces on such a vehicle via something called dynamic pressure, q. The effects of dynamic pressure can be felt simply by placing one's hand out the window of a moving car flat against the air stream, noting that as the car speeds up the pressure against your hand increases. Dynamic pressure, q, is equal to .5 multiplied by the density of the air, , multiplied by the velocity squared. Dynamic pressure is totally independent of a vehicle's shape or size.

Force is equal to pressure multiplied by the affected area, so the surface area of a flight vehicle is another important parameter.

Will and Orv found that when they measured the forces acting on a vehicle moving through the air (or those on a vehicle with air moving around it, such as a model in a wind tunnel) and divided those lift and drag forces by the dynamic pressure and reference area of the vehicle, that the resulting non-dimensional coefficients called "lift coefficient," CL, and "drag coefficient," CD, would totally represent the effects of the shape and attitude of the vehicle. Furthermore, if these coefficients were multiplied by a larger (full scale) vehicle reference area and dynamic pressure (assuming that the larger vehicle had the same shape), then the forces acting on that larger vehicle could be calculated and predicted. Thus, the wind tunnel tests of a small model, at a different density and different velocity than a full scale article, can be used to forecast the performance of a full size airplane.

The glide ratio of an airplane is simply the lift divided by the drag: L/D. It can be shown that the reciprocal of this, D/L, is the tangent of the glide angle of an unpowered airplane. L/D is also the ratio of how far the vehicle can travel from a given altitude. An example of this would be a sailplane launched at 500 feet could travel 9,000 feet in still air. The ratio of lift to drag is also the ratio of CL to CD, so comparisons can be made between gliders of all sizes and shapes flying at all sorts of speeds.

OPTIMUM SPEED FLYING

Blaine Rawdon

There are many skills involved in thermal flying, among them controlling the plane, thermal seeking, and contest strategy. One of the most essential skills is usually gained only after a bit of experience. This is the skill of flying the plane at the right speed.

In still air, it is simple to fly the plane the right speed. If you are just trying to stay up, you fly it at the speed at which it sinks most slowly; "min sink." If you are trying to get someplace, then you fly at the speed at which the plane goes farthest for the altitude lost; "best L/D." Best L/D is usually about 10 percent faster than min sink.

When the air is moving the problem is much more interesting. Actually, it is not so interesting if you are simply interested in duration because regardless of what the air is doing, you just fly at min sink for maximum duration. This assumes that you are not going to move into a different air mass.

If you are going for distance, however, things are more complicated. If you are flying into a headwind, for instance, at your still air best L/D speed, then your ground speed is reduced while your sink rate is not. This means that your glide ratio with respect to the ground is reduced. It works out that if you speed the plane up a bit, its ground speed goes up more than the sinkrate, thereby improving the glide ratio. The trick is to know how much faster to fly in order to optimize the glide ratio. That is what the graphs can tell you.

In a tailwind condition, the opposite holds true and you want to fly the plane someplace between min sink and best L/D, so this is a trivial case.

In sinking air, the sinkrate of the airplane is increased but not the airspeed, so the glide ratio is reduced. Speeding up increases the ground speed more than the sink rate, so the glide ratio is improved. Once again, the trick is to know how much to speed up.

In lift, the glide ratio can be improved by flying slower; someplace around min sink will be best. It won't make much difference, so again this is a trivial case.

The trick in this problem is to figure out a way to quantify headwinds and sink so that you don't have to remember eight million numbers in the middle of some contest. It turns out that if you quantify everything in percent of best L/D speed, things are very much simplified. The first graph, "Headwind" relates the degree of headwind to the amount you must speed up to optimize glide ratio. Since it is quantified in fractions of best L/D speed, some nice things happen: Of the five planes tested in the first L/D trials, there are no massive differences; I was amazed to find that a full size ASW-20 fits right in there with the models; also, changes in wing loading due to ballast should not change the graph significantly.

The data to form these graphs was pulled from the glide polars that the SFVSF gained from the first L/D trials, which were published in the August 1979 Model Aviation Magazine. In short, it is done by sliding the origin of the polar around to simulate headwind or sink conditions.

Perhaps the major thing I learned from the "Headwind" graph is how little speeding up is required in a mild head wind. Note that in a head wind of 50 percent of best L/D speed, that no plane except the ASW-20 should be speeded up more than 10 percent! I know now I've been flying too fast in mild head winds.

The second graph, "Sink", tells you how fast to fly in sink. Once again, the models are fairly closely grouped, but for some reason the ASW-20 is now in a different ballpark. Note the basically uncurved nature of the graph--you can make up a rule of thumb, say, "in sink of X%, speed up 2X%." This seems to hold pretty true for the Mirage.

Now how you judge the strength of the sink, I don't quite know. You might try judging the glide ratio. For instance, in 5% sink, most models will look like their L/D is halved. In 10% it is a third. Beyond 10% you might as well judge the angle of the plane's descent. At 20% it will be about 15°. At 30% it is 20°. More than 30% and you had best be watching out for the ground!

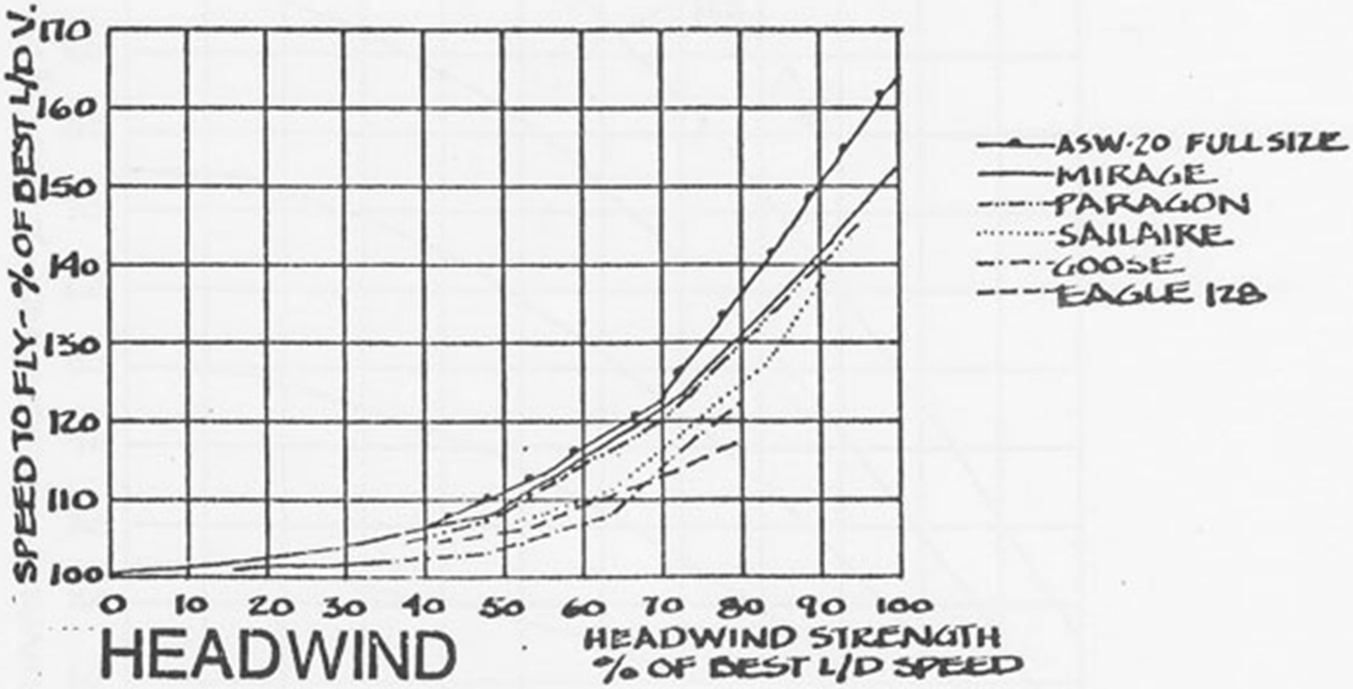
I sure wish some of you electrical types would get around to an airborne airspeed and sinkrate sensor/sender!

The two other graphs are auxiliary. The "Sidewinds" graph converts sidewinds of five strenghts to direct headwind equivalents as a function of the bearing of the wind.

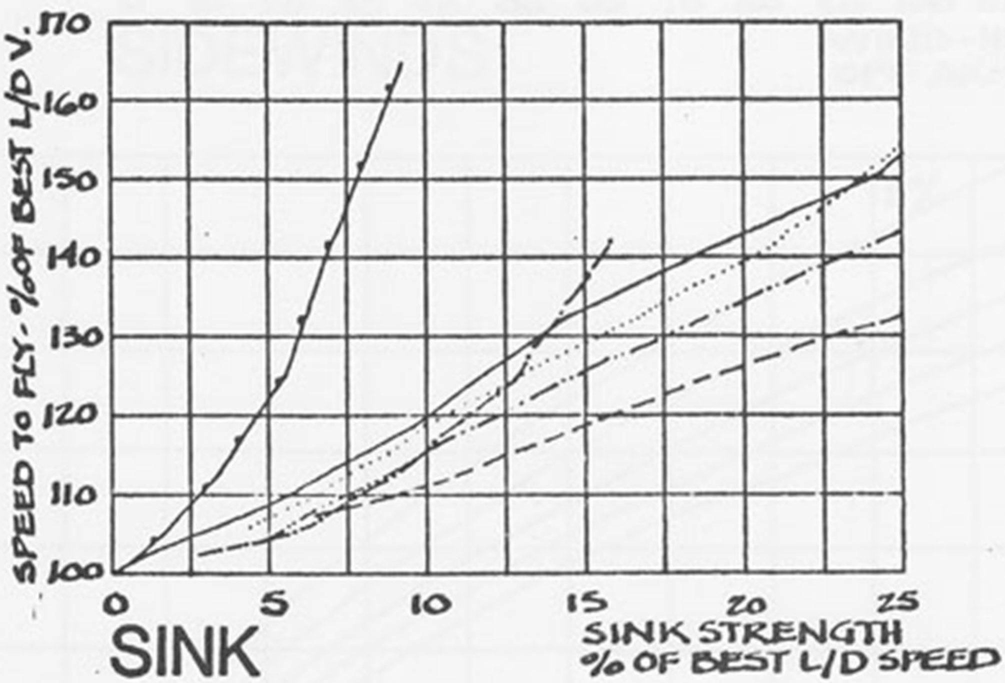
The "Best L/D Speed" graph just tells you about what speed your best L/D is depending on your wing loading and mean camber line. This graph should be taken with a bit of salt, but it should be fairly close if you've got a 12% thick wing. Better than an outright guess anyway.

Now for some parting comments about the real world in the sky. This information is most useful for FAI distance, and duration inter-thermal flying. In inter-thermal work, it might be smart to assume that if you are not in lift, then you are in sink. So while you are cruising for thermals, keep an eye out for the sink too, and be prepared.

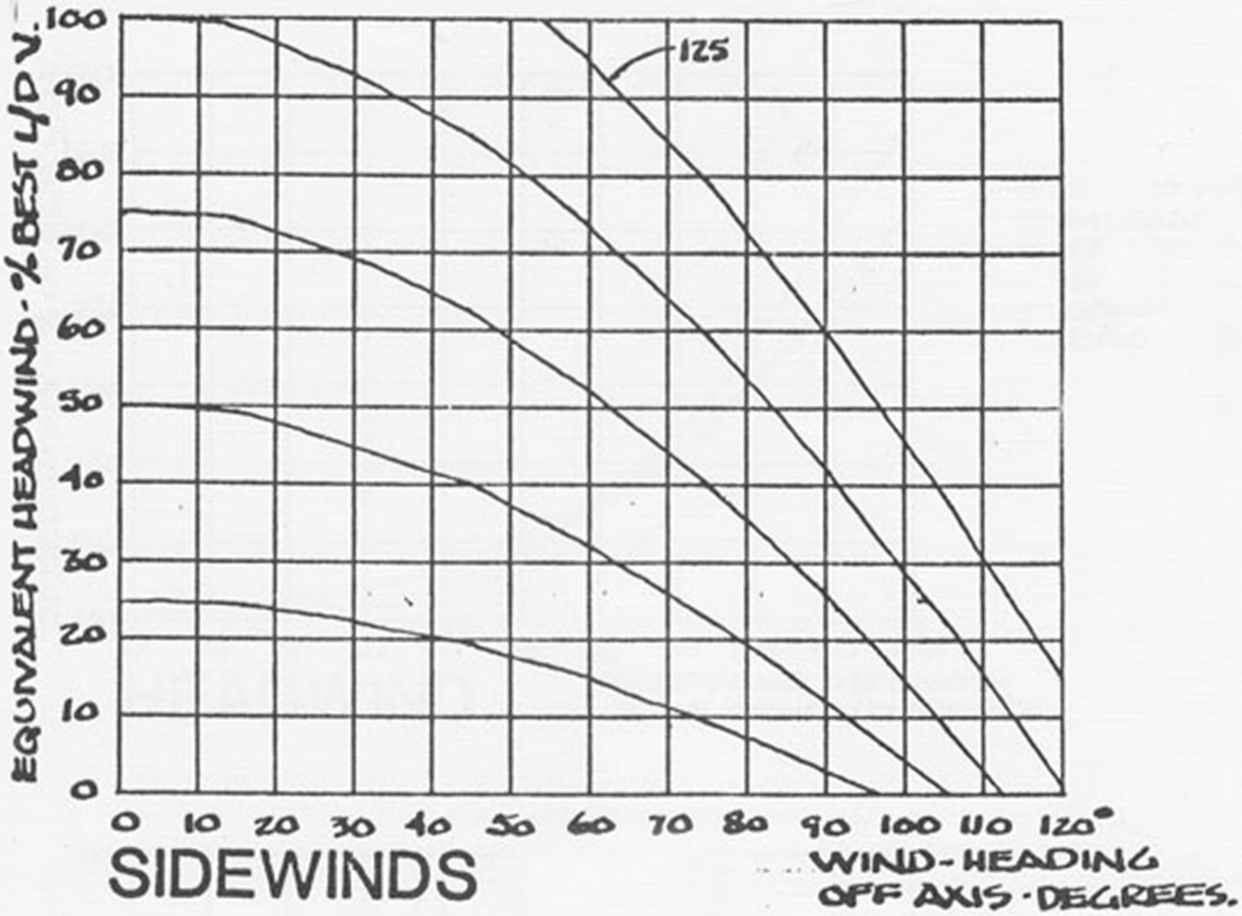
Also, a word about flying speed errors. In sink or headwind, it is best to speed up. Not speeding up quite enough is much worse than speeding up a little too much.



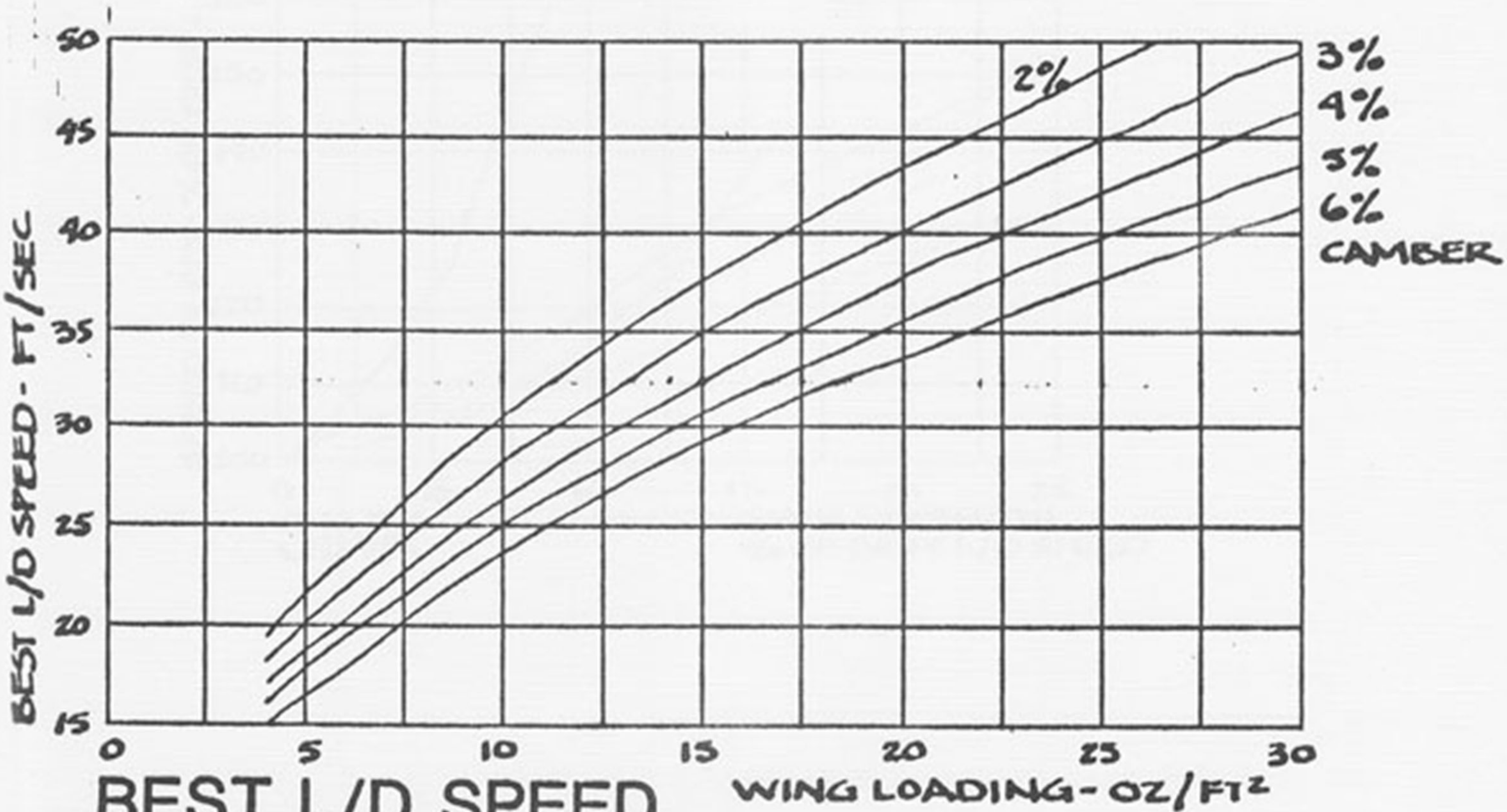
HEADWIND



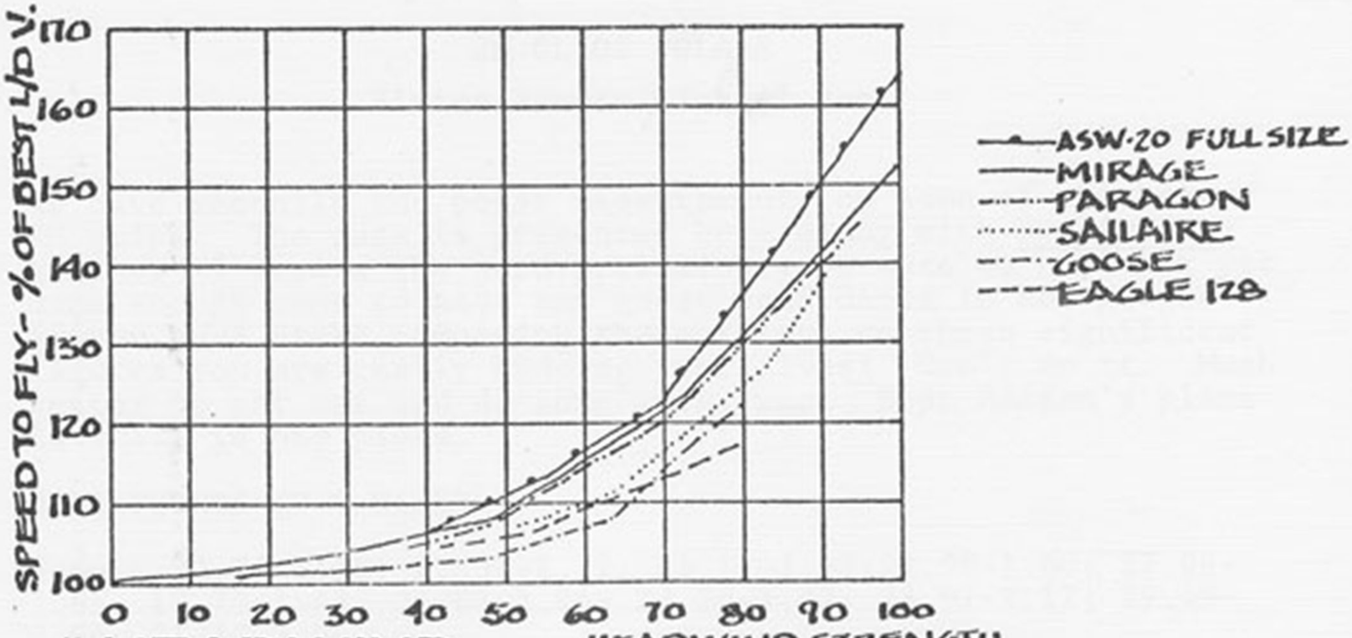
SINK



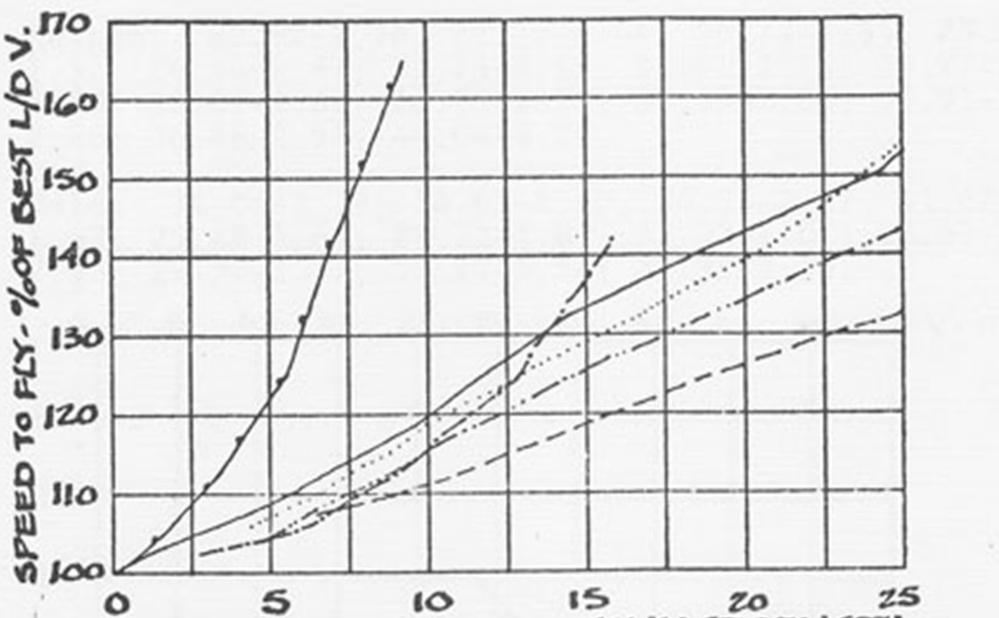
SIDEWINDS



BEST L/D SPEED



HEADWIND



SINK

2M GLIDE POLARS

Blaine Rawdon/Michael Bame

We have recently run polar measurements on some of the better 2M ships. The data is presented here along with preliminary graphs. I stress the word preliminary because we have not yet done enough runs to have any great confidence in the graphs. If you guys start comparing these things to three significant figures you are really kidding yourselves! Don't do it. Much better to get out and do some more runs. Hope Reagan's plane is still in one piece.

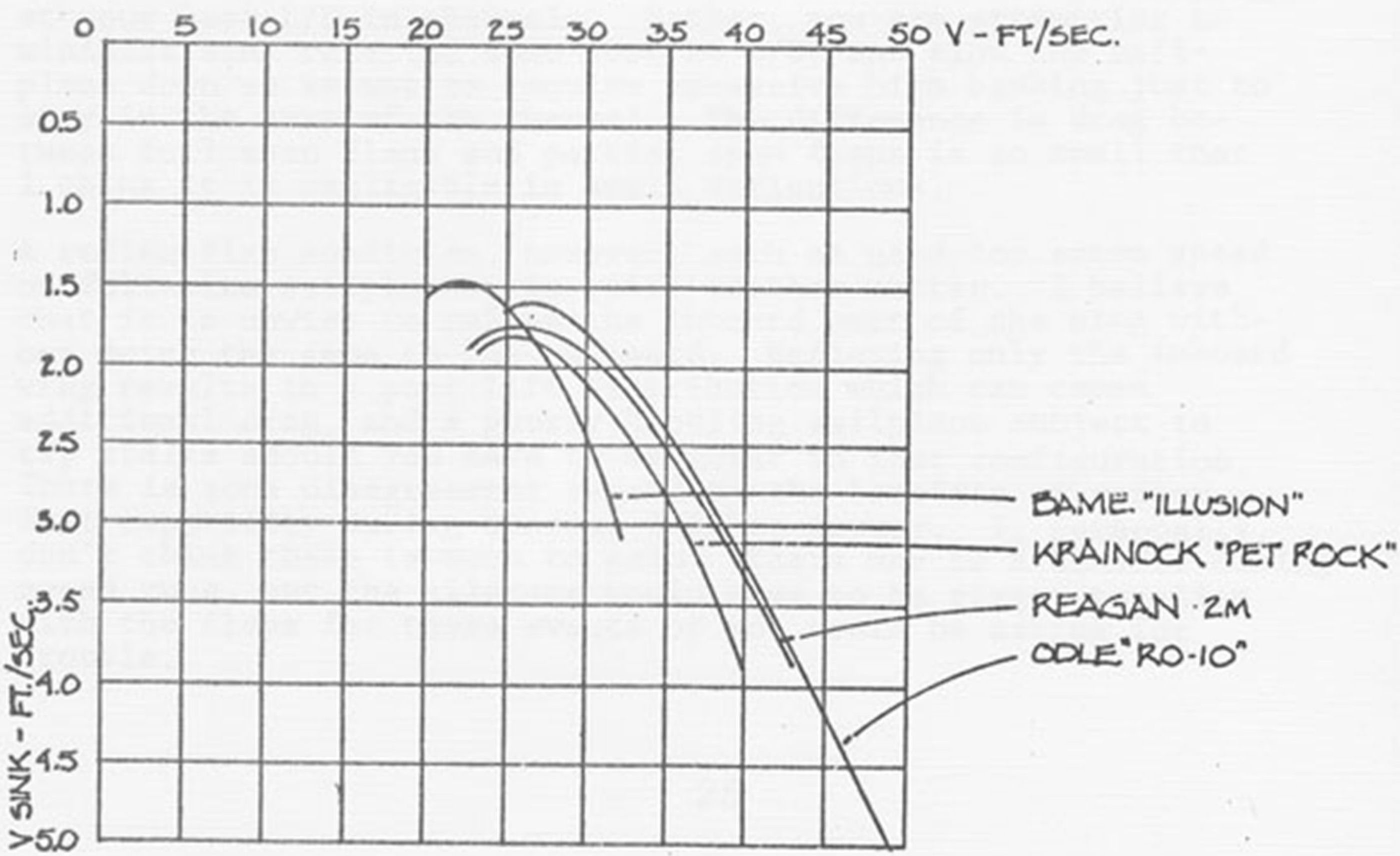
DATA POINTS (V-V Sink)

Bame: 22.78-2.35; 21.34-1.72; 24.17-1.62;22.98-1.60; 22.98-1.85; 19.70-1.49; 24.08-1.84; 23.35-1.47; 28.97-2.17; 29.49-2.66; 31.17-3.04.

Krainock: 23.65-2.04; 29.49-2.00; 25.99-1.82; 25.99-2.08; 28.34-2.18; 24.85-1.89; 26.67-2.06; 35.09-3.60; 35.95-2.98; 35.76-3.37; 36.50-3.43; 21.69-1.82.

Reagan: 27.92-2.26; 31.17-2.44; 26.73-1.85; 25.00-1.96; 24.12-1.32; 24.44-1.67; 21.73-2.19; 32.01-2.76; 29.77-2.47; 25.41-2.00; 29.69-2.68; 26.73-1.75; 32.65-2.56; 33.91-2.06; 33.82-2.46; 36.86-2.94; 44.04-3.59.

Odle: 34.00-2.79; 34.63-2.40; 34.35-2.57; 31.62-2.04; 28.16-1.87; 25.48-1.64; 28.72-1.87; 32.73-2.07; 26.51-1.53; 32.40-2.05; 29.56-1.77; 52.28-5.56; 37.39-2.33.



LET'S TALK TECHNICAL

Doug Ford

I got a letter from our good friend, Sean Walbank, the other day (he is now in New Zealand--"Down-Under" across from "Out-Back"). Sean was interested in my opinion of the use of flap-erons versus flaps and ailerons for R/C sailplanes. Sean quotes Geoff Dallimer of RCM&E as stating that partial span flaps give poor results, partially due to the extreme tip wash-out with flaps down and tip wash-in with flaps slightly reflexed or at a negative (up) position.

Of course, most of us will agree that tip wash-out and the additional camber generated by partial span flaps deflected down is beneficial when you want the highest possible launch because the ailerons retain their effectiveness. Partial flaps down during landing slows the aircraft down while leaving, again, the ailerons in their most efficient configuration. With flaperons deflected down, and the aircraft slowed (i.e., for a landing), "aileron" deflection results in a great amount of adverse yaw. On a scale ship with separate rudder control this can be handled, but on a pure performance R/C sailplane featuring only coupled rudder (or no rudder at all), this can be devastating.

Now, what about partial flaps down during thermaling? Well, I have to admit that partial span flaps are draggier than properly designed full span coupled ailerons and flaps; that is why most full-size "flapped" sailplanes move the ailerons with the flaps. But, let's be reasonable. You are not flying at your best L/D in thermals. Rather, you are attempting to minimize sink rate (at some cost to L/D) and slow the sail-plane down so as not to require excessive high banking just to stay in the core of the thermal. The difference in drag be-tween full span flaps and partial span flaps is so small that I think it is negligible in small deflections.

A reflex flap condition, however, such as used for extra speed on full-size sailplanes, is quite another matter. I believe that it is unwise to reflex the inboard part of the wing with-out doing the same to the outboard. Reflexing only the inboard wing results in a poor lift distribution which can cause additional drag, and a poorly handling sailplane subject to tip stalls should you have to maneuver in that configuration. There is some disagreement regarding the benefits of reflex flat capability during thermal flights anyway. I, personally, don't think there is much to gain. There may be a benefit during speed runs, but the ailerons would have to be rigged to align with the flaps for those events or you could be asking for trouble.

So, all in all, I think that flaperons are not the answer. If your design features a way to move ailerons with partial span flaps when desired, while retaining the ability to move the flaps separately, then I think you've got something (although rather complicated).

Another subject of interest these days is the so-called "lifting tail." Some flyers are convinced that the horizontal tail should be carrying some lift load, rather than pushing down. Maybe the term "total surface loading" perpetuates this concept. Well, believe it or not, a lifting stabilizer is not beneficial and is almost unobtainable for R/C sailplanes. It takes a lot more to make a stabilizer lift than just putting a lifting section on it--it takes tail area, lots of it. Not only that, the horizontal stabilizer is generally not as efficient at producing lift as is the wing. Loading up the tail with lift is, therefore, draggy.

What about the free-flight guys and their lifting tails, you ask? Examine one of those things sometime. The tail is HUGE and has to be in order to carry lift while keeping the model STABLE and in TRIM. Those free-flight machines were designed that way to take advantage of rules that calculated minimum allowable wing loading without including tail area.

The truth is that a typical airfoil produces a nose down moment. This, together with the required relative angle of a wing and tail (incidence) and the necessary location of the center of gravity needed for stability and trim, results in the requirement that huge tail area is necessary if it is to carry lift! If a lifting section horizontal stabilizer is used to replace a standard flat or negatively lifting surface of the same size, nothing has been changed except the required trim angle of the tail (more incidence and thusly, more drag). The forces and moments generated by the wing and fuselage still must be kept in balance by the forces of the tail. The requirements have not changed. (And may the force be with you.)

What you really want is minimum drag which usually means a certain amount of negative tail load. Examine a commercial airplane sometime (a 707, 747, DC8, etc.) Low and behold! All their tails have negatively lifting surfaces.

LET'S TALK TECHNICAL

Doug Ford

WASHOUT

I've heard some interesting comments recently on the subject of wing tip washout. Many pilots, it seems, do not understand what washout can do, both good and bad, for sailplane performance.

Now, for those of you new to the sport, washout is the general term for twist in the wing causing the tip to have a lower angle of attack than that of the root. There are two basic reasons for putting washout in a wing. First, if the tip is flying at a lower angle of attack than the root, then the tip is less likely to stall than the root when turning sharply and/or flying slowly. A so-called "tip stall" can be violent and should be avoided.

The other main reason for tip washout is to "adjust" the spanwise lift distribution in such a way to minimize induce drag, i.e., to approximate an elliptical distribution. Full-size airplanes seldom use washout for this purpose, but accomplish the same thing by changing the wing section along the span, or by varying the wing planform (such as the British Spitfire).

The reason that wing twist is not a good way to "adjust" lift distribution is because this method only works for a specific angle of attack. If a wide speed range is desired, wing twist can actually do more harm than good.

As the speed of a sailplane is increased, the average angle of attack on the wing must decrease. If the wing has washout, then a speed will exist at which the outboard parts of the wing will have a zero or negative angle of attack, and a zero or negative lift load. Recently, a sailplane with about 3 degrees of washout was observed to have DOWN BENDING in the tip panels at high speeds! This undesirable lift distribution results in high induced drag, and a slow sailplane.

A polyhedral sailplane has, in a sense, a type of built-in washout without adding any wing twist. The geometry of a polyhedral wing results in the tip panels actually flying at a lesser angle of attack than the root (trust me, it's true). A polyhedral wing is, therefore, less likely to tip stall than an untwisted straight dihedral wing.

Should washout be added to your sailplane by twisting the wing? Well, it depends on the sailplane design and your flying style. If you tend to tip stall the heck out of the thing, then a little added washout may be in order. If you want maximum performance throughout a wide speed range--forget it.

GLUING TO CARBON FIBER

Terry Hall and Mike Bame

Recently, Terry Hall, who works for Northrop Aircraft, gave me some information on carbon fiber design and fabrication techniques. One item which caught my eye concerned bonding to cured carbon pre-preg (the kind found in Hi-Flight carbon spars). It seems that proper preparation of the carbon is very important for a good bond. The recommended preparation is as follows:

1. Wipe with acetone or other solvent using a lint-free cloth.

2. Scrub with a Scotch-Brite pad and concentrated household detergent such as Tide. Rinse thoroughly with water. Note: At this point you should be wearing rubber gloves so as not to contaminate the carbon with your skin oils.

3. Dry with a heat gun or hair dryer.

4. Scuff-sand with 180 grit sandpaper, being careful not to sand too deep.

5. Tap the back of the carbon to dislodge any loose dust. DO NOT WIPE WITH SOLVENT!!!

The carbon is now ready for gluing. The reason you don't want to wipe the surface with solvent is that instead of removing any remaining contaminants, you would spread them in a thin film over the entire surface! Also, the remaining surface dust acts as a filler to <u>strengthen</u> the bond.

Gluing should be done with a slow curing epoxy. The only one that I have used is West System Epoxy available from California Custom Yachts in Redondo Beach. I would think, though, that Hobbypoxy Formula II would work fine. (It has for me--ed.) Apply epoxy to both surfaces to be joined, then clamp parts together until the epoxy is cured.

RC SAILPLANE SPAR DESIGN

Blaine Rawdon

Increasing interest in strong gliders makes me think that an article on spar design might be of some use. After attempting an article which explained the principles involved I gave up because a 40-page newsletter is a bit much. Instead, this is a pure cookbook, paint-by-the-numbers approach. Some approximations are made. This is merely an illustration of how I do it; and I cannot accept responsibility for any consequences.

For an example, I use an all-out 2-meter.

I. Compute loads

A. Determine:
(1) Span - 78.75"
(2) Area - 630 in^2 (chord = 8.0")
(3) Max gross weight - 7.70 lbs.
(4) Estimated empty wing weight - 1.5 lbs
(5) Max g-load = $\left(\frac{V_{max}}{V_{stall}}\right)^2$

$$= \left(\frac{130}{30}\right)^2 = 18.8 \approx 20$$

(6) Max towline tension - 200 lbs.

B. Determine if max g's or towline tension governs:

(1) Find maximum fuse effective weight
= max gross - 0.8 (wing weight)
= 7.70 lbs. - 0.8 (1.5 lb) = 6.50 lb

(2) Multiply effective fuse weight by max g's:
= 6.5 (20) = 30 lb

(3) Compare to max towline tension
200 lbs 130 lb so towline governs

Note: 200 lb gives $\frac{200 \text{ lb}}{6.5 \text{ lb}} = 30.8$ g's = $\frac{V_{max}}{V_{stall}} = 5.6$

C. Determine moment at several stations along wing

(1) Find effective max wing loading:
= $\frac{\text{Towline + effective fuse}}{\text{Wing area}}$

or $\frac{\text{Effective fuse x g's}}{\text{Wing area}}$

Since in our example towline tension governs, we use the former:

$$= \frac{200 + 6.5}{630 \text{ in}^2} = 0.33 \text{ lb/in}^2$$

(2) Find the moment at several stations along the wing: Pick at least 4 approximately evenly spaced points (spanwise) along the wing.

Moment = Force x Distance

M = (area outboard of point)(max wing loading) x 0.45 (span outboard of point)

Note: 0.45 gives effective distance to center of lift. 0.40 can be used when high taper ratio planforms are used.

$$M_{Root} = \left(\frac{78.75''}{2}\right)(8'')(0.33 \text{ lb/in}^2) \times 0.45 \left(\frac{78.75''}{2}\right) =$$

1842 lb·in

$$M_{10''} = \left(\frac{78.75''}{2} - 10''\right)(8'')(0.33 \text{ lb/in}^2) \times 0.45$$

$$\left(\frac{78.75''}{2} - 10''\right) = 1025 \text{ lb.in}$$

$$M_{20''} = (39.38'' - 20'')^2(8'')(0.33 \text{ lb/in}^2)(0.45) = 446 \text{ lb.in}$$

$$M_{30''} = (39.38'' - 30'')^2(8'')(0.33 \text{ lb/in}^2)(0.45) = 104 \text{ lb.in}$$

Note the very rapid decrease in moment with span. Also, if you keep all your measures in inches and pounds things will work out right.

D. Determine shear at several stations along wing:

V = Shear = Lift outboard of station
= (area outboard of station)(Max wing loading)

$$V_{Root} = (39.38'')(8'')(0.33 \text{ lb/in}^2) = 104 \text{ lb}$$

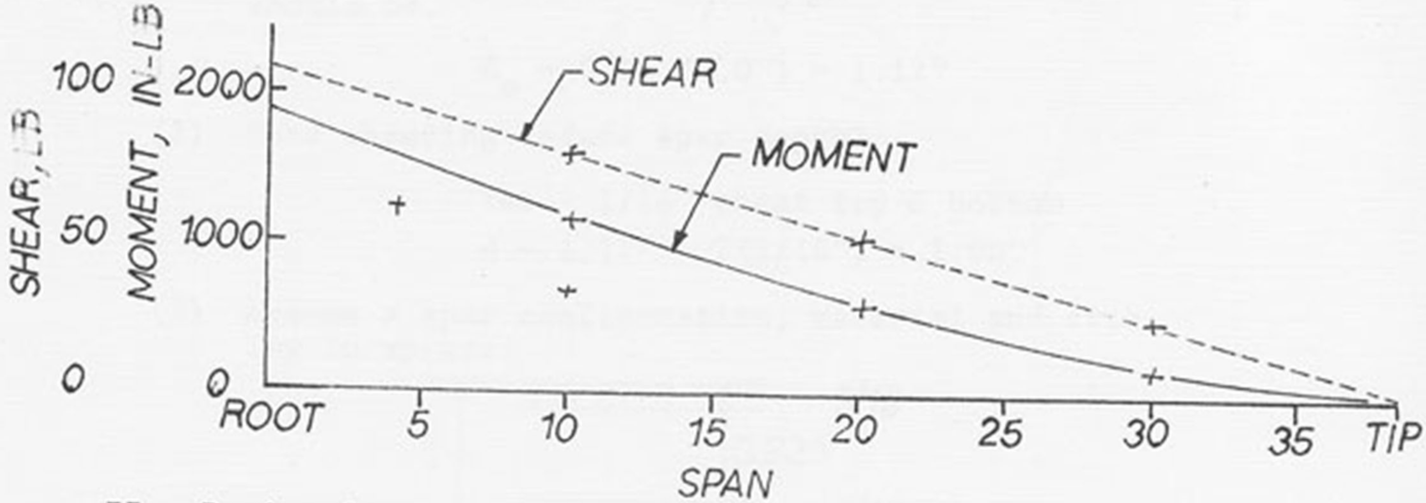
$$V_{10''} = (39.38'' - 10'')(8'')(0.33 \text{ lb/in}^2) = 77.6 \text{ lb}$$

$$V_{20''} = (39.38 - 20'')(8'')(0.33 \text{ lb/in}^2) = 51.2 \text{ lb}$$

$$V_{30''} = (39.38 - 30'')(8'')(0.33 \text{ lb/in}^2) = 24.8 \text{ lb}$$

Note the proportional decrease of shear with span.

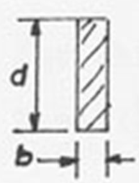
E. I like to graph shear and moment to help visualize and aid in design:

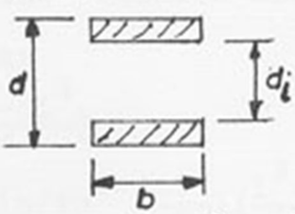


II. Design Spar

Spars have the capability of generating a moment determined by their physical configuration (type, size, depth, etc.) and by the strength of the material.

Physical configurations and their "Section Properties"





$S = \frac{bd^2}{6}$ $\qquad$ $S = \frac{b}{6}\left(\frac{d^3-di^3}{d}\right)$ $\qquad$ $S = \frac{\ }{32}\left(\frac{d^4-di^4}{d}\right)$

$I = \frac{bd^3}{12}$ $\qquad$ $I = \frac{b}{12}\left(\frac{d^4-di^4}{d}\right)$ $\qquad$ $I = \frac{\ }{64}\left(\frac{d^5-di^5}{d}\right)$

$V = 1.5\ V_{avg}$

<u>Approximate</u> strength of materials - all in units of PSI

	Tension	Compression	Shear 1	Shear 11
Balsa	1000 - 4000 Punk Hard	1000 - 4000 Punk Hard	300±	70±
Spruce	10,000	10,000	?	200
Ply	5,000	5,000	1000± Edge	300± Face
Carbon	100,000± Varies w/ thickness	75,000± Varies w/ thickness	12,000± Varies w/ thickness	3,000±
Foam 1 lb	-	-	10	-
2 lb	-	-	30	-
3 lb	-	-	50	-

A. Determine spar configuration

(1) Find wing depth @ 25 - 30% chord where the spar should be.

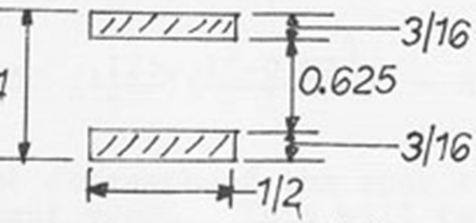
$$d_o = 0.14\ (8.0") = 1.12"$$

(2) Does sheeting reduce spar depth?

Yes - 1/16" sheet top & bottom

$$d = 1.12" - 2(1/16") = 1.00"$$

(3) Assume a spar configuration, material and site. Try in spruce:



(4) Find the moment capacity of the proposed spar:

M = FS   Where "F" is the tension or compression strength, whichever is weaker. "S" is the "section modulus" from above.

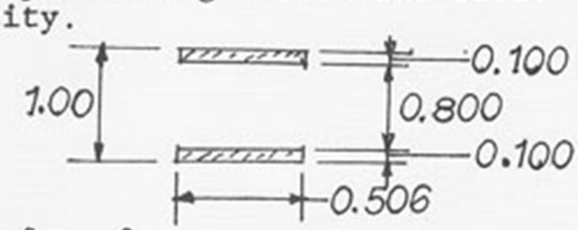
For this spar

$$M = F\left(\frac{b}{6}\right)\left(\frac{d^3 - di^3}{d}\right) =$$

$$= 10{,}000\ \text{lb/in}^2\ \left(\frac{.5"}{6}\right)\left(\frac{1^3 - .625^3\ \text{in}^3}{1\ \text{in}}\right) = 630\ \text{lb.in}$$

The moment that can be generated by this spar is much less than the requirement imposed by the loads at the root. Rather than wind up with a 2 x 4 spruce spar, I'll switch to carbon.

Again, assume a spar configuration and size. Then check its moment capacity.



$$M = 75{,}000\ \left(\frac{.5}{6}\right)\left(\frac{1^3 - 0.8^3}{1}\right) = 2033\ \text{lb.in} \qquad 1842\ @\ \text{root}$$

The strength of this size spar is greater than necessary, try .090" caps:

$$M = 75{,}000\ \left(\frac{.5}{6}\right)\left(\frac{1^3 - 0.82^3}{1}\right) = 1869 \qquad 1842\ \text{so}$$

½" x .090" will do it at the root. The bottom cap can be thinner because carbon is stronger in tension. Don't thin it if you have a symmetrically loaded and flown airplane; e.g. an aerobatic ship.

Repeat this process several times until you have a good idea how strong the spar is when it is tapered. You can taper in cap thickness, cap width, in spar depth and in spar material. For this example, I taper only cap width.

b = .375 $\quad M = 75{,}000\left(\frac{.375}{6}\right)\left(\frac{1^3 - 0.82^3}{1}\right) = 1402$ in.lb

b = .250 $\quad M = 75{,}000\left(\frac{.250}{6}\right)\left(\frac{1^3 - 0.82^3}{1}\right) = 935$ in.lb

b = .125 $\quad M = 75{,}000\left(\frac{.125}{6}\right)\left(\frac{1^3 - 0.82^3}{1}\right) = 467$ in.lb

Compare and match the strength of the spar to the moment required on your moment graph. This will tell you how much spar you must have at any given station. So now you have the caps figured out--next month we do shear webs, joiners and stiffness. (5)

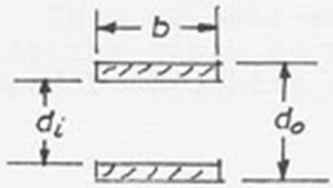
R/C SAILPLANE SPAR DESIGN (continued)

Blaine Rawdon

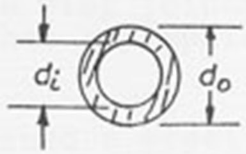
First, I correct the errors in the first part:

1. The formula for moment of inertia is

for



$$I = \frac{b(d_o^3 - d_i^3)}{12}$$



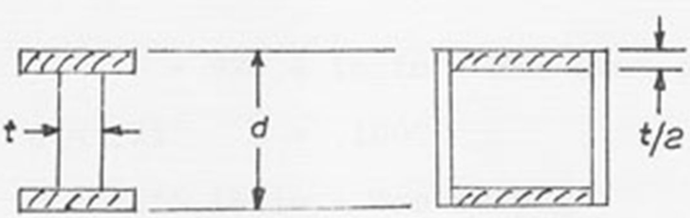
$$I = \frac{\pi (d_o^4 - d_i^4)}{64}$$

2. Michael Bame wins the gold star this month for discovering that the spar size calculations on page 5 used an F of 50,000 psi instead of 75,000 psi, so the spar is 50 percent oversize.

Okay--now for......

SHEAR

The shear stress in the web, or at the web/spar joint is proportional to the shear at that station, and is inversely proportional to the overall spar depth and the web thickness.



$$f_v = \frac{V}{dt}$$

or

$$t = \frac{V}{d F_v}$$

Where f_v is shear stress generated

F_v is shear stress allowed by weakest link connecting top and bottom spars

V is the shear load from the loads diagram

So, in our example using balsa webs with F_v = 300 lb/in^2, we can find the required web width at the root....

$$t = \frac{V}{dF_v} = \frac{104 \text{ lb}}{1 \text{ in } (300 \text{ lb/in}^2} = 0.35 \text{ inch}$$

So, 3/8" will do it

You can calculate the required thickness at various stations, but it is quicker to recognize that shear drops proportionately with span. Thus at half-semi-span the web can be ½ maximum width. At the tips, no web is required except for shear loads imposed by crashing and upsets.

JOINER DESIGN

The main idea of a wing joiner design is to pick a material and section that has appropriate strength and stiffness for the wing.

In our example assume a steel tube wing rod of 4130 chrome moly with approximate F=80,000 lb/in^2. The moment capacity of the wing rod should be near to that of the wings--depending on what you want to go first. Since steel bends and carbon breaks, I suggest making the tube weaker.

For example, let's try for a wing tube of M = 1600 lb.in.:

1st try d = .50" t = .125"

$$M = FS = F \frac{\pi}{32} \frac{(d_o^4 - d_i^4)}{d_o}$$

$$= \frac{80{,}000 \text{ lb}}{\text{in}^2} \frac{\pi}{32} \frac{(.5^4 - .25^4)}{.50} \text{ in}^3$$

$$= 920.4 \text{ lb.in - Not even close!}$$

2nd try d = .75" t = .100"

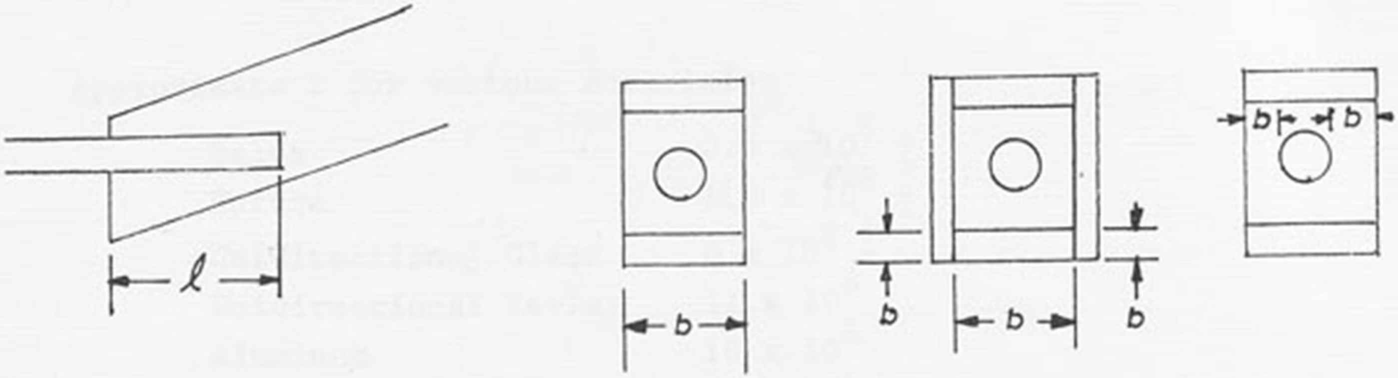
M = 2355 lb.in - Too strong

3rd try d = .75" t = .0625"

M = 1716 lb.in - Close enough!

RECEIVER DESIGN

The big thing about receivers is that the shear is fantastic. This means the top and bottom spars must be extra well connected around the receiver. The longer the receiver, the less the shear.



$$f_v = \frac{\text{Max Moment @ Joint}}{\text{in inches } (b \text{ in inches})(\text{inch})}$$

or

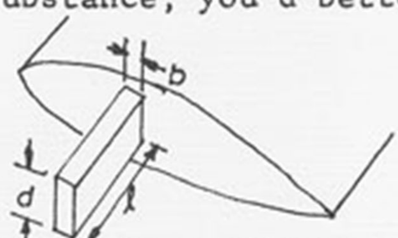
$$\ell = \frac{\text{Max Moment @ Joint}}{F_v \ (b \text{ in inches}) \ (\text{inch})}$$

Check the stress in the web at the various levels moving from the top spar to the bottom. Look out for the weak links.

In our example, assuming at least ½" of plywood connecting the spars,

$$\ell = \frac{1842 \text{ lb.in}}{\frac{1000 \text{ lb}}{\text{in}^2} \ (0.50 \text{ in})(\text{in})} = 3.68"$$

Also, if you are using as a joiner a ply blade or some other breakable substance, you'd better check it for shear, too....



$$f_v = \frac{1.5 \ (\text{max mom @ joint})}{d b \ell}$$

STIFFNESS

Stiffness and bending strenth are related but they are not married....you can have a weak stiff wing or a strong flexy one, although in general a stiff wing will be stronger than a flexy one.

If you wish to compare stiffness of one spar to another or to a joiner rod it is easy.

Stiffness is proportional to the section property "moment of inertia," "I", and it's proportional to the stiffness of the cap material "E". The stiffness of the shear web must come into play, but I haven't figured out how yet. As a first cut, the web stiffness can be ignored.

Approximate E for various materials:

Balsa	$0.5 \times 10^6 \pm$
Spruce	$1.5 \times 10^6 \pm$
Unidirectional Glass	$6 \times 10^6 \pm$
Unidirectional Kevlar	11×10^6
Aluminum	10×10^6
Unidirectional Carbon	18×10^6
Titanium	$20 \times 10^6 \pm$
Steel	29×10^6

In order to get relative stiffness, just multiply I x E.

DIHEDRAL--MECHANISM AND MEASUREMENT

A tidbit for the technical

Blaine Rawdon

This article is to explain the dihedral mechanism and to quantify it so that meaningful comparisons may be made between planes and configurations.

The purpose of dihedral is to produce a rolling force in the wing when it is flown with a yaw angle. This is how our rudder and elevator planes turn. The rudder causes the plane to yaw and the dihedral causes the plane to roll.

There are many ways to visualize this mechanism, but the one I favor at the moment is not common. I like to think about the angle at which the air flows over the wing when the wing is yawed. Imagine a dihedral wing yawed forward; the air passing from the leading edge to the trailing edge now moves over the trailing edge at a lower point on the wing than its entry point at the leading edge, thus the effective angle of attack is increased. Likewise, if the wing is yawed to the rear, then the leading edge is lower than the trailing edge, reducing the angle of attack.

By this analytical method you can also see that washout will reduce the dihedral effect.

In an untwisted, unswept wing the change in angle of attack is approximately proportional to the dihedral angle and the yaw angle. The formula for this relationship can be shown to be $\Delta\alpha = \mathrm{TAN}^{-1}(\mathrm{TAN}\,\theta\text{-YAW} \quad \mathrm{TAN}\,\phi\ \text{DIHEDRAL})$ for smaller angles.

Now, what about polyhedral, you say? Polyhedral is just a more efficient form of dihedral. The idea being that a certain rolling moment is desired for a certain yaw angle, and you want it with the least possible amount of wing to span ratio. If you have a lot of dihedral, you have more wing for the span so the plane is less efficient. Polyhedral is more efficient because it puts the dihedral out near the tips where it has the best leverage, and doesn't waste it in the center where it has no leverage. These gull wing jobs with more dihedral in the center and less at the tips are silly.

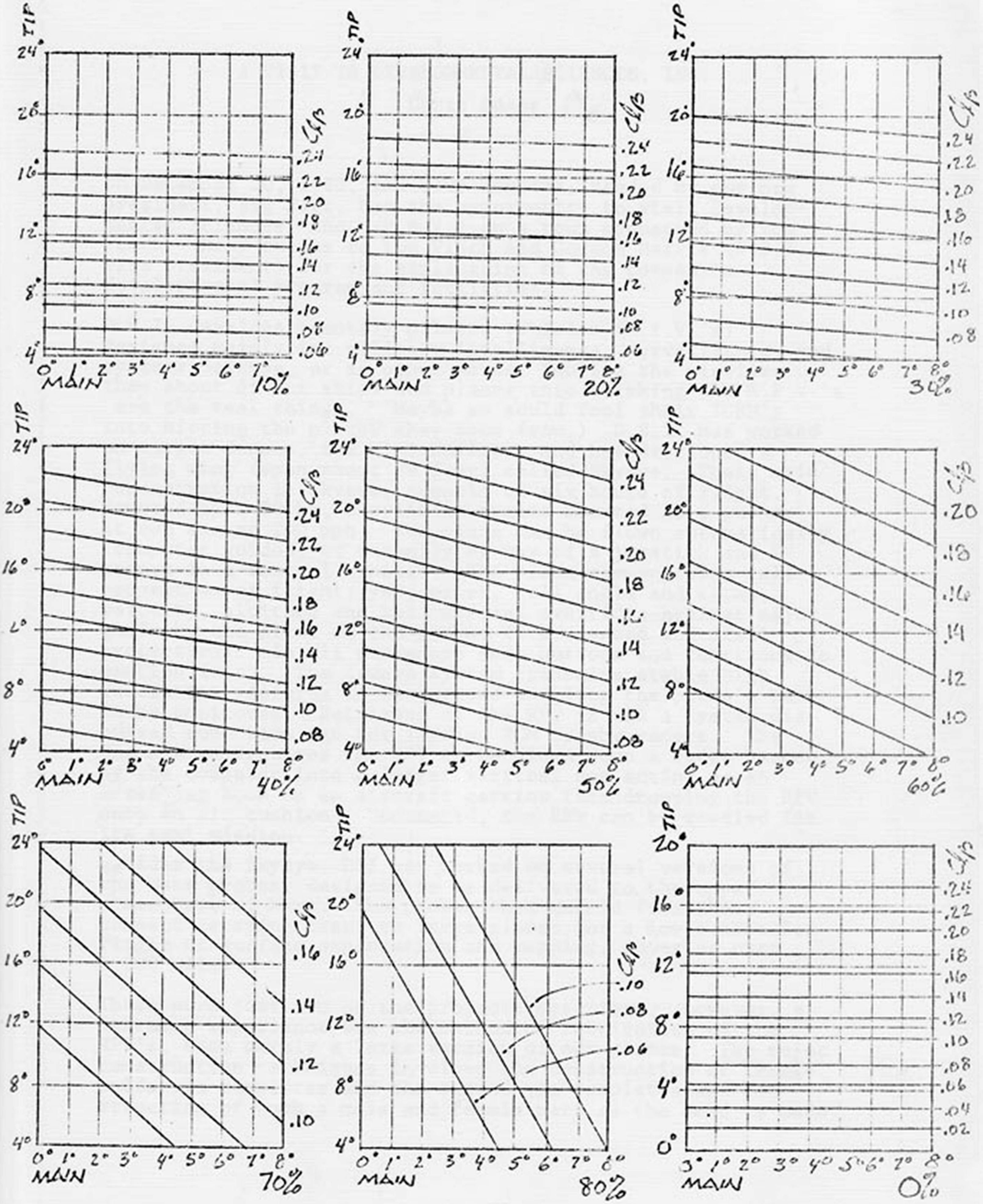
There is a way of quantifying the overall effectiveness of a dihedral/polyhedral configuration. The term for it is C or "Cee-el-baitah" (C_{1B} Aligator?). It can be calculated from a standard chart as a function of the inboard panel angle with horizontal, the outboard panel angle with horizontal, and the location, as a fraction of the semi-span, of the polyhedral break.

The C_{lB} coefficient in combination with the average lift coefficient and wingloading will determine the rolling force on the wing for a given yaw angle. So other things equal, a plane with a large C_{lB} will roll more rapidly, yaw less in circles and in general be more maneuverable.

From the charts on the right which I have expanded from the basic chart, you can find the C_{lB} for most any configuration. To give you some idea of what a reasonable number might be, Id say that anything less (in magnitude) than -.10 and you'd better have ailerons. -.12 is still pretty miserable (Oly II). -.15 is getting there. -.165 is known to be good (Paragon and Mirage). I have a feeling that for larger slower planes, and ones where maneuvering is important, -.180 to -.20 may be the way to go.

How to use the graphs: Select the chart with the polyhedral break location (eg. 60%) closest to what you have in mind. Go up from your main panel angle and over from your tip panel angle to get a point. Judge where this point is on the C_{lB} scale. Nothing to it! You can run it backwards from the C_{lB} scale into panel angles if you feel like it. Or you can fix panel angles and C_{lB} in order to find your panel break location. Any which way.

One last point is that in general you can expect airplanes that fly at lower lift coefficients (low camber airplanes) to be more responsive in yaw/roll couple. This is because a given change in angle of attack means more to a wing when it is already at a low angle of attack. This is why your plane is more responsive in roll at higher speeds.


TIP
MAIN
Clp
10%
20%
30%
40%
50%
60%
70%
80%
0%

A VISIT TO DEVELOPMENTAL SCIENCES, INC.

Chris Adams

On December 30, 1980, ten club members, headed by our new president, Big Jerr, had the opportunity to visit Developmental Sciences, Inc. (D.S.I.) on a tour sponsored by Tom Finch. Many thanks to Tom Finch and Gordon Harris (D.S.I. vice president) for the explanation of the company's developmental program and facilities.

D.S.I. develops remotely piloted vehicles (R.P.V.'s) designed mainly for military intelligence, surveillance, and systems defense, or in other words, fooling the missiles they shoot at our ships and planes into thinking the R.P.V.'s are the real things. (Maybe we could fool their ICBM's into hitting the places they came from.) D.S.I. has worked on target drones, the Mini-Sniffer, and has developed a flying wing (span about 20 feet) called Skyeye. Their main concentration is Skyeye, capable of six hours of flight. Powered by a 20 hp, 2-cylinder engine mounted as a pusher it can exceed 200 mph. The plane can be flown automatically (computer guided) or manually by way of a joystick and TV camera in a control trailer. The plane communicates all properties of flight; yaw, pitch, roll angle and rates, velocity, altitude and has internal overrides against major goofs by the pilot on the ground (i.e., speed and stall protection). In all there are more buttons and functions to mention (sic). The camera system transmits stable high resolution pictures to the ground enabling the plane's path to be monitored. Retrieval of the RPV is via a system discussed some time ago for landing RCM trophy racers. The DSI system requires the RPV to be flown down a radar beacon by the computer into a larger vertical net acting as an arresting hook on an aircraft carrier then dropping the RPV onto an air cushion. Undamaged, the RPV can be readied for its next mission.

Besides the Skyeye, DSI has worked on several versions of the Mars probes, designed to be delivered to the upper atmosphere of Mars. The probes then unfold from their compact carrying cases to large planes for a slow controlled flight of surface exploration and mapping, covering over 6,000 miles.

These were just two of the projects described; however, a learning experience was the method of fabrication of the RPV's, each merely a large version of our planes. The major construction techniques involved the construction of female molds via templates and the second via templates and construction of both a male and female part as the mold is made.

I will attempt to describe the two methods by diagrams. The larger Skyeye had a tapered wing, swept, with a changing airfoil. To construct the mold, an outer template was constructed of the airfoil (Fig. A), top and bottom contours. The airfoils at severl stations are plotted and cut out. The metal contours are mounted on a flat table, and the reference lines aligned in a level plane. Since the airfoils are accurately cut with respect to these lines, once level, they have any built-in twist that has been designed into the wing. A wire mesh support and filler is placed between the templates and reinforced (Fig. B). A crude layer of plaster cement strengthened with hemp fiber is then layered to within half an inch of the template form (Fig. C). After curing, a layer of fine plaster is placed in each section. A straight-edge is then pulled along the templates and the plaster smoothed to the relief contour of the templates (Fig. D). The technique is much like cutting a foam core and what is made resembles the outer, throw-away section of the core. Both bottom and top surfaces are made and the wing skins then cast and assembled like a fiberglass fuselage part. During the procedure of molding the part, the fiberglass and resin are vacuum-bagged to ensure even bonding and efficient penetration of the resin into the glass.

The second method involves a combination of both male and female mold construction at the same time. First, one prepares templates of the bottom contour and the top contour with respect to the top surface. (Fig.E). The template is mounted so it can be passed level across a flat table (Fig. F). Plaster is added to the table surface, and the template moved to sweep out the lower surface contour (Figs. G & H). After curing, the mold surface is prepared with mold release and new plaster is poured in. The top template is now passed over the plaster sweeping out and leaving the upper contour (Fig. I). This now has made a smooth plaster male mold and one-half of the main mold. After plaster surface preparation, the upper female portion is layered on, and after curing, removed (Fig. J). The male mold is now removed and the wing molds are prepared for skin casting as you would a fuselage part.

Both methods appear to be rather quick and could lend themselves to more one-model designs (since we hardly ever build two of the same model). The tapered wing mold is more work if many stations are employed; however, the constant chord method could yield wing skins in less than a week and suit many of our club's design purposes.

HOW TO MAKE A VACUUM PUMP

Bill Forrey

The first thing you must ask yourself is the question, "Why do I need a vacuum pump?" The answer is, if you are an average modeller, you probably don't.

However, if you wish to advance into composite structures involving carbon fiber, you are going to NEED a vacuum pump. Pre-preg C-F MUST be cured at high temperatures and high pressures and carbon tow doesn't achieve maximum strength until it too is cured under pressure with the right resin/fiber ratio.

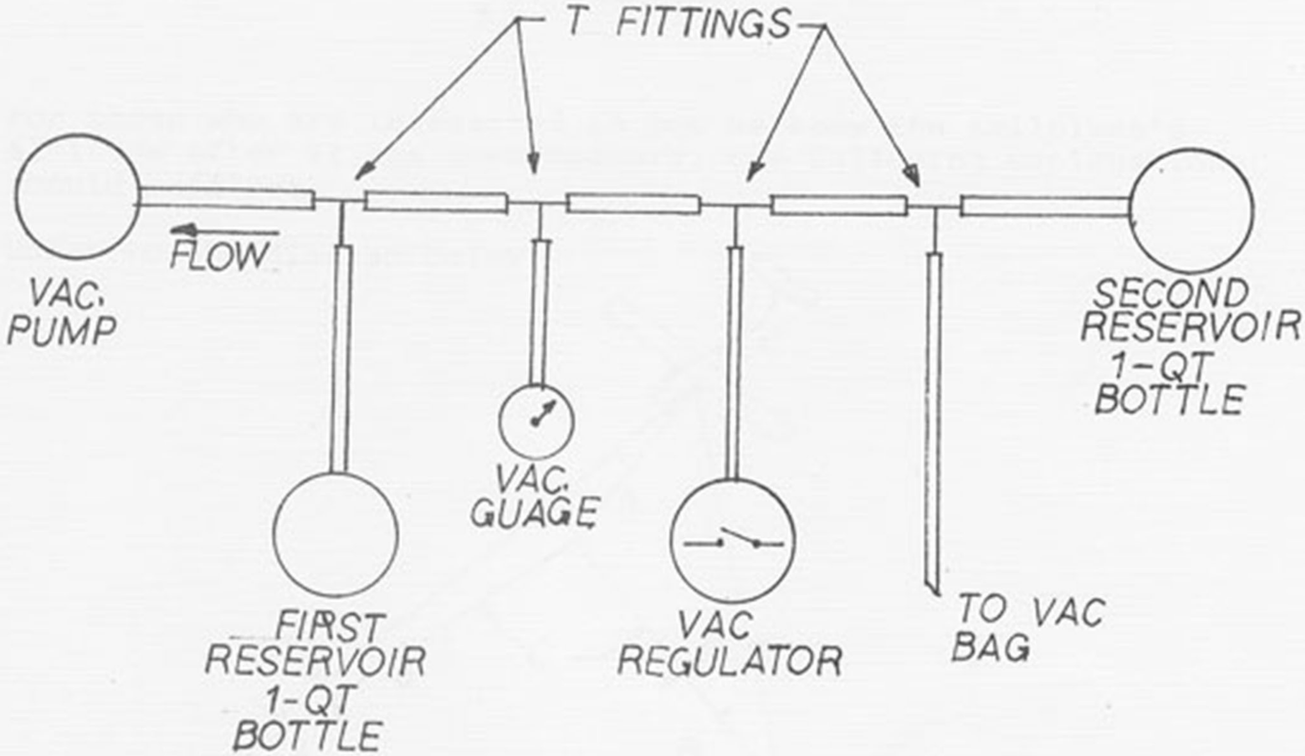
Bonding wing skins to foam cores is a lot easier with a vacuum pump. You can get as much pressure as you need to bond any skin, no matter how stiff or inflexible to the foam surface. In fact, you can get TOO MUCH pressure and smash the foam if you are not careful.

I hope you realize that by "pressure" I mean atmospheric pressure caused by the vacuum inside the vacuum bag. There is a limit to how much pressure you can achieve with a vacuum pump; roughly 14 lbs/in^2. But it is plenty because at about 9 lbs/in^2 the foam crushes.

Mike Bame has discovered an amazing way to sheet a foam core. He takes 1/16" balsa, wets it out with epoxy (West System), squeegees off ALL of the epoxy, then vacuum bags the skins to a fully prepared foam core. He saves a lot of excess weight (epoxy is heavy stuff), and gets a complete foam-to-wood bond. You can't peel up the balsa without taking out chunks of foam. This takes a lot of pressure and can't be done with encyclopedias and textbooks unless you can pile them half way to the ceiling.

Mike also discovered a great way to get super-strong spars. He takes an extruded aluminum channel with an inside width measurement of 3/8", waxes it, then lays up as many layers of C-F/epoxy as necessary in the channel, slides a 1/8" x 3/8" spruce spar into the channel, covers the channel with poly-ehteline plastic (1 mil. OD), places a 3/8" sq. steel bar into the channel so that it sticks out of the channel 1/8" or so, then vacuum bags the whole affair until it cures. Excess epoxy oozes out the sides leaving an excellent fiber to epoxy ratio. The spar that pops out of the channel is perfectly shaped, beautifully smooth, and incredibly strong. It would be tough to duplicate without the vacuum pump.

Other uses might include molded wing skin manufacturing, molded fuselage manufacturing where there are tight corners that glass doesn't want to form to, applying balsa skins to stab cores, and who knows? We are just beginning to discover its uses.

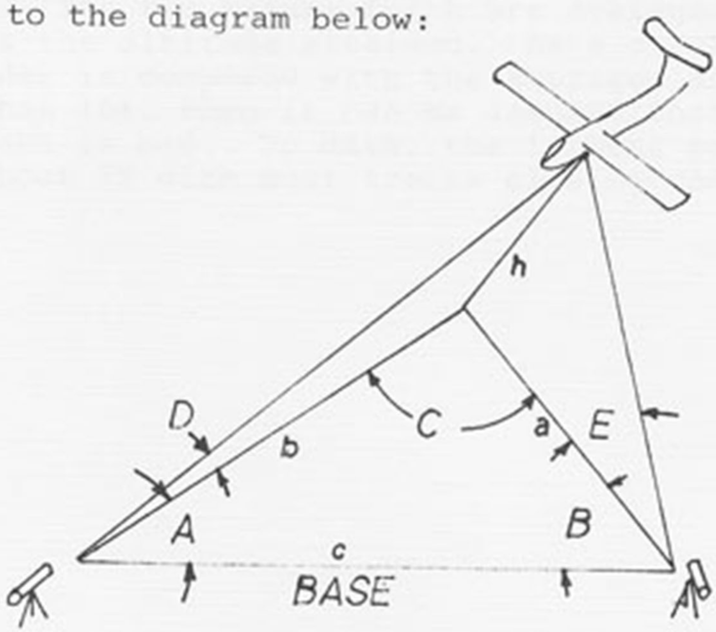


CALCULATING THE ALTITUDE OF MODEL AIRCRAFT USING THEODOLITES

Michael Bame

For those who are interested in how we know the sailplane's altitude after it has been measure, the following explanation should suffice:

Refer to the diagram below:



Angle A and B are the azimuth angles as measured by the theodolites.

The baseline is a measure distance which separates the two theodolites.

Since the three angles of any triangle add up to 180 degrees, angle C equals 180 - (A + B). With angle C, A & B, and Base C known, the law of sines states that:

$$\frac{c}{\text{SIN } C} = \frac{a}{\text{SIN } A} \qquad \frac{b}{\text{SIN } B}$$

Therefore:

$$a = \frac{c \text{ SIN } A}{\text{SIN } C} \quad \text{and } b = \frac{c \text{ SIN } B}{\text{SIN } C}$$

With elevation angles D & E and triangle leg lengths a & b known, the altitude h can be calculated by:

$$\frac{h}{a} = \text{TAN } E \text{ and } \frac{h}{b} = \text{TAN } D$$

so:

$$h = a \text{ TAN } E \text{ and } h = b \text{ TAN } D$$

NOTE that we have two altitude measurements. Ideally, the two would be the same, but it's almost impossible for this to occur because of small errors in tracking the plane and reading angles. The two values for h are averaged with the average used as the altitude attained. As a check, each of the measured altitudes is compared with the average, and if they are off by more than 10%, then it can be assumed that somebody goofed and the track is bad. To date, the largest percentage error has been about 7% with most tracks closing under 2%.

THICK VERSUS THIN

Jerry Krainock

For over two years, some members of the club have been experimenting with airfoils having a thickness ratio of greater than 12%. I am going to attempt to summarize our progress to present.

I don't know what actually got us started in this direction, but I do know some of the elements. In the June 1978 issue of Sport Aviation, there was an article by R. T. Jones about airfoil development that really caught my eye. He had some illustrations showing a comparison of a 21% airfoil and a piece of wire .006" thick with the same drag values at 6,000,000 RN (Reynolds Number). "The drag coefficient of the wire is about 1.0, and that of the airfoil is 0.006; hence the diameter of the wire is only .006 the chord of the airfoil." (Chord is 1" - Ed.) Now, I knew the 6,000,000 RN was a hell of a lot different than the 120,000 RN where most models fly, but it was still very intriguing. Jones then went on to show drag curves for a thin, flat plate and a 12%, N-60 airfoil at 40,000 and 120,000 RN. At the latter RN, the 12% section was superior.

The next thing that happened was the RCM Trophy Race of 1979. Ken Kilbourne and Mike Reagan both entered and after the races Ken, Mike, Gary Ittner and I concluded that Ken's and Mike's ships were the fastest there.

Next, we had an impromptu session of FAI speed runs at Pierce College with Mike Reagan flying his racer. He got lousy tows but still did a 9.6 speed run. Then he broke his ship. Because it wasn't repairable, he cut the wing up in slices and very carefully measured the thickness and camber. If my memory is correct, it turned out to be 13.9% thick and had a 1.9% camber.

When Ken Kilbourne heard about this he carefully measured his wing and it turned out to be 12.8% thick.

So, here we were, looking at two very fast sailplanes with wings over 12% thick. Thie obvious conclusion was that 12% thickness was not a magic number as far as airfoils are concerned, and if 13.9% could be fast, perhaps camber and not thickness was the important factor in wing sections. As it turns out, that's not the whole story, but it did get us going in a good direction and has led to the following conclusion:

> Thickness is only one of many factors that determine the lift and drag characteristics of an airfoil.

A review of NACA Reports 460 and 628 will both show a section like a 2415 (15% thick) having lower drag curves than a 6409 (9% thick), for instance. (Editor's note: the 2415 is a low camber section, the 6409 is high.)

In the "Profilpolaren fur den Modelflug" by Dieter Althaus, he has drag curves for the Eppler 193 (10.2% thick) and our old friend, the NACA 2415. At 100,000 RN and a Cl of .7, an area where our models fly, the 2415 has less drag.

In a NASA report on motorless flight, Gunter Helwig did a study on optimizing a full size 15 meter standard class wing. He included an airfoil study on 4 unflapped Wortman sections: the 60-126, 61-163, 66-s196VI and the 61-184 (thickness is shown by the last three numbers). In order of descending desirability, the sections were listed in this order: 61-184, 60-126, 66-196, 61-163. Even in full size, you don't have to be "thin to win." Interestingly enough, the Nimbus III advertises a new thin wing; it's 14% thick.

The obvious comment to make here is that I'm using data at 3 to 6 million RN to support conclusions for the 120,000 to 250,000 RN. Still, my experience is that our conclusions are sound.

Our first efforts concentrated on 15% sections with 3% camber (NACA 65_2 - 415, a = .5) and were very successful. Then Gary Ittner produced his "Tai-Pan" with his own 16½% section and Mike Bame came up with his 15% - 2½% camber section, used on the latest Gemini (M.T.S.). All are very good sections.

The question now is, what are the benefits of the thicker sections?

1. Greater strength in the wing.
2. A very gentle stall characteristic.
3. Generally lower drag due to camber of 3% or less which leads to better L/D and penetration.
4. Higher tows, either standard or zoom. With a strong wing, you can use 12 volts and stand on it for a good zoom. On a 6 volt winch, the soft stall characteristic allows you to fly at very high angles of attack and kite up to high altitudes.

Competition is always an interesting indicator of success or failure. So, how did the thick sections fare? Just fine thanks! The obvious structural benefits allow loading lots more ballast and that shows up in speed. Gary Ittner, flying his Tai-Pan tied for fast time (10.6 sec.) at the FAI team selection finals. At the recent LSF Tournament, Gary again won speed with Tai-Pan while Alex Bower placed second with a Gemini M.T.S. Alex also had the honor of turning fastest time in the tournament at 10.5 seconds.

So all right, it's the pilots. Right? There were 30 fine pilots at the FAI Finals and about the same number at the LSF Tournament. No one went faster than the thick wing ships of Alex and Gary.

Gary Ittner's 14' cross country ship has a 16% profile with 2% camber. Warming up for the "Great Race," Gary had a flight of over 20 miles (In poor weather conditions--heavy, low cloud cover--in Illinois - Ed.) In August he set an AMA thermal duration record with a flight of over 8 hours with this same ship: his "Little Pigeon." Does that sound like a ship that is not working?

I've built two thick wing ships myself and had one mediocre success ("Pet Rock"--34 seconds in four lap speed at 2MWC) and another two-meter ship that flew, albeit, for such a short time (Mid-aired at RCM Trophy Race, 1981, first flight - Ed.) I can't say if it was a success or not. I've flown Ittner's ships, Mike Bame's, Reagan's, Forrey's, numerous Gemini M.T.S., Dick Odle's thick winged ships, Blaine Rawdon's thick-wingers, "Punk Rock" among them, and others. They all flew very well and the only noticeable failure was Blaine Rawdon's two-meter ship with the Liebeck section. I don't believe Blaine is too happy with his 14% Miley wing either.

The Gemini will be the first kit to benefit from our efforts and I expect more to follow. It has to be flown a little differently than a Sagitta; nevertheless, I would expect the intermediate and expert fliers to get more out of it for a couple of reasons. First, because it handles so well, it is very easy to fly. Second, it is very strong. The wing will easily stand up to a 12-volt launch. Because of its strength, the experienced flier will be able to out-ballast the competition.

So, where do we go from here? Well, it's obvious that even subtle variations of L.E. curvature can have noticeable effects on wings, not to mention the location of the high point; smoothness of the surface; sharpness of the L.E.; lack of ripples, waves; accuracy of contour; and our old friends, thickness and camber. Even now, Dick Odle and Reagan are trying new sections.

Perhaps the most important lesson learned was to NOT be afraid to try something just because it hadn't been done before. The greatest benefit has surely been to the people who participated in the experiment and learned how to scratch build. They are now free to build any kind of sailplane and experiment with any kind of airfoil they can dream up.

Somewhere in the infinite variety of shapes lurks the "MAGIC AIRFOIL." It will have a really broad speed range, high L/D ratio, and give a phenomenally low sink rate. With any luck, we'll find it.

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REYNOLDS NUMBER

What it is, What it does, and how to use it

Blaine Rawdon

Editor's note: Mr. Rawdon has been heavily involved in the design and manufacture of several noted aircraft in recent years: The Gossamer Condor, Penguin, Albatross, and the Solar Challenger. He also is an active modeler and designed the Mirage, a high-performance thermal sailplane.

WHAT IS REYNOLDS NUMBER?

For the purpose of our model airplanes, Reynolds Number (Rn) is the product of wing chord, velocity, and a constant "fudge" factor. This number is indicative of aerodynamic regime, and thus, performance. Two wing sections with the same section but different chords will have the same performance if the Rn's are the same. This means that the shorter chord is going faster, of course.

SO WHAT?

In many aerodynamic regimes, Rn doesn't make much difference, but as it works out, R/C sailplanes operate in a region where Rn makes a great big difference. Increases in Rn always increase section performance. Different sections improve with increased Rn at different rates and at different Rn's, so there is no rule or formula to specify how Rn effects a specific section. Generalizations can be made, however,

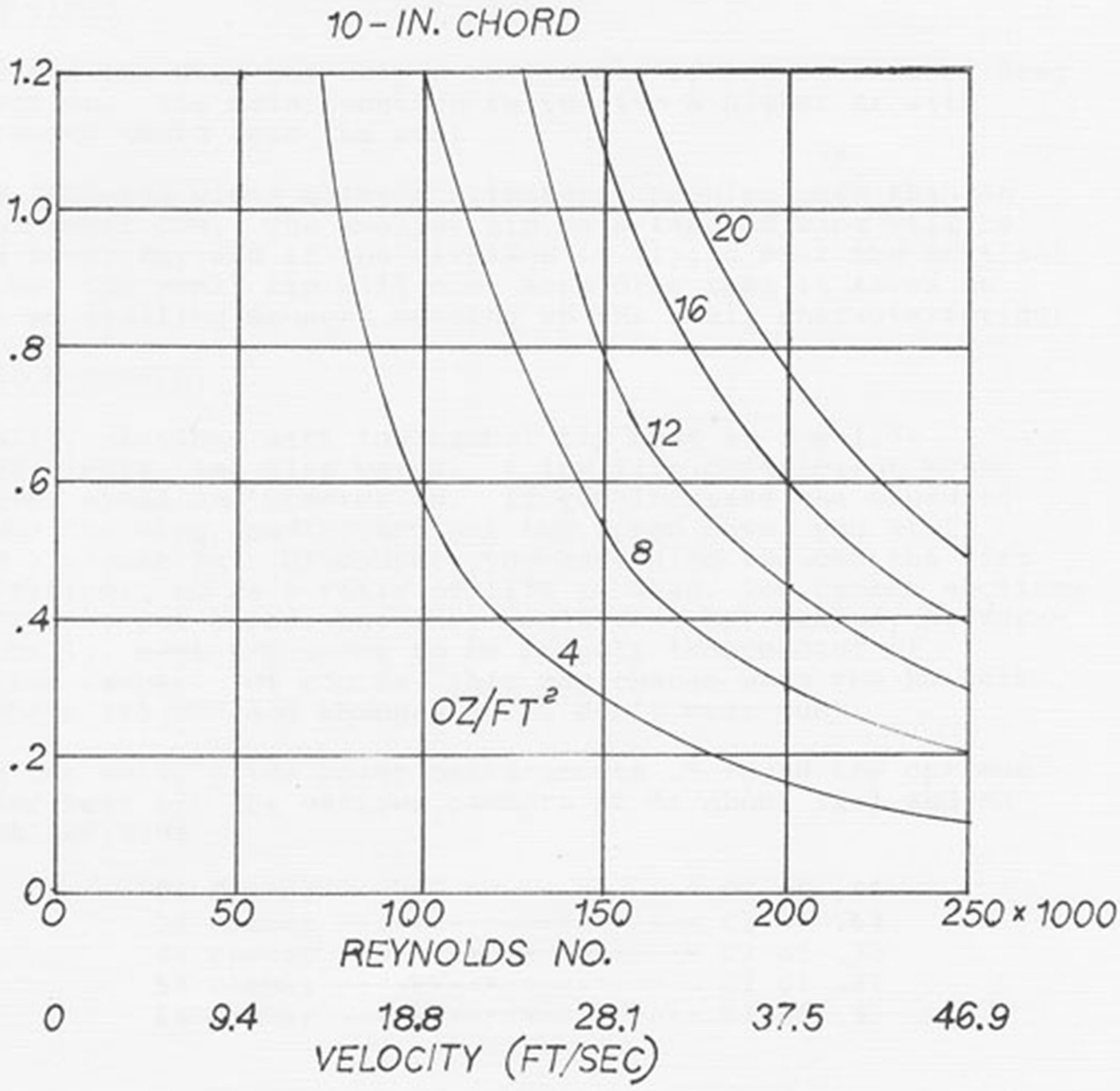
TURBULATION

At low Rn, there is a tendency for the airflow over the top of the wing to remain laminar and separate wholesale from the aft region of the wing. At higher Rn, the flow naturally becomes turbulent before it reaches the recovery region and separation is not a problem. To solve the problem at low Rn, flor strips or turbulators are placed on the upper surface of the wing near the leading edge. These turbulators bump or stir up the air so that the laminar flow transitions to turbulent flow. It takes a bit of distance for this transition to occur, more for lower Rn. As a generalization, sections of less than 100,000 Rn benefit from turbulation.

The location of the turbulator should be as far aft as it can be and still be effective. Near 100,000 Rn the turbulator wants to be at 20-25%. On Nordic (free-flight) gliders at 40,000 Rn, some designs go so far as to suspend the turbulator in front of the leading edge. If the turbulator is farther forward than necessary, then the efficient laminar flow in the forward portion of the section is destroyed prematurely. Above about 100,000 Rn, most sections perform better without turbulators.

THICKNESS

At low Rn, say 40,000, thin sections perform much better than medium and thick sections. At 40,000 Rn, typical contest sections are 6% thick. At moderate Rn, say 100,000, medium sections perform significantly better than thick sections and just as well as thin sections. At 100,000 Rn, typical contest sections are 10-12% thick. At 150,000 Rn, medium sections hold only a slight edge (say, 10% of section drag, maybe 4% overall) over thick sections. At 150,000 RN, typical contest sections are 10-15% thick. Another way to say this is that thin sections are good from 40,000 RN up; medium sections are good from 100,000 Rn; and thick sections are good from 150,000.



RN VERSUS ASPECT RATIO

Simplistically, increasing the aspect ratio (Ar) of a sailplane will increase the glide ratio by reducing induced drag. This doesn't quite always work out though, since as you increase Ar (with a fixed span and loading), you decrease Rn and thereby increase the section profile drag. For every section, wing loading, and task, there is an optimum aspect ratio.

Basically, you want to be sure that you stay above the Rn at which the section goes bad. Thus, slow airplanes should have lower Ar's than fast ones. Airplanes with thick sections should have lower Ar's (big relative chords, high Rn's) than ones with thin sections. Of course, this can get you into trouble since fast, high Ar airplanes with thin wings are going to have structural problems that don't quit. This is one of the wonderful frustrations of R/C sailplanes for the designer to resolve.

WING TAPER

Tapering the wing has only a very small effect on induced drag reduction. Its main function is to give a higher Ar with increased chord near the root.

Thus, tapered wings solve a structural problem more than an aerodynamic one. The smaller tip on a tapered wing will be at a lower Rn, and if the airplane is flying near the critical regime, the small tip will cost more drag than it saves as well as stalling sooner, messing up the stall characteristics.

SECTION CAMBER

Finally, sections with low camber fly best at low lift coefficients, and visa versa. A low lift coefficient means greater speed and greater Rn. If you increase the chord to reduce the wing loading and get the speed down, you still have a higher Rn. Of course, you have also reduced the lift coefficient, so as a ratio of lift to drag, low camber sections don't come out ahead, but they don't come out behind, either--typically, best L/D seems to be roughly independent of section camber. Of course, this may change when the Rn gets up above 150,000 and changes in Rn don't mean much.

From our early glide polar measurements we found the optimum Cl for best L/D for various cambers at Ar about 12:1 and Rn about 100,000:

2% Camber -------------------- Cl of .55
3% camber -------------------- Cl of .64
4% camber -------------------- Cl of .73
5% camber -------------------- Cl of .82
6% camber -------------------- Cl of .91

STRESS

An Examination of the Advantages of Carrying Ballast in Tubular Wing Spars for F3B Soaring Competition

Sean Bannister

INTRODUCTION

At the high speed and high 'g' situations encountered in modern F3B or triple task competition, with soarers necessarily large enough to be competitive in all tasks, an appreciation of the structural implications can be useful. 10' 0" wing span, 120 mph, 7.00 lb. all up weight and 20 g are not uncommon data. The following analysis relates to a particular wing but the conclusions are pertinent to wing layouts of similar proportions. For the purposes of calculation, wing loadings are considered to be uniform per unit area and will therefore approximate very closely to the actual loads encountered on this tapered wing plan form. Working stresses are directly proportional to bending moments and the diagram of bending moments can be considered as a compound pictorial illustration of working stresses along the wing span, which must be resisted by the structure, if the wing is to remain a part of the complete aircraft structure. As "g" is increased the shape of these curves remain the same but their vertical ordinates are multiplied by the "g" factor under consideration.

The wing works as a cantilever attached to the fuselage with maximum bending moments/stresses occurring at the wing root. The compound bending moments encountered in flight can be broken down into their simple constituent components for the purposes of constructing the compound moment curves. In this case there are four simple bending moment component curves to be considered.

1. The negative bending moment produced by the unballasted wing panel self weight.

2. The negative bending moment due to the wing tube mounted ballast only.

3. The parative bending moment in flight produced by the unballasted airframe.

4. The parative bending moment in flight produced by a fully ballasted airframe, with the ballast carried in the fuselage as a point load, NOT carried in the ballast tubes as a uniformly distributed load.

From the above bending moment curves, three in-flight compound Bm curves can be constructed:

A. The unballasted in-flight condition

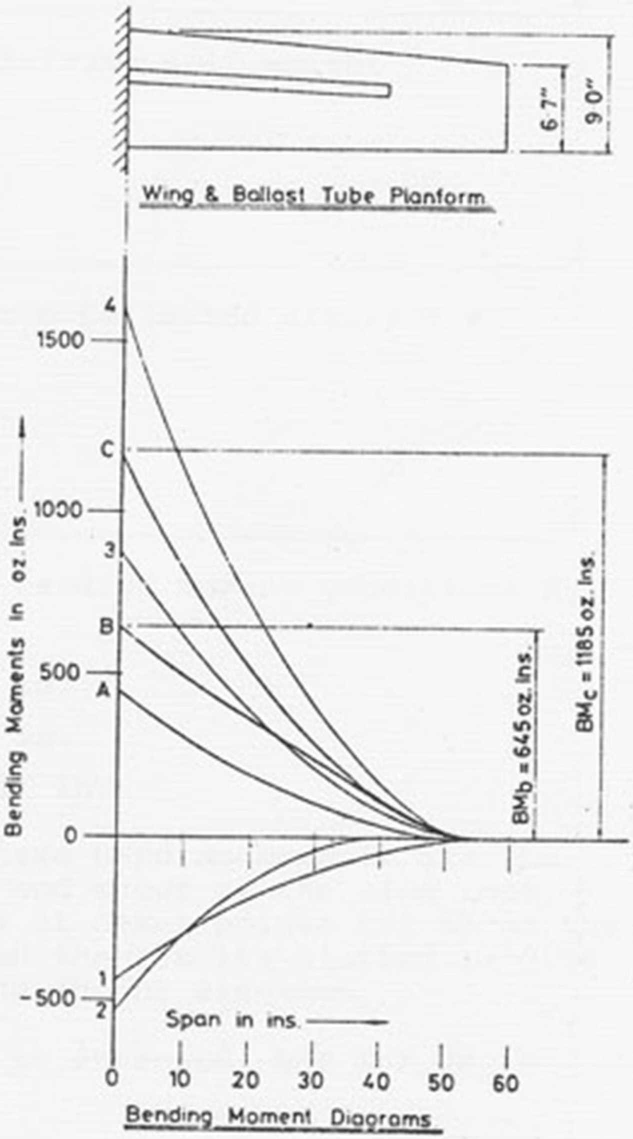
= 1 + 3

B. The ballasted in-flight condition with the same amount of ballast as C, but carried in the 40" tubular spars

= 1 + 2 + 4

C. The ballasted in-flight condition with ballast carried in the fuselage

= 1 + 4



CALCULATIONS

Dry airframe weight
= 64 oz.

Tubular mounted ballast
= 27 oz./wing panel

Dry wing panel weight
= W oz.

Lift from wing panel
= L oz.

Unit lift from wing panel
= l oz./in^2

Maximum bending moment (occurs at wing root)
= M

Wing panel self weight
= 16 oz.

Unit wing panel weight
= W oz./in^2

Now $W = \dfrac{16}{58 \times \dfrac{(9.0 + 6.7)}{2}} = 0.0351 \text{ oz/in}^2$

Now $M = \dfrac{W \times 6.7 \times 58^2}{2} + \dfrac{W \times 2.30 \times 0.5 \times 58^2}{3}$

Now M = 12.560W

Negative Bending Moment (Bm) due to wing panel self weight =

$- 12.560 \times 0.0351 = -441$ oz. in ______ 1

Negative Bending Moment due to ballast only of 27 oz. carried in 40" long tubes =

$\dfrac{-27 \times 40}{2} = -540$ oz. in ______ 2

Parative Bm due to unballasted airframe self weight =

$$\frac{64 \times 12.560}{2 \times 58 \times \dfrac{(9.0 + 6.7)}{2}}$$

= +882 oz. in ______ 3

Parative Bm due to fuselage mounted ballasted airframe =

$$\frac{(64 + 2 \times 27) \times 12.560}{2 \times 58 \times \dfrac{(9.0 + 6.7)}{2}}$$

= +1626 oz. in ______ 4

From the introduction, in-flight bending moment conditions A, B and C can now be enumerated:

A = 1 + 3 = 441 oz. in.

B = 1 + 2 + 4 = 645 oz. in.

C = 1 + 4 = 1,185 oz. in.

As stated in the introduction, these bending moments are the maximum value for each condition and occur at the wing root. The hard sums for bending moments at other points out along the wing panel have been completed and the results plotted to give each curve as drawn in the bending moment diagrams.

By mounting the ballast in tubes as arranged, the max Bm is reduced from 1185 to 645 oz. in.

Expressed in percentage this is $\dfrac{645}{1185} \times 100$ i.e. 54%

Therefore, by mounting the ballast in tubes the wing structure is effectively de-stressed by approximately half. If you prefer it the other way, the wing root stresses will be doubled if the ballast is removed from the tubes and mounted centrally in the fuselage.

'G' UP

So what! we can hear you armchair types saying (the silent majority). Well, you should know that all glider flyers do it silently, but also wisely consider the effects of gravity, 'g'.

A competitive F3B soarer will complete the speed task course at an average speed of 100 mph which also includes one 180° turn. Observation has revealed that this turn can be completed in less than one second but the average time is in the 2-3 second range. Aiming at a 1 second 100 mph 180° turn, 'g' becomes worthy of consideration.

My physics master taught me that:

$$F = \frac{Mv^2}{gr}$$

Now 100 mph = $\frac{88 \times 100}{60}$ - 147 ft/sec

Hence turn radius r = $\frac{147}{}$ = 47 ft.

Also, $g = 32 \text{ ft/sec}^2$

$M = 7.375$ lb

$r = 147$ ft/sec

$$F = \frac{7.375 \times 147^2}{32 \times 47} = 106 \text{ lb}$$

g pulled in 100 mph 1 second turn =

$$\frac{106}{7.375} = 14.37 \text{ g}$$

The other operational situation in which g must be considered is on tow. 100 lb. breaking strain line is used for launching and this line has been known to break. These breakages are probably due to local weaknesses and fishermen will tell you that a line will break at its knot with about 60% of the nominal strain load applied.

Considering maximum line pull at 60% x 100 lb = 60 lb, and remembering that this loading condition is the same as adding ballast to the fuselage (i.e., a point load) then this load will stress the wings by $\frac{60 \text{ lb} \times 1185}{645} = 110$ lb when compared with the above 100 mph turn which produces 106 lb.

You will have noticed that these two loadings are of the same order *and this observation is very important. This phenomenon* will save you a lot of trouble because if your wing structure is suspect it will fail on tow and thus save you the trouble of walking up the course to pick up the desiccated airframe. Don't worry though, either way the ground will break its fall.

MORE SUMS

Let's now examine the structural resistance to bending of a ½" outside diameter 18 swg. (48 thou) wall thickness high tensile aluminium tube.

Maximum working stresses, f, will be of the order of 30,000 lb./in^2 = 480,000 oz/in^2

The section modules zxx for this tube is

$$zxx = \frac{(R^3 - r^3)}{4}$$

Now R = 0.250" & r = 0.202"

$$zxx = \frac{(0.250^3 - 0.202^3)}{4} = 0.0170$$

The tubes resistance to bending, M = f zxx

= 480,000 x 0.0170 = 8,180 oz.ins.

Assuming that the tube receives good lateral support from the wing structure, the load carrying capability in terms of 'g' is

$$\frac{8.180 \text{ oz. ins}}{645 \text{ oz. ins. (BMb)}} = 12.7 \text{ g}$$

Therefore in the 100 mph, 14.37 'g' turn, 12.7 'g' can be supported by the tube alone leaving the wing structure to support only 1.67 g. Does this give you confidence? If an enthusiast wishes to analyze the load carrying capability, minus tube, they are to be encouraged, but I have far too much building to do, installing tubes!

SUMMARY AND CONCLUSIONS

Summing up this examination, we gain the advantages of a compound effect:

(a) The wing root bending moments are halved by carrying ballast in 40" long tubes.

(b) These same tubes give a bonus resistance to the above applied bending moments of 12.7 g.

Considering the disadvantages, these tubes have to be carefully installed and given lateral support as part of the wing structure and add 4.6 oz. in weight per panel. However, the weight can be reduced to 3.0 oz. by tapering the outer 30" of tube from 48 thou to 5 thou with no loss in overall strength.

A soarer of this nature would probably have a heavy spar system and 3.00 oz. for this facility is economical. If you must use foam wings don't forget the reluctance of the foam to motivate its passive resistance in order to provide lateral support to the tube and veneer stain, reduces its overall resistance to bending.

WEIGHT OF VARIOUS COVERING MATERIALS

	COVERING MATERIAL	WEIGHT OZ./100 in^2
1.	Yellow Coverite	.298
2.	Silkspun Coverite	.194
3.	Econokote (red)	.146
4.	Solarfilm (red)	.162
5.	Solarfilm (black)	.145
6.	Solarfilm (trans. blue)	.152
7.	Monokote (black)	.138
8.	Monokote (silver)	.141
9.	Monokote (chrome)	.141
10.	Monokote (white)	.176
11.	Flight Kote (orange)	.162
12.	Silk	.040 *
13.	Jap tissue	.028 *
14.	Brown wrapping paper (light)	.149
15.	.00025" Mylar Film	.0192
16.	.003" Drafting Mylar	.2617
17.	"35 lb." Egg Carton Foam	.393
18.	1/32" Balsa (7 lb. density)	.2025

* From an old book by R. Hoffman