Building and Flying Electric Sport Scale

Transcript of Keith Shaw's presentation
to the 1992 Electric Model Fliers of Southern Ontario
General Membership Meeting, March 1992
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Kingston, Ont.
(There have been changes made to make this easier to read and more organized. Prices quoted are U.S. dollars. Keith lives in Ann Arbor, MI)

What It Takes To Be a Successful At Building and Flying Electric Airplanes

There are four parts to SUCCESS:

1) Good equipment
2) Sensible Choices
3) Craftsmanship
4) PRACTICE

GOOD EQUIPMENT:

There is an old saying, "Buy cheap, buy twice." I know of people who have *tinkered* with electrics for years. They have purchased the cheapest motors they could find, because they didn't want to spend the money on cobalts. They spent their money trying different motors, brushes, fiddling, tinkering, trying to make things work. If you were to ask them how much they had spent trying to get their plane flying, they'd tell you about $150.00!! Compare that with spending $80.00 on a cobalt. My advice is to bite the bullet and buy the a cobalt. My advice is to bite the bullet and buy the good stuff. I have cobalts that I've had since 1978 and I'm still flying them on the original brushes. They are good investments.

The same goes for chargers. Many people are involved with seven cell airplanes. Any charger is going to run $25 to $100. An Astro Flight 112PK only runs a few dollars more and it will charge all the way up to 32 cells. For getting into larger systems, it's a good investment. It, always, has a good resale value. Some of the European charges can run $300 to $400 and I'd think twice before I bought one. Many of the Astro Flight chargers are an extremely good buy. The SR Smart Charger and TRC-6 are also good chargers.

SENSIBLE CHOICE:

A sensible choice is really important. I see a lot of failures in this category. Everyone wants the dream airplane, but they have to go through the steps to get there. At best, you can talk them into a trainer and then their second airplane is a B-17 with retracts! Always the way.

There is a point where you really need to progress and realize that the skills have to be developed and that they are not just going to magically appear. This doesn't mean that you have to stay with trainers forever. The next airplane should be a little bit more complicated and take a little more skill to fly than the first one, but be reasonable in the progression of the steps.

If you want to build a WWII fighter and you are flying trainers, the logical progression is to build some low wing tail-dragger. With this sport plane, you can get practice in taking off and landing a tail-dragger, because that's what most fighters were. A good idea is to take the power system that your dream will need but build a "trainer" for that system. Nominally the same wing area, don't bother to taper the wing if the dream plane has a mild taper. If it is a violently tapered wing, then go with a wing with a fair bit of taper to it. Make the system trainer with a small, typical sport fuselage, easy to build and easy to repair. Make it a tail-dragger and generally the same shape and size of what your dream plane would be. Fly the "trainer" for a while. Make provisions for adding ballast a bit at a time to get up to the weight that you think your scale airplane will weigh. This way you can develop the necessary skills to fly the airplane you want to build. I have, literally, an attic full of "trainers" that I've built. I'm still doing it.

If I've got a plane in mind, that is different from what I'm used to, or I have to solve some problem, I don't build the exact scale airplane. I build something that is close to it; to get all the bugs out of it. Maybe I want to play around with some strange force arrangement or it's a strange configuration that I've not flown before. I throw together one of these "trainers" in three days or a throw together one of these "trainers" in three days or a week or whatever, fly it a half a dozen times or so to learn whatever I need. Then I stick it in the attic as a radio test plane. Finally, I build the plane I really want.

I've been doing that for 35 years. These "trainers" are a very good way of picking up the skills you need, or figuring out a "different" airplane.

CRAFTSMANSHIP:

You can save a tremendous amount of weight just by making sure that every part put into the airplane does its full job. If you cut a part that doesn't fit and you use a lot of glue, or whatever, to make it work, you are adding a lot of weight that isn't doing anything better than the original part could have done with a lot less weight. If you spend some time making every part do its job, you save a lot of weight and end up with a stronger airplane.

PRACTICE:

The bottom line is just practice. Get as many hours flying as you can. Fly everything you can. Push yourself. By learning to land carefully, you can probably save half the weight of the airframe. Most the stuff that is in an airplane is to allow it to survive the "occasional" hard landing, (crash). The extra structure's weight is there just so that it can bounce off the ground once or twice. I don't mean really smashing it, just a hard landing. If you think of the model as a full size airplane, most of our landings would have the FAA all over it - "No, you can't fly it again until we check it out!" That is why our structures are so over built. You know the typical "good" landing - good approach, beautiful flare - six feet high; the airplane stalls, drops one wing, does three cartwheels, flips, goes end over end a couple of times and ends on its back. The pilot is mad because he broke a prop! Then he blames the prop manufacturer for making fragile props!

Once you get to the point where you are making decent takeoffs and landings, the structure required to hold the airplane together, through the most strenuous aerobatics, is amazingly light. Fifty percent of the weight, of most model airplanes, is so that it can survive a hard landing. To make it survive really hard landings, the weight goes up 2 or 3 times. When you get this heavy, you have to stick a glow motor on it!

You must decide where you want to go and what kind of model you're going to end up with.

complex

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complex fuselages	pattern
custom canopies	simple pylon racer
custom cowlings	sport scale
retracts	

(6 - 12 months to build)

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Sport planes are really simple. You can dress them up a bit with commercial cowlings, wheel pants, canopies, etc. A few cosmetics can make the simplest airplane look good. A few curves in the tail can make a big difference. These simple changes and additions can make a decent looking airplane out of a stick, one that doesn't look like a stik. (Ugly Stik, Sweet Stik, etc.) You have to decide where your interest is. If you're flying basic trainers, you need to ease into the more involved models.

STRUCTURES:

One of the best ways, I've found, to learn how **NOT** to build airplanes is to look at kit plane crashes and see how things fail. There are kits on the market that have built in failure modes. They put in excess weight and then they put a weak point where it will break.

Look at crashes and try to figure out exactly what it took to make the airplane break that way and then don't do that with your airplane.

When I was flying free flight, in the 50's, we had an old adage; look at what didn't break in a crash and then LIGHTEN that. It must have been too strong, and so too heavy, or it would have broken along with everything else. It sounds funny, but it's something to keep in mind. If you can look over the demolition at your club field, take a look at what survives. I don't think I have ever seen a broken tail. I know guys with walls covered in tails of broken airplanes, mounted like trophies, lined up! You can take that as a lesson. You can back off on the tail structure a bit. It will still hold together. You will often be surprised at just how far you can back off on the structure. The only reason that most planes have all that wood back there is that the kits are designed by guys who learned building kits 30 years ago! Nobody asked questions.

Every time I look at a set of plans, or look through a magazine - I find airplanes that are very simple and have some interesting structural features, some really good , some very bad. I often find some cute way of doing something that is new to me; it's lighter or it makes a part come off easier, when I want it to. I sometimes find these in the strangest places. I always read the free flight columns, especially free flight scale. There are a lot of interesting ideas in them. You have to be a little careful scaling up because we have a large battery pack parked in the middle of the structure. Despite the cautions, there is always

simple
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(note spelling)

tions, there is always something interesting to be found.

Specifics About Structure

These are the three basic premises in looking for good structures. This doesn't just apply to electrics. It can be for 200 mph pylon racers or gliders or anything you want to think about.

1) **TIE THE MOTOR, BATTERY, WING SPAR AND LANDING GEAR TOGETHER** and everything else is a shell going along for the ride. These are the places where forces occur from the outside world. The motor is obvious. The wing spar supports the lifting surface during aerobatics, takeoffs and landings. There are loads induced upon the landing gear and in the landing gear system. There are forces trying to push the gear back and out during landings. Battery mounts should be added, as the battery is a great deal of weight in proportion to the rest of the airplane. The battery has to be kept in place for all normal maneuvers, but there is no way of keeping it permanently in place. If the plane crashes, the battery **WILL** find its way to the ground. If there is anything in front of the battery, it will be struck with the force of a sledgehammer. The battery should be held in place, but provide for it to exit the airplane with a minimal amount of structural damage. It is not a good idea to mount the speed controller right in

front of the battery pack, unless you really want to support your local speed control manufacturer.

Basically, tie all these systems together and then things like the outside edges of the fuselage, the rest of the wing, the ribs, the trailing and leading edge and to a lesser extent, the tail, are "tack-ons"; the forces on them are much less. The "tack-ons" can be, in proportion, of much lighter structure. The central structure is where to invest weight in order to make the airframe stronger, not in the outside shell of the fuselage. You can home in and say, "That's the part that needs strength", and a little extra weight, say a spruce spar instead of a balsa spar, and increase the weight by a few grams but increase the strength by a factor of 3 or 4. The difference between skinning the airplane with 3/32" balsa instead of 1/16" balsa is that the airframe weight increases by 10% but the strength is only increased by .001%. It doesn't make it stronger, but it adds a lot of weight.

2) The second structural mechanics premise is: **TRIANGLES ARE STRONG**. Do everything possible with triangles. Rectangles are weak, but as soon as you make a triangle, then you maximize the strength.

3) The third thing is to **PREVENT STRESS RISERS**. A good example of a stress riser is the foot long, 1/4" dihedral braces at the main spar, the secondary spar, the leading edge and the trailing edge, all attached to 1/4"

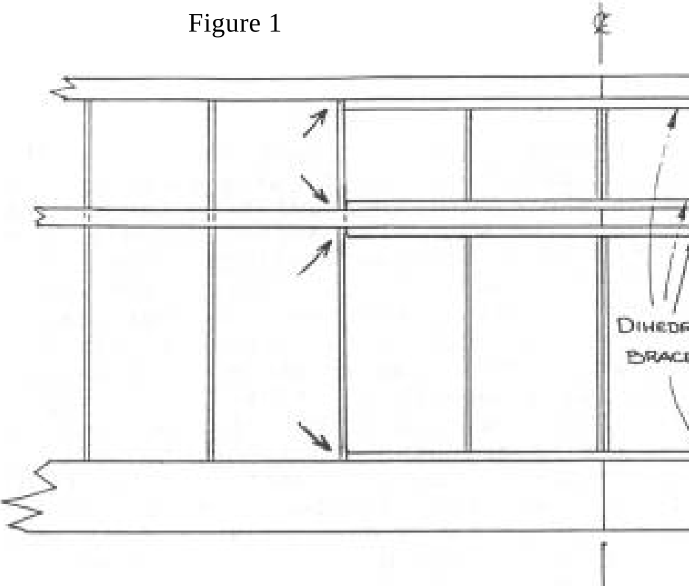
leading edge and the trailing edge, all attached to 1/4" balsa spars, etc. going out from there. The first time the wing is stressed, the only point that the wing wants to bend is right next to those braces. The entire wing is bending right at that point. (see the free standing arrows in Figure 1) The center section sure won't bend! The wing will fail right where the braces stop.

All that 1/4" ply didn't do a bit of good.

Glues:

I can't use any CA glues because of really bad

Figure 1



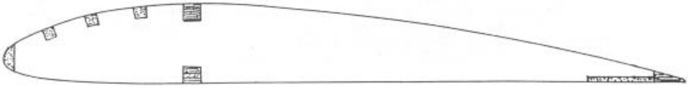
asthma, even UFO's. You should be careful around them because you can develop reactions and sensitivities to them.

For foam wings, the glue I have had the most consistent success with is Dave Brown's Sorghum. It's a thin, water-based, cement. I've tried a LOT, but this is the stuff I always come back to. The only exception to this is the high performance F5B type planes that need epoxy adhered sheeting.

Wings:

How the wings are going to be used determines their sturcture. Structures will be very different from a light, floater type glider to a moderately aerobatic sport plane, to a full, fire-breathing aerobatic plane, to a pylon racer. There are different levels of structure needed for the various stresses and strains. (Along with pylon racers, I'd put in the F5B gliders. They are basically pylon racers that have to be thermaled.) You have to decide what the goal is; what you are looking for, and then build the structure to support it.

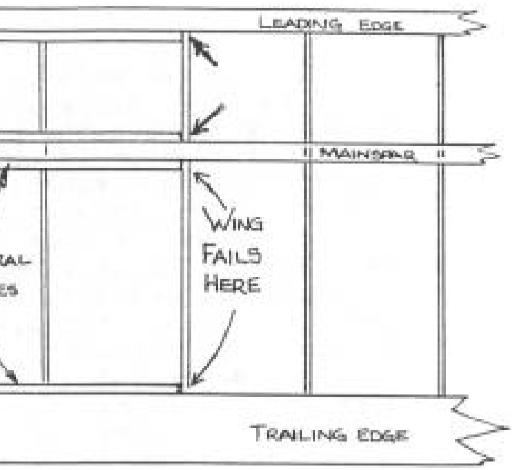
If you are flying a light floater type of glider, say a 2 meter glider with a 6 or 7 cell 05, probably the best wing is a multi-spar wing.



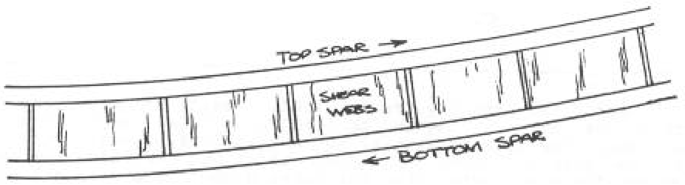
The wing structure is going to be open, keeping the

The wing structure is going to be open, keeping the sheeting to a minimum. In designing a floater type airplane, you want the absolute minimum weight. All the plane is going to do is go up and slowly descend, hoping that a thermal is going to run over it and it goes up. A typical 2 meter hasn't any penetration to speak of. Old timers are the same, they just don't have any penetration. The object is to stay up as long as possible with minimum sink. The absolute lightest structure is what is needed. Plan on never putting this airplane into a vertical dive or looping it.

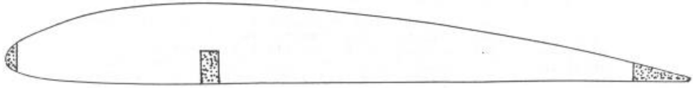
The way to do this is to use a set of spars top and bottom. The best thing to do is to put



shear webs BETWEEN the spars. An "I" beam is much, much stronger. If you think about a wing, as the tip flexes up, the two spars appear to slide in opposite directions. The shear webs prevent this.



The bottom spar is under tension while the top spar is under compression. All of the materials, typically used for models, balsa, spruce, carbon fibre, are usually 3 to 10 times stronger in tension than in compression. If you want to build a strong wing, you have to think about the materials. Many designers put just a spar on the bottom. That doesn't make sense; it should be on the top. One of the worst airfoils is:

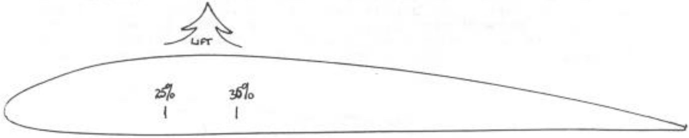


It's probably the weakest wing design. Putting the spar on top helps a little, but not much. Using a top and bottom spar with shear webs and making an "I" beam jumps the strength by factor of 10 at least. The shear webs are really important.

Even light 1/16" balsa will work wonders. Make

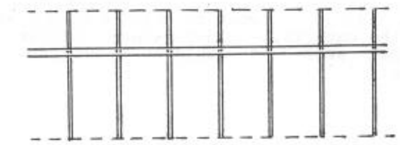
Even light 1/16" balsa will work wonders. Make sure that the grain is vertical. It's harder to cut, but they are stronger.

Put the spars at the center of lift, which, for our airfoils, is around 25% to 35% of the chord. Even though every part of the wing is providing lift, if you add all the vectors, it all magically appears as one big arrow at the 25% to 35% point, so that's where the spar goes.

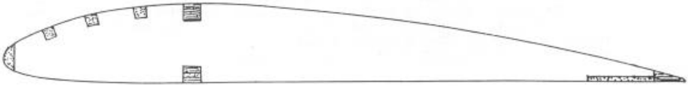


For just strictly bending loads, that's all that is needed. Just that one spar sitting in the middle. There are a couple of problems with having only ribs and an "I" beam spar. Trying to put any sort of covering on when there is no leading edge is just one. We have to stick something up at the leading edge. Everything else, other than the spar, doesn't add strength but is there to maintain the airfoil. If that was all you did, you would find the covering sagging between the ribs and the airfoil between the ribs would be nowhere near the designed foil.

In the rear half, it's not so important, but near the front of the airfoil, it needs something to shape the foil.



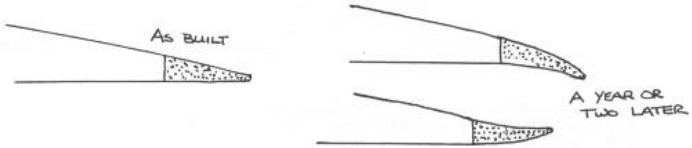
The simplest way to do is called the multi-spar.



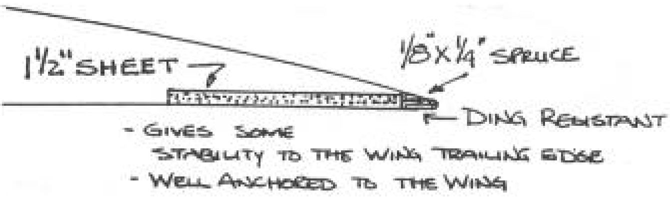
Maintenance of the airfoil is the origin of the multi-spar. Although the "spars" are usually small, typically 1/8" sq. and not real spars, they are just keeping the covering out where it belongs.

There is a little advantage in that very slow airplanes can have problems with air flow separation. The multi-spar wing helps the air follow the airfoil. A very clean airfoil, flying slowly, hasn't got enough air flowing to keep the air attached to the airfoil. Somewhere, about the middle of the airfoil, the air flow is going off making turbulent air flow over the whole wing. It means that, for all the care you took with a nice wing, the air isn't following the airfoil you chose. It's forming its own airfoil. The air flow must stay "glued down". By putting appropriate bumps on the airfoil, turbulence is induced early. It is sort of like a bunch of little marbles that make a little tiny boundary layer and the air flows over them very nicely. The "spars" act as little turbulators and give a nice efficient airfoil. Once a flows over them very nicely. The "spars" act as little turbulators and give a nice efficient airfoil. Once a plane gets up to 25 or 30 mph, they don't do anything. At 10 to 20 mph, they help a lot.

The trailing edge is where many people have a lot of trouble. Most kits use great big chunks of triangular wood, butt joined to the back of the ribs. No matter what is done, after about two seasons, the trailing edge is hanging up or down.



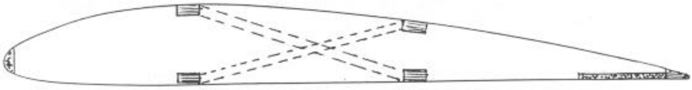
I haven't got the best solution, but what I've always done, because there isn't much strength required to hold the back of the wing straight, is to use a piece of sheet balsa, 1 1/2" wide and then, right at the back, glue on a piece of 1/8" x 1/4" spruce which I carve or sand to shape.



For light wings this works well. When dealing with cap strips, make sure the ribs are cut back so that the caps fair in with the spruce trailing edge.

Going faster and playing around with aerobatic airplanes means that, unfortunately, sheeting will have to added. This means weight, but the separation factor of a faster flying airplane, for doing aerobatics or for doing pylon racing, is not so much from bending loads, (loops or pylon turns) - the wing spars still take those - but the faster a plane goes, it sets up a chance for a thing called flutter. Flutter is caused by the turbulence going over the tips and the trailing edge. The whole wing is trying to twist. If you have ever heard it, there is a loud buzzing and, "Oh my god!", shortly followed by the wing going "BOOM!", followed by a bunch of crying.

The next level of structures are to provide torsional rigidity.



One method is to add a second set of spars and then, somehow, add some structure between them, but this

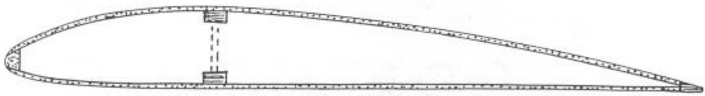
One method is to add a second set of spars and then, somehow, add some structure between them, but this adds a lot of structure and doesn't do that good of a job.

The best way is to add leading edge sheeting which, with some sort of leading edge, ties everything together.

This is a "D" tube structure. It is like a completely closed tube. If you have ever tried to twist a tube, it's pretty hard to do. This is where the torsional rigidity comes from.

If you really want to get carried away, you can close in the rear to form a double "D".

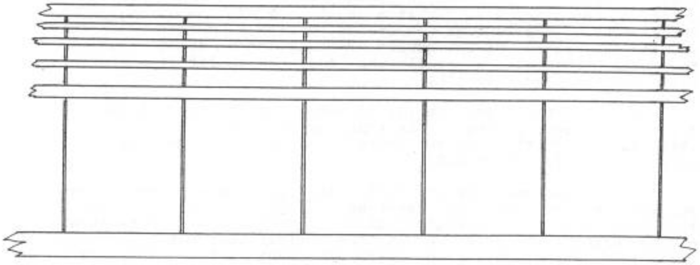
The last step is to sheet the entire wing, which is the strongest. Now the whole wing is acting like a tube.



The front "D" tube is OK for up to 70 to 80 mph airplanes. When the planes start getting faster than that, or doing heavy duty aerobatics with lots of snap rolls, the secondary spar is a good idea. After that, you go to the fully sheeted wing or go to foam with high tech stuff like CF and Kevlar.

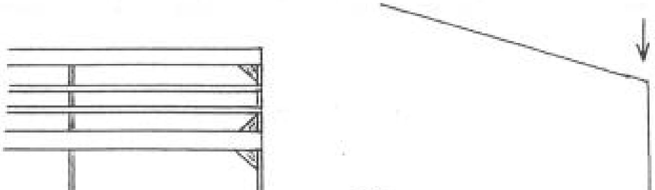
OK, that's the side view, looking at the ribs.

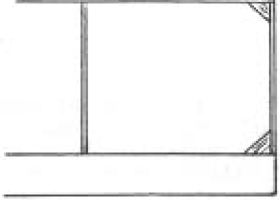
Backing up a bit to the multi-spar wing:



If you touch one wing tip on landing, the whole wing panel will try to parallelogram.

You may have seen airplanes that have made a "nice" landing (!), but every rib bay has a diagonal split and a broken rib at each spar and trailing edge joint. It still looks like a wing, but you might as well take the radio out and put the wing in the garbage. The way you solve that is really simple. Gusset the wing tips. Make sure that the gusset grain goes across the joint.





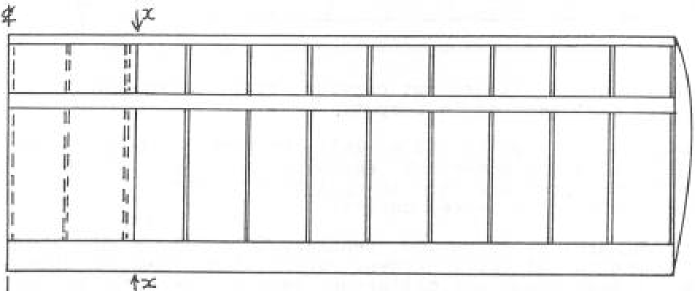
With the grain parallel to either side, it's not doing any good. As soon as there is any strain on it, the grain will split.

If you have any of those great shelving units for your basement, they use little short pieces of metal on the diagonals. That's about 90% of the strength of those units.   That's what the gusset is doing. All the wood in the center of the gusset probably isn't doing anything. You could take out of the middle and just use a little strip of balsa for the same strength.

The other thing you can do is add a lot of 1/8” diagonals. A lot of gliders do that, the Amptique does it. Anything like that adds a fraction of an ounce to a wing but decreases parallelogram failure a lot.

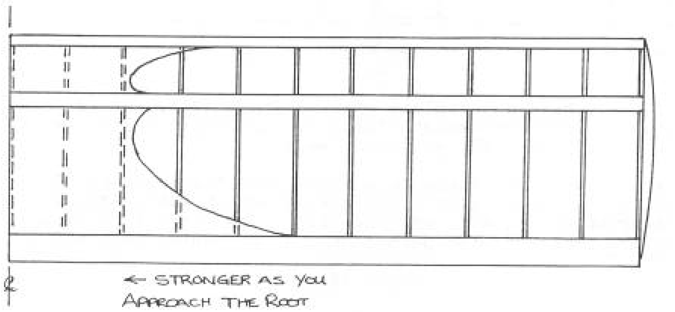
If you use Monokote or Micafilm, both have a very high surface tension. The covering is giving a tremendous amount of strength, preventing the wing from twisting or fluttering. This is why so many gliders can get away with such light structures, even if you dive them a bit. There is a lot of strength in that thin film. Solarfilm, Econokote, Black Baron, things like that, those are very soft covering materials. They give very little torsional rigidity to the structure. A strong wing is required underneath. The worst case scenario is the iron on fabrics. They are 2 to 3 times as heavy as Monokote and have less torsional rigidity. It is like covering the structure in a tent.

When sheeting a wing, the sheeting can add a lot of strength if done properly. In a simple thermal glider wing there is a big strong spar and a lot of ribs. Most gliders have the center two bays sheeted so you can put on the rubber bands. The designers stop the sheeting suddenly. That's a problem because there is something nice and strong transitioning to something that's trying to flex. If a little load is put on this wing, it breaks right on the x (see figure) . The most notorious case of this is



the performance glider design by a major west coast manufacturer. I've seen many of these planes blow up. As long as they are flying without strain on the wing, As long as they are flying without strain on the wing, they're great. Get them into a little bit of a dive, over speed them a little, so that they start to get some torsional flutter and bang. All the load ends up at the leading edge and snaps it. The wing twists and blows off. That's usually the failure mode.

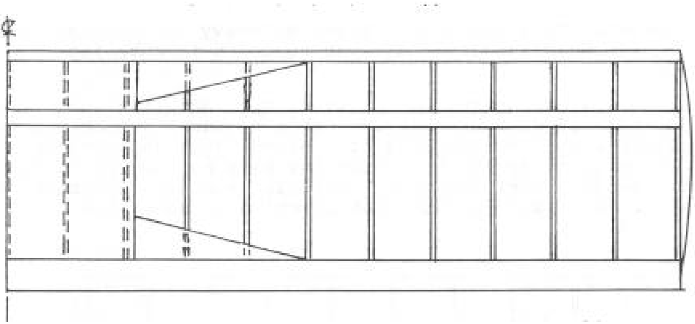
How do you solve it? You have to get around the *stress risers* by distributing the loads over the area, by cutting the sheeting to spread the loads over a couple of rib bays.



Another solution is to taper the amount of sheeting. (see figure top of next column)

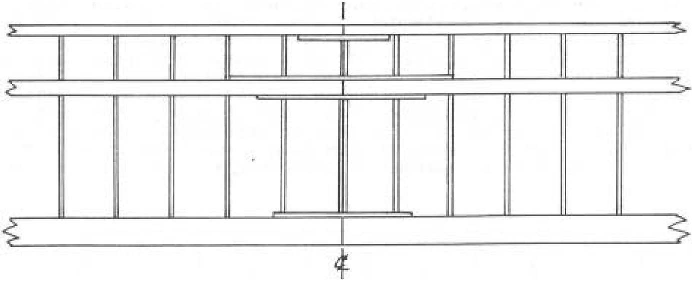
If you don't like to cut curves, straight lines are OK, just don't stop the sheeting in one spot.

If it is a full "D" tube, I'm not sure how important it is to curve the rearward sheeting. It does look nice. It also prevents that funny little "pocket" that forms in the



Monokote at a 90 degree corner.

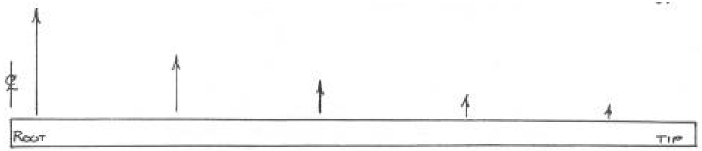
When putting in dihedral braces, don't make them all the same length. Make them all different lengths so that they're not concentrating all the stress on one part, (or in one line).



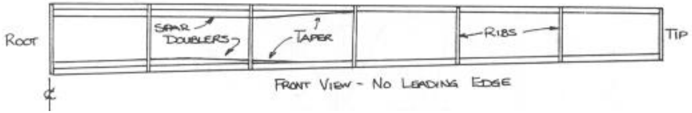
If the plane is not in need of a fully sheeted airfoil, but you are concerned about loads, you can make a tapered spar. It's a lot or work, but you might want it.

Think about the loads on a wing. The tip is supporting itself and providing lift. The next panel is

Think about the loads on a wing. The tip is supporting itself and providing lift. The next panel is providing lift and also supporting itself, and the tip. The next is lifting and also supporting the end two panels and so on, until you get to the center section which is providing lift and supporting the whole rest of the wing.



If you think about the load on the wing, the spar doesn't need to be as strong at the tip as at the center. Tapering the spar is a pain and it doesn't save much weight. If you have an extremely strong wing and want to use a "D" tube and cap strips, scarf in spar doublers for 2 or 3

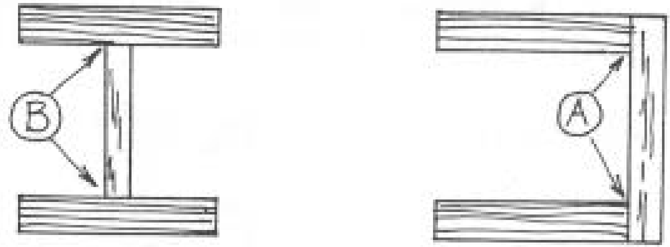


rib bays out. Taper the end to transfer the strength gently to the outer spar material at the tip. It only has to be 2 or 3 rib bays. The center section will be a little bit stronger, especially around the landing gear. That is where a lot of load is provided from landing. On most of my big airplanes and pattern airplanes, this is the spar system I use. If the upper and lower spars are 1/8" x

3/8" spruce then the doublers are 1/8" X 3/8" also.

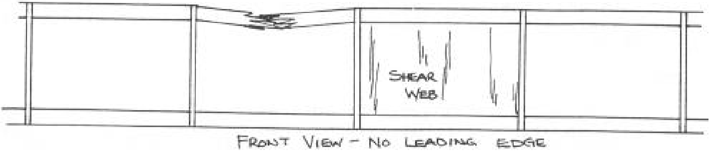
Spars:

For the best bending conditions, keep the spars thin and wide, as a cap. If you put shear webs against the face of the spar, the glue joint at "A" is in shear and



glue is not very strong in shear. There is not a lot of gluing surface. A good shear web in-between the spars is stronger, because the joint at "B" is not in shear and the glue is just there to hold it in place - not really much load on it.

If you don't have shear webs, the bottom spar doesn't fail under load. The top spar fails "out" or "in" . By putting the shear web in-between you control the breaking, to some degree.

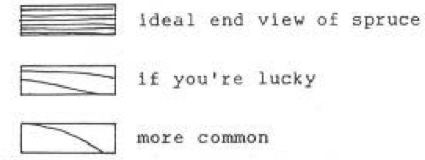


FRONT VIEW - NO LEADING EDGE

If there is one place to spend more time on craftsmanship than anywhere else, it's on making shear webbing. If it doesn't fit, pitch it and make another. It's only sheet balsa. It only takes a few minutes.

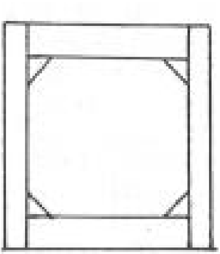
If you want to increase the spar size, you have a choice between thicker and wider, remember wide and thin is better.

There is a caveat. Spruce, that is bought in the hobby shops, is a faint memory of what we used to get. Balsa has gotten bad; spruce is worse. The good stuff is difficult to find and cut. If you can't find any, you are better off going to a square piece. You at least have some chance of the grain going in the right direction. The grain in the end of good spruce looks like a leaf spring



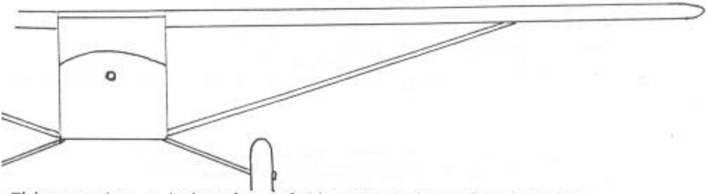
If you find shear webbing bothersome to glue between the spars, with square spars, gluing to the face is better than with flat spars. The gluing area is that much larger. The shearing effect is spread over much more of the glue joint. You can get away with it.

The strength of an “I” beam is linear to the strength of the caps, but it is the square of the distance between them. Get as much of the good stuff as far out as possible. BUT the wider the spar, the harder it is to find good wood for them. It's worthwhile, any time you are in a hobby shop, to check out the spruce rack and if you find any good stuff, even if you don't need it, BUY IT! The same holds true for 1/16" balsa. There just isn't enough out there to rely on getting it when you need it.



Box spars are used when you don't want to sheet the wing. You use wide spar caps and full webs front and back. This approximates a tube and that is rigid. A "D" tube is bigger and stiffer. On real airplanes it is used to avoid a "D" tube, (fabric covering). For models, you are better off with the "D" tube.

A note on struts: If a wing has struts, (i.e. a Cub), it's always a good idea to make them functional.



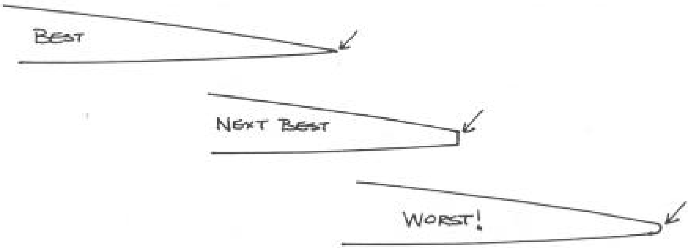
This creates a triangle and the strut is under tension.

A note on trailing edges:

This creates a triangle and the strut is under tension.

A note on trailing edges:

NACA research has shown that the perfect trailing edge is a razor sharp trailing edge. The NACA research also showed the next best was a square trailing edge, as much as 3/16" on a 12" section. The worst is a rounded off section, the way most models are done!



Foam Wings:

Foam wings can be very, very strong but are also often very heavy. It has nothing to do with the materials. It is the glue. People cut the core and bond the sheeting, and that's OK. When they put on the leading and trailing edges, instead of sanding the core smooth, so that a thin film of glue works, they gouge it and slap on about an ounce of epoxy and stick it on. They cut a big hole for the bellcrank and mount it on 1/4" ply, and use a pool of epoxy as a cure-all for their sins. THAT'S where all the weight in a foam wing comes from, adding all the other things. A carefully made foam wing, with balsa sheeting, can be as light as a built up aerobatic wing. If you are dealing with a light, floater type wing, it's senseless, but things like F5B gliders have to use foam. I believe that you couldn’t build a wing strong enough with conventional construction.

My little ducted fan uses a foam wing, 260 sq. in., with 1/16" sheet and weighs about 4 oz., which is about as light as a conventional wing could be and as strong. It just a matter of taking care to keep the amount of glue to just what is needed.

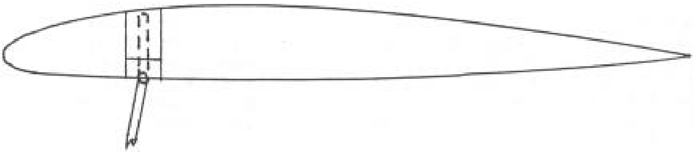
The foam is really the shear web. It's basically keeping the sheeting apart. The sheeting is the spar and the foam is just keeping it from going anywhere. The bond must be good, to stop the sheeting from popping loose. A spar is usually counterproductive, as it creates a stress riser. That means the sheeting fails near the spar. It also needs shear webbing which negates the purpose of using the foam in the first place, namely to try to minimize the internal structure.

(Going to glass or carbon fibre could be another five hour discussion.)

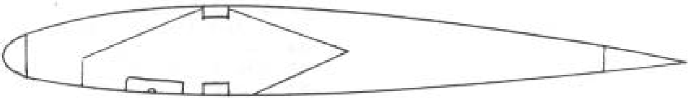
Foam wings can be used with electrics. I do it all the time, especially with high performance airplanes. You do have to be careful where you add weight. The leading and trailing edges can be made from the softest material you can find. The skin is the strength. You do material you can find. The skin is the strength. You do have to be careful. If you are the sort of person who takes the wing and throws it into the back of the car and the tool box rubs up against it on the way home and you put a good healthy crease in it - guess where it fails? That sheeting is the spar and if you damage it, you've got problems.

Wing Mounted Landing Gear

The landing gear is another area where a lot of kits and magazine articles put in an inordinate amount of weight and no strength. The wing mounted trunnion block is typically made of 3/4" solid maple, while the vertical block is too often pine or spruce. All the load is in that vertical block. The big block is just there to stop the wire from sliding back and forth on the wing.

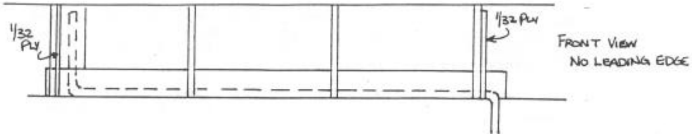


If you want to do a trunnion block set up use 1/32" ply laminated to the rib and notched to the spars. The



block, instead of maple, can be made of 3/32" ply with say 1/8" x 1/4" spruce fore and aft to stop the wire moving.

At the other end is where all the forces are going to concentrate. When you come in for a landing, the wire flexes back. The vertical block is trying to rotate out the front of the wing. If you are going to use maple anywhere, use it there.

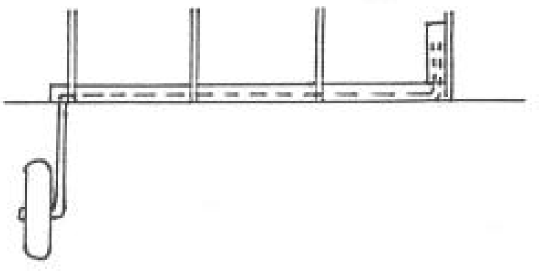


If you insist on using spruce, don't put the grain vertical, put it horizontal, so that the wire can't split the grain. The grain should run front to back on the wing and the hole for the wire goes up through this. This vertical piece is glued to the ply rib doubler on the inner end. That' where all the strength in the airplane is, at that one joint. The rest is going along only to prevent the wheel from wandering.

Retracts:

It is possible to put retracts on electrics. I have 3 or 4 now. In general, the problem is not the weight of the

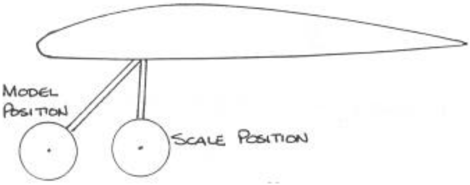
It is possible to put retracts on electrics. I have 3 or 4 now. In general, the problem is not the weight of the retracts.



With fixed landing gear you have a torsion bar, a piece of wood and plywood to support it, the wire and the wheel. You want to make it into a retract. You've still got the wheel, most of the wire, some ply facing on the ribs to distribute load. You don't have those two pieces of torsion block on a retract, instead you've got the retract unit. These are pretty light. You've got a servo in the middle to run the retracts and you've got a slight difference of weight in the retracts themselves. To give you an example, the retracts on my 40 size Spitfire cost me 3.5 ounces.

The problem with retracts is not the weight factor. Real airplanes take off from grass or pavement. In proportion, we take off from hay fields. To make most scale airplanes work, the landing gear is pushed forward so that the bending action, that the gear goes through on landing, doesn't cause the plane to land on its nose.

That gave me fits with my Mew Gull. I tried a scale

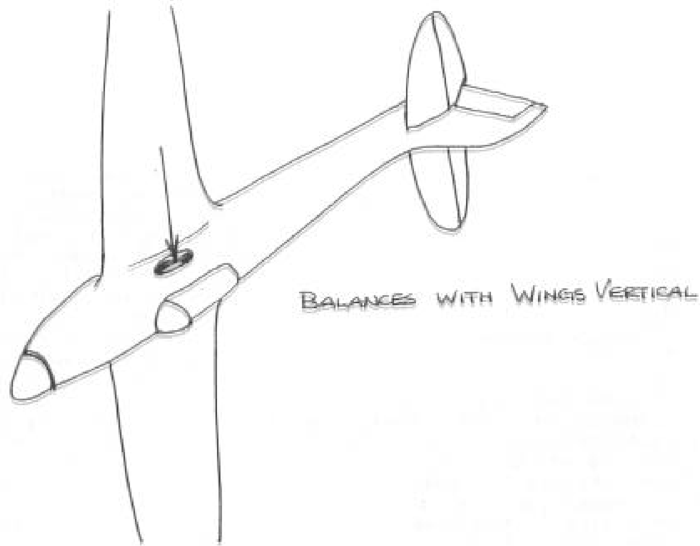


landing gear location and no matter how careful I was, no matter how much I flared, every time I came in, right up on its nose instantaneously. I don't think there was even any roll. I even put flaps on it to try to slow it down to see if I could come in to land better. I was trying to get away with a scale landing gear location. It wasn't even retracts.

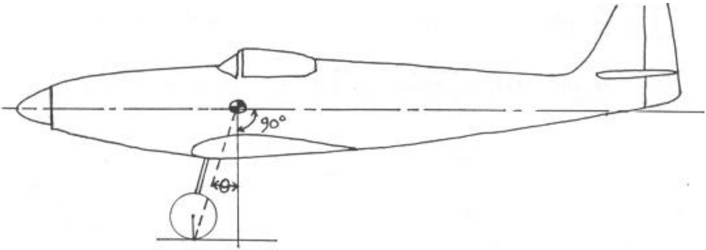
What I did was to make a new set of wheel pants and cant them forward. If you see my plane you'll notice that the center line of the wheel isn't anywhere near the center line of the wheel pant. That's the only way I got it to land.

How to get the retract unit back up into the hole in the wing is usually a problem because when the wheel returns into the wing it is at quite an angle. If you're going to go off and play with retracts make absolutely sure you know where the wheel is supposed to be.

To figure out where to put the wheel requires the vertical center of gravity. To find this, (unfortunately the airplane needs to be virtually complete), take the whole airplane and find where you have to hold the airplane with the wings vertical to balance it.



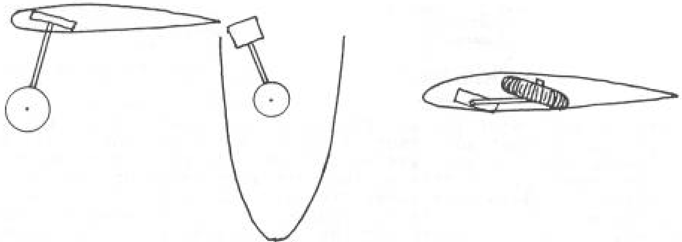
Once you have that point, draw a picture of the airplane in flying stance (see figure) and drop a line



down through the vertical center of gravity. This is the magic angle. Wherever the wheel contacts the ground is the point we are concerned with.

If you are flying off pavement, and you are only flying off pavement, you can get away with 5-10 degrees. That's what most scale airplanes are set up for. If grass, it's more like 15-20 degrees. If you're flying off a hay field, it's up around 25-30%. A lot of airplanes get into trouble if the gear is too far back even on take off. The airplane's sitting there, you add a little throttle, the nose goes down so full elevator is applied. The airplane somehow walks away. In order to keep the plane from going over, it requires holding full power and full elevator. Guess what? The airplane floats off the ground in full stall, snap rolls and goes in. It never got into flying stance. It causes a lot of crashes because the gear is so far back that you are having to balance the airplane.

In general, with 40-60 size airplanes, you can probably put in retracts with no trouble because you can play with the geometry to get the gear up and down.



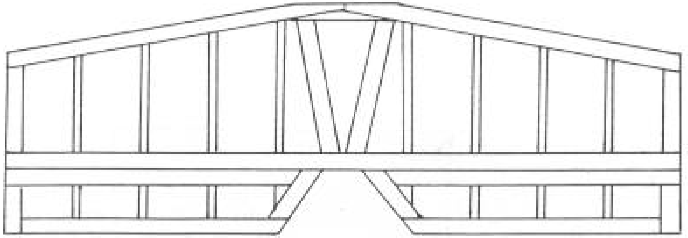
With 15 size and smaller, it's probably not such a good idea. You are dealing with a wheel so small in proportion to the grass that they have to be awfully far forward and therefore difficult to get off the ground.

In order to get the wheels to retract back and up, it's an intricate set of geometry. You end up having to tilt the retracts forward and out.

Retracts are really nice if you really have to have them. You'll spend a lot of time getting take offs and landings down right. Sometimes it adds so much trouble that you don't like the airplane.

Tail Surfaces

Remember I said that tail surfaces are over built? When not dealing with a scale airplane, with specific rib locations, it's a classic case of where triangulated structures add a tremendous amount of strength for the same weight.



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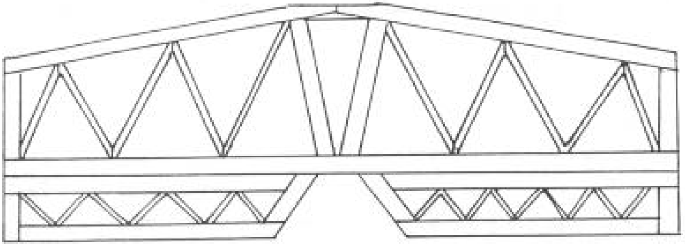
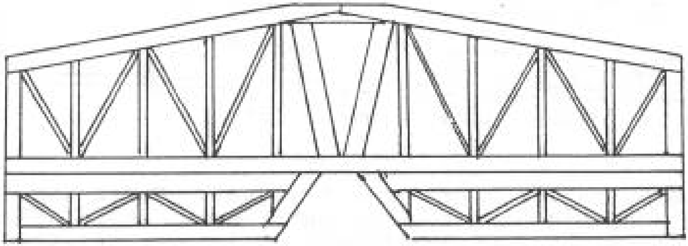


If you're worried about having the lumps showing through the covering, you can use a combination of these two. Put in the needed ribs and put in 1/8" x 1/16" diagonals that don't touch the covering.

This gives geodesic strength and the right appearance, using triangles.



In the tail there is probably only one piece that has to have a little strength added. Most of the plans and kits I've seen just make the tail out of heavy wood. Sometimes it is sheeted. This type of stab often fails. The reason is that the tail isn't the whole story. There is a fuselage in there.

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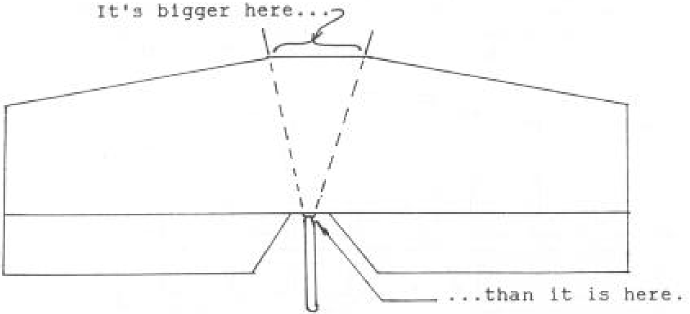
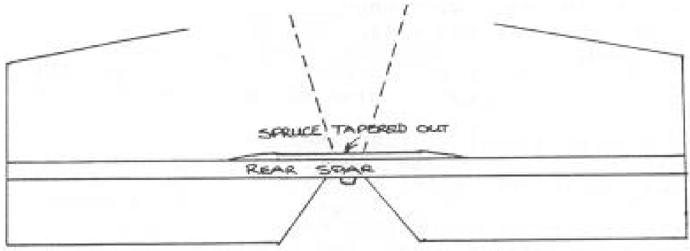


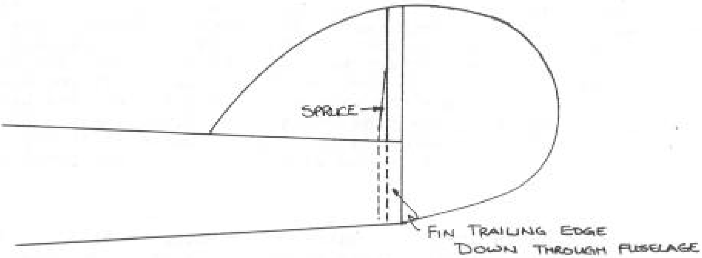
Moving the elevator is causing loads on the tail. Most of the load is caused by deflecting the surface, not because there is an air load on it. The forces are occurring at the back of the stab, which is sitting on the narrow end of the fuselage. The stab is flexing up and down at the rear. There is a stress riser where the stab rests on the fuselage. That's where the stab fails. It cracks and the stab fails. A cure for this problem is a piece of 1/8" X 1/4"' spruce tapered out at the ends. It adds a gram or two and increases the strength by 100 - 200%, even for a fully sheeted stab, it adds a lot of strength. (see figure top of next column)

Vertical stabs can be done the same way. Lots of airplanes have the tail glued on top of the fuselage.

When building the fin, continue the trailing edge of

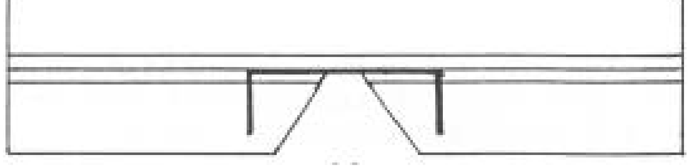


the fin down through the fuselage. Reinforce this with a small piece of spruce, tapered to avoid a stress riser.



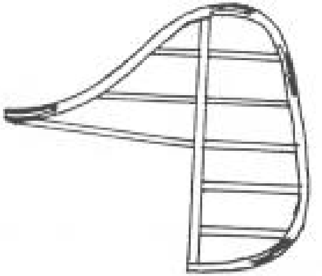
Little tiny pieces do wonders.

Make the elevator spar continuous through both sides. Make both sides as one piece and tack glue it to the stab. It's all one piece. It is carved and sanded and then the two parts are popped apart. I always set in a piece of block on both sides of the elevator.



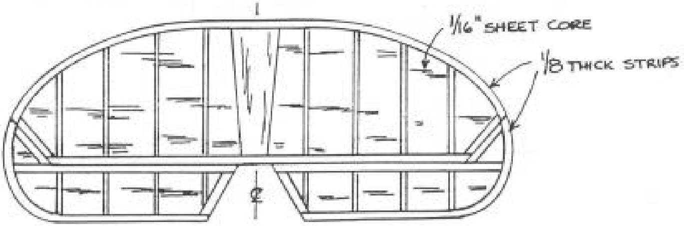
Take a piece of wire (small airplane 1/16", medium 3/32", large 1/8") and make up a "U". Slot it into the two halves while they are still attached to each other. When you are done, you can cut it apart. Glue the stab in and finish the sheeting. You can still fish the wire through the fuselage when you're finished. Glue on the elevators with epoxy when everything is lined up nice and straight. It seems to work pretty well. Keeping wood in there makes sure that everything is straight when you make the final attachment.

Some planes require different ways of doing things. Sometimes you have to run two push rods and horns to 2 separate halves.

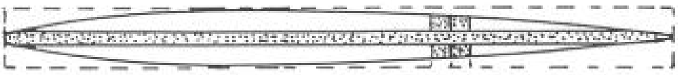


To make a curved tail outline with straight pieces is a pain. Making a laminated tail is easier. Use a piece of ply or foamboard, and under cut the outside dimensions by about 1/4". Cut strips of 1/16" X 1/4" balsa and stack it up with white glue between the laminations, wrap it around the ply or foamboard form and tape it in place. Let it dry, take the tape off, pin it down and fill in inner structures. You can use 1/32" strip for the really small airplanes. It is very strong, like eggs and circles. It weighs virtually nothing.

If you don't want to do all that, you can use the "core" method.



Turn it over and repeat on the other side. Then sand it to section.

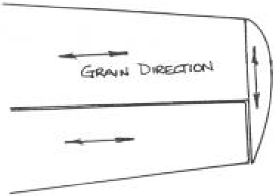


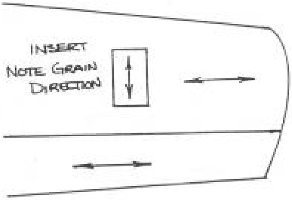
A lot or people think that by cutting a bunch of lightening holes they are cutting a lot of weight. If you add it all up, you save a few grams and end up with a floppy piece of sheet. It probably isn't worth it. The same is true for ribs. It's unbelievable how little weight you save. It looks nice, but that's about it. That doesn't mean that you shouldn't lighten that great big piece of 1/4" ply, but for typical lightening of balsa, it's usually

1/4" ply, but for typical lightening of balsa, it's usually not worth it.

Small planes don't need a built up tail. Use sheet balsa. Use "C" grain. It's that speckled, very stiff stock. My little Shrike has that. It is very stiff for its weight. It gives strength and torsional rigidity. This is the place you use "C" grain. It doesn't bend very well, so of course that's what you get in kits for wing sheeting or fuselage sides!

On small airplanes a sheet balsa tail is not a bad idea. If you are using a sheet balsa tail and you're worried that it's going to warp, you can add tips of balsa with the grain going the opposite direction. This prevents the sheet from cupping. Another ancient trick is to cut a slot in the middle of the panel and let in a small piece of balsa with the grain going the other way. If you know that one, you're showing your age.





These are both ways of dealing with a sheet tail. On small airplanes, (250 to 300 sq.in.), you'd probably end up heavier with a built up tail. It would be thicker and therefore cause more drag.

FUSELAGE:

This is the single biggest piece of structure that people over build.

A lot of old timer kits and plans knew what they were doing when it came to wings and tails. The wings were beautifully designed. The tails were works of art. Unfortunately, the fuselages were built like baseball bats. The reason was that they were built to crash half a dozen times before they were trimmed out. We don't have to worry about that, ("It says here in small print").

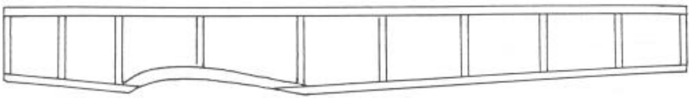
Fuselages are one place to save a lot of weight. Unfortunately, it depends on what you want to do with the fuselage. If it's a sport plane (it doesn't matter what size it is) you can get away with sheet balsa and a few stiffeners. With 05's, use 1/16" sheet balsa sides and 1/8" sq. in the corners. For 25 to 40 use 3/32" sheet with simple cross bracing and 1/16" sheet top add bottom, cross grained, and you're done.

If you're talking about big scale fuselages, try doing the same thing and it weighs a ton. As the size goes up, the volume goes up as a cube. The fuselage becomes very heavy, so you have to look at other ways to do the realistic or scale structures.

The following is more for realistic or scale structures.

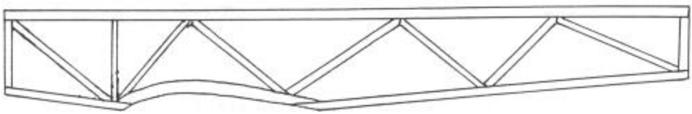
structures.

The simplest way is the old box type old timer structure.

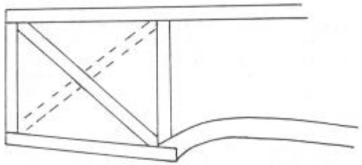


Then you put in cross braces, jig the whole thing and cover it up. That's okay, but remember the triangles.

You're better off with diagonal braces.

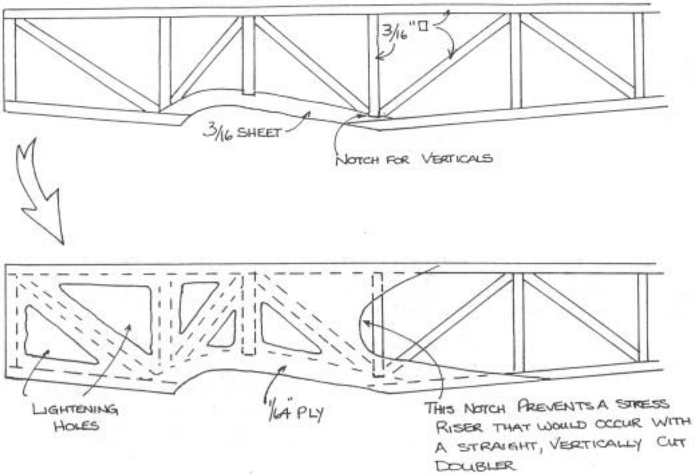


Even with verticals at the bulkhead position, you want to add a little strength so put in a diagonal like this:

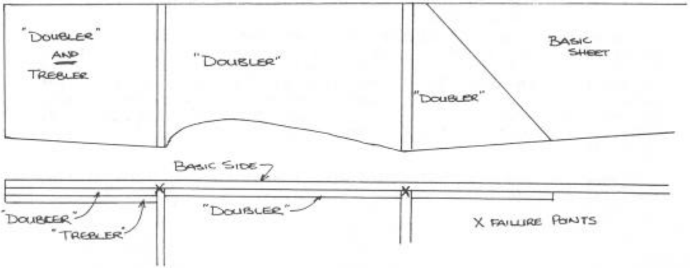


If you think about it, as you come into land, the motor wants to continue down and this diagonal, in compression, prevents the bay from parallelogramming. The triangle is doing its job. You can also put one going the other way.

Another thing that you can add for very little weight, but a tremendous amount of strength in the front end is 1/64" plywood.



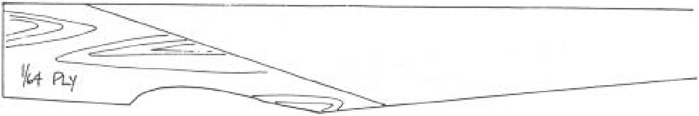
Many kits use a very poor design for fuselage construction.



With the above construction, the plane comes in, bounces and breaks. There you have it - a fishead, lying on the flying field.

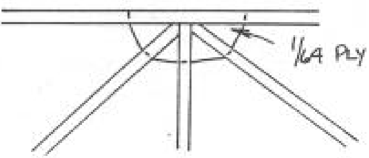
bounces and breaks. There you have it - a fishead, lying on the flying field.

You're better off using 1/64" ply like this.

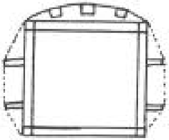


If you think you need extra strength, this is the way to go. The nice thing is that every square inch of this 1/64" ply can be used. Save everything for gussets and local strengthening. Never throw any away. The smallest pieces can be used.

If you are building a truss structure style fuselage, and you want to make it bulletproof, take 1/64" ply and gusset the inside of all joints. It adds hardly anything to the weight, but adds a tremendous amount of strength.



This is OK for box fuselages.



The method to the side is okay for box fuselages. In a lot of old timers, boxes are fine. Then you can add some formers and stringers and it looks a little nicer and you can get some really attractive fuselages.

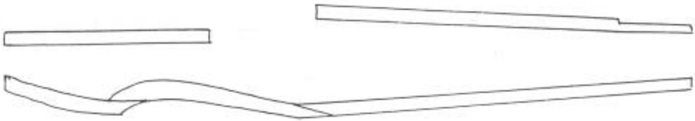
Sometimes the structures get more complicated and you can get carried away and park great big sheets of balsa as formers and stringers or sheeting. The basic truss structure box is redundant as the outside of the fuselage is not taking all the loads and the stress. The structure never sees any load. When the outside structure fails long before the inner sees the load, suddenly the load shifts to the inner structure and it fails instantly.

When you see huge bulkheads with a small box in the middle, it's time to redesign.

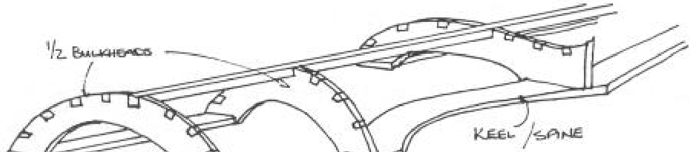
Half-shell:

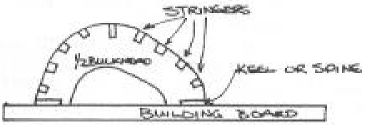
This is an old free flight method. I love building on a half shell, or crutch, which is similar.

First lay down a spine:



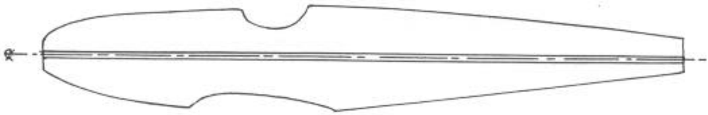
Make all bulkheads in two pieces and glue the bulkheads to the keel. Then add the stringers.

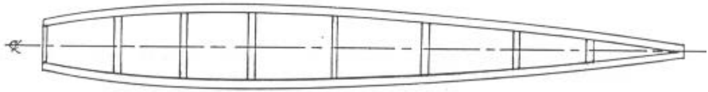




Essentially you are building a complete half of the fuselage. After finishing it, unpin it from the board, add the remaining bulkheads and the remaining stringers. If everything was done properly, it should end up straight. This is building on the half shell. The Mew Gull and the Spitfire were done this way.

A method similar to this is using a crutch. When building a fuselage that is normally a great big circle , and you don't want to build on the half shell, this method works well if the original airplane was built with the inside on some sort of tubing framework, but the outside is more streamlined. Use a datum line as the





basis for a crutch. It even looks like a crutch.

Basically, it is two pieces of spruce, say 1/8" x 3/8", with a bunch of lightweight cross braces to hold the shape.

All the bulkheads are glued to this. Cut the bulkheads in half, glue all the bottom (or top) halves in place. Then you can set your wing saddle arrangement and stringers. Take it off the board, add the other side's pieces to finish it off.

This technique is really great for biplanes because the crutch is used as a reference for the cabane struts. The mounting blocks can be adjusted, the struts added, top wing mounted and everything jigged straight. Glue on the last pieces and finish the stringers. There's a nice hard surface to work on, and because you build it flat on the board, it is FLAT! The board and crutch are now good reference points to measure everything for the wing. The Gee Bee and the Stearman were done this way.

When building truss structures, spend time on the longerons. It's worthwhile making them from spruce, not so much for strength but, because sooner or later you're going to come in from a nice day of flying and you're going to put the fuselage down on something on you're going to put the fuselage down on something on the workbench and the balsa longerons will break. If you don't want to go to full spruce, you can go to a laminate of spruce and balsa, especially if the longerons are curved. It's a lot easier to bend two pieces and glue them together than to use one large piece. Use carpenter's glue and pin it down. Once it's built there is no stress transmitted to the other parts. The best thing, when making up structures, is to have every piece remain curved if taken out of the structure. The fuselage side and stringers should remain curved. When parts are pulled together, stressing them with great big clamps, then preloading of the structure occurs, so much that if hit lightly, it could fail because the structure is already close to breaking, due to the preloaded stress.

When working with large bulkheads, many people cut the middle out, forming a ring. No matter how the grain is arranged, somehow it's going to break. Two pieces of balsa could be glued together like balsa ply, but it's a pain.

There is a wonderful material called foamboard. It can be purchased at art stores. It's basically 3/16" foam with index card bonded to both sides. It has no apparent grain. Therefore, great big holes can be cut out of it. It weighs about the same as 3/32" balsa. It's a little thicker. Virtually every single airplane I fly has bulkheads made of foamboard. A great big sheet works out to about $3.00. That is enough to do a lot of bulkheads on a lot of airplanes. The only drawback is that you MUST use RC56 glue. I haven't cut a balsa bulkhead in many, many years. I just don't know how to cut balsa bulkheads without grain fractures.

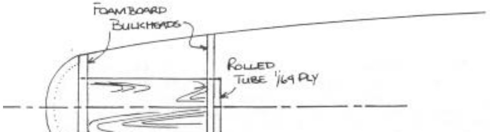
Don't get the plastic covered foam. The plastic covered stuff suffers from some funny failures with age. Remember that foamboard is great material to play with.

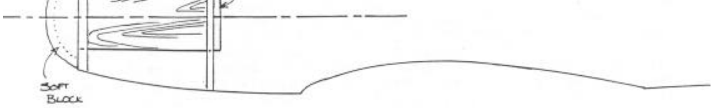
Weldbond also sticks to the foamboard. If you use epoxy or typical white glues, it makes a very hard joint, causing a delamination failure. Weldbond All Purpose Adhesive, (identical to RC56), can be purchased from a hardware store. It's a milky white liquid that smells a little like vinyl. It's actually a polymer. You can use that to glue the foamboard to the balsa.

The bulkheads can be cut on a band saw. Just treat it like balsa. On great big airplanes, I've used it for ribs - I mean 14 foot wingspan.

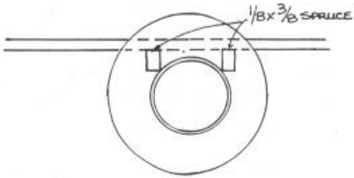
In the forward fuselage there are usually enough stringers for strength. Use some sort of balsa block for the nose with another bulkhead just aft.

I'm a big fan of the rolled up tube of 1/64" ply that the motor is pushed into. I don't usually try to reinforce





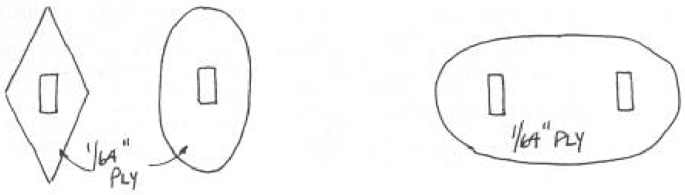
any more than that. Remember to tie the battery pack, the motor, the spar and the landing gear together. With foamboard half shell fuselages, on every bulkhead, somewhere in the middle, like with the crutch, set up a place where there is going to be a pair of lengthwise 1/8" x 3/8" pieces of spruce. This goes back and becomes the stabilizer seat and also ties into the motor tube.



The spruce is also a strong sport for hanging the battery pack.

All of the outer structure is gong along for the ride. It is just there to make the model look like a real airplane. The inner structure is carrying the load.

Since the bulkheads are load bearing, face small areas of the bulkheads with 1/64" ply to help carry the



load. The load goes from the strips to the 1/64" ply and is transmitted across a larger surface of the foam board, tying them together, distributing the load.

Because electric motors have virtually no vibration, it really doesn't take much structure for the motor. When using a speed controller, the start and stop are smooth. Using an on/off switch limits you to about a 15. Hard starting a 25 with a gearbox and a large prop will probably break every glue joint in the airplane.

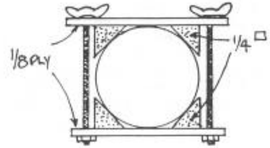
As an example - I was testing the forerunner of the Astro Flight 25 in a pattern plane about 1981. I was coming out of a dive to gain altitude, trying to do what may have been the first vertical 8 with an electric, and at the bottom of the dive, one of the tangs on the commutator popped straight up. The motor stopped in about a 1/2 a turn with a loud CLUNK! The front of the airplane was literally turned upside down. Every glue joint was broken; it was hanging on by a couple of pieces of Monokote and the motor wires. There was a lot of energy in that motor when it decelerated that fast.

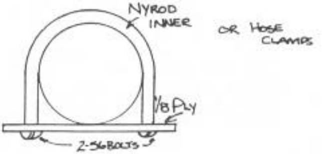
A speed controller starts and stops smoothly, so it's not that much of a problem. Trying to hard start some of the larger motors is NOT a good idea.

MOTOR MOUNTS:

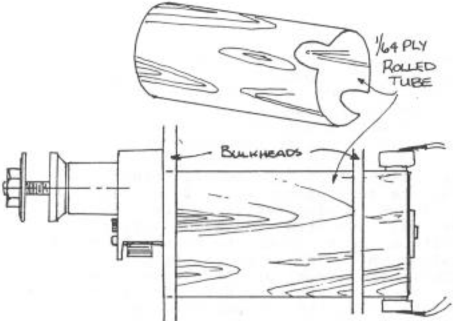
These depend upon the power levels you are dealing with. When using ferrite can-type motors, almost anything will work.

anything will work.





I prefer the rolled up 1/64" ply tube. I use Astro Flight cobalts in almost every airplane I have. The first reason is quality. The second is the price. They are about 1/2 the price of the European motors, or less. The third being that you can get the parts locally or send it back to "Uncle Bob" and he fixes if up for you.



Make the tube the length of the motor and cut slots for the brush housings. The slots act as an anti-rotation device.

Another trick is to trap the motor with the gearbox. The motor can't move back and forth. Without the gear box, a snug fit is achieved by putting a strip of masking tape on the motor and pushing it into the motor mount for a snug friction fit.

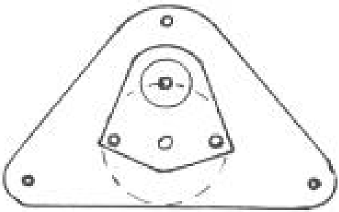
Astro Flight makes a nice little plastic motor mount. It's like a tube mounted on a plastic backplate mounted to a firewall. They work out very well. The motor is held in with a locking screw. For smaller motors, SonicTronics makes a nice little mount that sort of clamps the motor with the wraps. The SonicTronics mount is rated for a 15 as maximum. Originally, it was designed for ferrite 05's.

Obviously, with electric motors, you don't have any vibrations. The great big mounts made like gas engine metal mounts, aren't such a good idea. I once saw an aluminum mount that looked like it was for a .60 glow on the front of an airplane. It had an 05 in it. The motor mount probably weighed 8 Oz. at least. That's too heavy.

When dealing with 250 watts and up, use tubes and other types of mounts. The commercial sport mounts are designed for relatively low power motors.

If the motor has threaded bolt holes in the front, for direct drive, you can bolt the motor directly to the plywood firewall. A different method is used for gear boxes, where you can't bolt the motor in directly. The 60 on the Mew Gull is bolted directly to the ply bulkhead. I also have a supporting bulkhead in the back. (The 60 weighs 24 oz. That's a little heavy for just the forward bolts.) The gear box and motor should be on the same side of the firewall. The motor and gear be on the same side of the firewall. The motor and gear box should not be separated by plywood because the plywood compresses, which will allow the gearbox and motor to loosen up with time. When the bolts are tightened, there is a lot of compressive force applied. Even worse is a hard spot in the plywood which results in a crooked mounting which is very hard on the gears.

I have, a couple of times, with special purpose airplanes, made something out of 1/16" sheet metal and trapped it between the motor and the gearbox. That was before I figured out the 1/64" plywood tube and trapping the gearbox with it that.



If you believe that you have to make a lot of motor thrust adjustments, either you have the angle between the wing and the tail way off (that's why downthrust is needed), or you haven't learned to fly rudder finesse (that's why side thrust is needed). Putting rudder offset in an airplane is done because you haven't learned how to use your left thumb. With a plane that is trimmed to fly perfectly straight, as soon as it gets out of that straight line, rudder correction is needed.

There are ways of minimizing things so that if you don't use rudder, you hardly see it. But, in reality, you need that rudder finesse to really fly airplanes correctly. Coordinated rudder is what you call it for level flight. Finesse is used when doing aerobatics. During a loop, even the most perfectly built airplane really should have rudder and aileron corrections all the way around the loop. When an airplane is flying fast, that disturbance is only a few inches, but in truth, the corrections still need to be done. The faster the plane flies, the less the correction that will be needed. There is no way of building an airplane, with a rotating prop, and getting it to fly dead straight through all maneuvers and speed ranges.

Motor cooling:

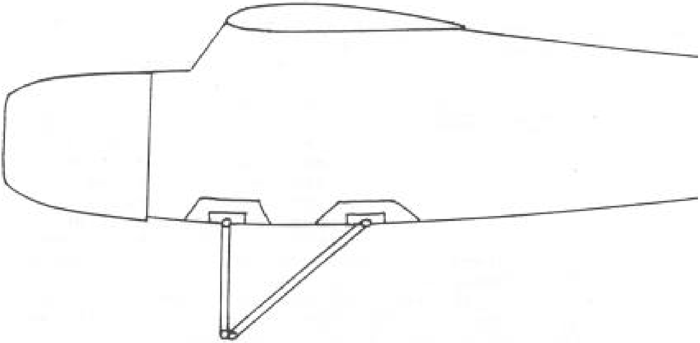
The amount of cooling required by a cobalt is not worth considering unless you go out with 16 battery packs charged. Don't laugh. We have a guy, Dave Grife, in our club like that. He shows up with a plane, transmitter, and a backpack and it's ZOOM, ZOOM ZOOM, one flight after another. I went over and touched his motor between flights and it must have been about 400 degrees (Uh, Dave, I think you should let it cool off.) I couldn't believe how hot it got because he never let it cool off; he literally flew continuously for 2 hours, my frequency too.

If you are going to do something like that, yes, try to get a draft to the motor to help it cool off.

LANDING GEAR: (fuselage mounted)

LANDING GEAR: (fuselage mounted)

In many construction articles and kits they try to make a nice light plane and then use a piece of 1/4" thick sheet metal landing gear with razor sharp edges. I don't believe this is a good idea. A better way is to make up two of those little trunnion blocks, like used in wing mounted landing gear, and then mount the gear to the bottom of the plane. If the bottom keel piece is gong through there, glue some pieces up around it to tie things together. Run twin wires out and make one of them the axle.

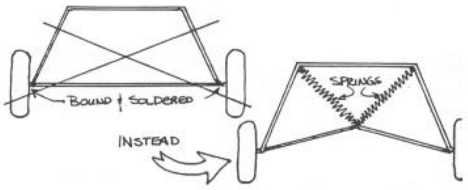


Like the trunnion block gear, this type also flexes out. Smaller diameter wire can be used than with the torsion bar landing gear of the wing. Use 1/8", 5/32", or 3/16" (for big planes), in wing torsion bar gear while 3/32" or 1/8" will work with this type of fuselage gear.

There are all sorts of variations on this and different ways of doing it, but this is a pretty good landing gear.

With this type of gear, the load is mostly taken by the landing gear flexing out and up, but if you hit really hard, it will try to rip out of the fuselage. That's were the reinforcing ply around the blocks goes to work.

Tying the gear together in a triangle defeats the purpose of the landing gear shock absorption. If you do want to tie the gear together, never go straight across. Instead, lash a rubber band or springs to take some of the load. The landing gear shouldn't be completely rigid, but you don't want it to jackrabbit down the field either.



Most sheet metal gear is either too soft, and the flattens on impact, or it is too rigid and doesn't provide shock absorption.

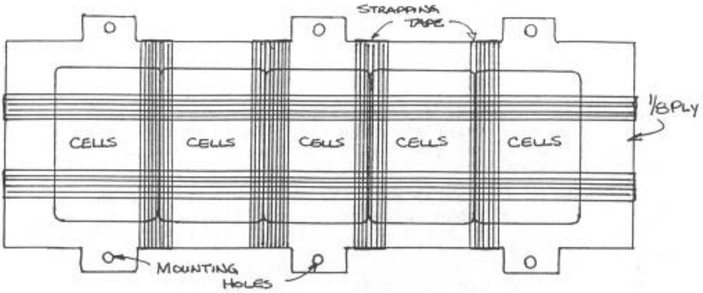
Battery Mounts:

In small airplanes, a piece of Velcro on the balsa fuselage bottom with another on the battery works well on 6 or 7 cell packs. It is not a good idea on 32 cell packs.

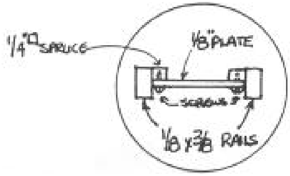
A hidden advantage of electrics is that **lead never has to be added** to achieve proper balance. Moving the

has to be added to achieve proper balance. Moving the battery pack about a 1/2 inch can get almost anything to balance. About 1/3 of the weight of the airplane is the battery. It doesn't have to moved far to balance the center of gravity.

Admittedly, I play with a lot of big airplanes, you might have to modify this a bit for small ones. I take 1/8 ply and make a plate and stack my cells like cord wood on it and hold everything together with winds of strapping tape.



Remember those two horizontal spruce rails in the fuselage? In the battery area, I glue 1/4 inch spruce to them to allow the plate to slide in and be able to be moved back and forth. By putting a number of holes in these rails the plate can slide back and forth to change the center of gravity.

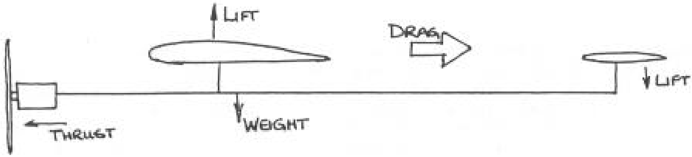


When the correct balance is achieved the plate can be secured with screws.

Fine tuning the CG

As the airplane gets close to its perfect center of gravity, the drag of the airplane drops dramatically, which means it takes less power to fly. Flying an abnormally nose heavy airplane, burns an extra 20% power just to counteract the nose heaviness.

It's the old weigh/lift/thrust/drag problem. Normally,



an airfoil creates drag which we can't get away from, but it also creates a pitching movement, which, with most airfoils, tires to push the nose down. In a glide, a typical flat bottomed wing will try to do a half outside loop. Symmetrical airfoils glide beautifully. For flat bottomed wings, something is usually done with the horizontal stabilizer. A lot of gliders get carried away and stick the stabilizer on at a drastic leading edge down attitude. This acts like up elevator which lifts the nose.

That's all well and good, but in order to get that to work, the center of gravity is fairly far forward, so that the airplane has a chance of flying. It becomes like a beam balance. The wing is creating lift and drag. The beam balance. The wing is creating lift and drag. The tail is also creating lift and drag but the lift is all down. That's the wrong way. The wing is lifting the whole airplane, so that if there is a pound of lift pulling the tail down, the wing needs to lift an extra pound, which increases its drag. Reducing the downward lift at the tail to just a little downward lift, which you need to counteract the wing pitching moment, can get the center of gravity back further on the wing and get the beam balance equation to work more efficiently. The tail is creating less downward lift, therefore less drag. The wing doesn't have to lift as much, so its drag drops. The drag of the airplane becomes reasonable.

An airplane with a lot of negative tail incidence, and the CG well forward, will glide at only one speed. If it goes any faster, it will try to loop. When the plane comes out of a stall, it will drop quite a ways before it recovers.

Where should the CG be? First, set up the CG according to your plans. Then, there are several tests you can make, aerodynamically, to find out what your CG is like. These tests are based on the idea that the angle between the wing and the tail is reasonable. You

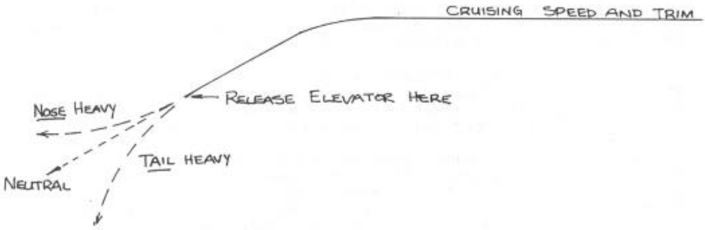
rarely need more than 2 degrees.

It sounds funny, but almost no matter what you do, the airplane will try to fly with the stab level. There are a few exceptions like biplanes.

A plane flying in the 30 to 50 mph range, probably needs 2 degrees difference between the wing and the tail. For a plane in the 20 mph range, it could be 3 degrees. At 100 mph, you only need 1/2 degree or even none at all. I've seen gliders with 5 to 7 degrees. Why they have it, I have no idea.

Assuming even semi-good wing and tail angles, a quick way of finding the optimal CG is to pull back to 1/2 throttle at altitude. Fly well above the minimum glide speed - cruising speed. Make several passes up and down thefield, at several hundred feet, playing with the elevator trim until the airplane flies level with no transmitter inputs.

Leave the throttle alone, but force a 30 to 40 degree dive. When the plane has gained a 20% to 30% increase in speed, (say 50 ft. or so), so that it's accelerating, take your thumb off the stick. If the airplane continues on straight, (hopefully not for very long!), it's at the lateral perfect center of gravity. It is neutrally stable. The airplane doesn't change direction, it just keeps on going. Ideally, I shoot for something that is just slightly trying to pull up, slightly positively stable.



If the stick is released, and the airplane tries to do a half loop, the airplane is very **NOSE HEAVY**. When the airplane picks up speed, the negative incidence, (or slight up elevator trim), acts like up elevator and will try to make the plane loop. (The increased speed makes the trim have more effect.) As the CG is moved back, there is less of a downward load on the tail, so speed has little or no effect.

On the other had, if the airplane dives steeply, it's **TAIL HEAVY**. If the CG is well back, the tail actually has to provide positive lift to balance. When the airplane flies faster, the tail lifts more and the dive is increased.

If the airplane always does a loop on the test, or has a 6 or 7 degree differential, put the CG further back, and reduce the difference to 3 to 4 degrees. That should add quite a bit of duration to the flight because of the reduced drag on the airplane.

Old timers, with lifting stabs, often have the CG around 70%. My Zomby trims out at almost 70% of the cord from the leading edge. It's way back!

Often, many of the old designers didn't mark the CG on their plans, simply because they didn't know either! They would say, "Balance to suit and get a good glide." ("When you've got it, call us and let us know!")

Old timers are very draggy airplanes. There is nothing that can be done to clean them up. Unfortunately, many had a tremendously bad force layout because the designers didn't know a whole lot about aerodynamics. Whether it worked or didn't work depended on which guy stumbled into a thermal. Then, if his plane was green, everyone went off building green airplanes because it took a green airplane to thermal! Few people knew what they were doing back then, so a lot of the old timers had strange force arrangements. Each individual old timer needs its own evaluation and set up, then it's almost cheating, because the original airplane wasn't built that way, so it's no longer really the old timer.

It's always best to get the stab incidence right rather than fiddle with the wing. There are many kits on the market that have the center of gravity in ridiculous spots and have incredible angles of attack. To them, if the plane flies, it's a good airplane. It really depends on what you want to do and what means something. If flying overhead with transparent covering is desired, then you can do anything. If super long flight times then you can do anything. If super long flight times mean something, then that means efficiency.

Designing and Building efficient airplanes:

In my articles from Model Builder (July 1987) for designing sport scale and from MAN (Dec. 1991) for twins, I go into great detail about this topic. (note: If back issues of these magazines are no longer available and you need/want them - send me proof that they aren't available - and I will provide copies. Ken) The concepts laid out in the articles apply to both sport planes and scale planes.

I have yet to see an airplane that an electric motor couldn't fly because the prop diameter was too small. In general, we can fly props so much larger than the gas fliers can use, we can come out lighter and beat the performance just on account of the props we can use. A case in point is my Gee Bee R1 which flies fine on a geared 25. Every other one that size, that I've heard of, uses a 60 or 90 to turn a big enough prop and they still crash.

If you do a lot of scratch building and draw your own plans, then you can pick any size you want and pick a power system for it. Another thing that can be done is to find a set of plans for a lightly built airplane and modify it for electric. Another way of doing it is to take a set of plans and just use the outline.

Glow kit conversion: There was a kit manufactured in Germany, a Klemm 25. Every country has a trainer. In the U.S., it's the J3 Cub, in Britain, it's the Tiger Moth and in Germany, it's he Klemm 25, the equivalent of a low wing J3 Cub. It has a huge wing on it, a relatively short fuse, and a big tail. It is a very nice flying little airplane. I haven't built it yet. It's a case where its built for gas, but I can't think of what to lighten. It's such a nice structure and really nice design. It's perfect for electric. Later, I'll go through the parameters to choose the motor to make the airplane fly well.

Using glow plan outlines:

Another case is when you find a set of plans for the airplane you want to build, but it's obviously built for glow engines. It has a 1/4" plywood firewall, 1/4" balsa sides, and foam wing with 1/4" dowel rod. Sometimes it's still worthwhile to get a set of plans just for the outline. If you know what the wing looks like, you've got the ribs, and you've got the fuselage cross section. Then you can say, "I'll ignore their structure and build in a nice light structure that fits." All the sizes and shapes and ribs are done for you. You just have to decide on the wood size.

I've got a set of plans for a Bearcat. My interest in aviation is mostly from 1925 to 1940. Virtually everything I build is a racing plane or aerobatic plane of everything I build is a racing plane or aerobatic plane of the Golden Age. I could care less about jets. I did the little ducted fan just as an experiment.

One of the few military airplanes I like was the Bearcat, and the Spitfire of course. I always intended to build an electric model of the Bearcat. I have plans for the Top Flite Bearcat, which is tremendously over-built. I intend to throw away everything and use just the outline.

Scratch building and drawing up the plans yourself:

Another route is to start from square one by taking a 3-view and blowing it up to the size you want. You can take a photo of the 3-view and use a projector to project the airplane onto a large sheet of paper mounted on the wall. Another way is to use a photostat and make an overhead transparency and again project it onto a wall. With the 3-view and some of the cross sections, you can then get some idea of the wing area, wing span, wheel size and prop size.

The plane's actual size may based on how big the back of your car is, how big your work bench is, or whatever. Once the "size" is decided, figure out the span, cowling diameter, prop, wheel size, length of the fuselage and cross section, and most importantly the wing area. That's the thing that's going to provide lift. How much weight you strap on that area determines how it's going to fly and its handling characteristics.

The higher the wing loading, the more your thumb has to be educated and the more careful you have to be flying. Light wing loadings, in general, are pretty easy to handle. The lighter the wing loading, the better, within reason, but we don't have too worry about that as, with our power systems, we are pretty much assured that we won't be too light.

You have to guess at what kind of wing loading you'd be comfortable flying. For light planes, 15 - 18 oz./sq.ft., for a large one and or a small one, 12 - 15 oz./sq.ft. would be better for a nice gentle flier. For an aerobatic or fighter aircraft, 20 - 25 oz./sq.ft. works well. For great big airplanes you can go to 30 oz./sq.ft. The Mew Gull is almost 30 oz./sq.ft. but it works out pretty well because of it's big efficient wing. I didn't intend the wing loading to be that high, but there's a lot of balsa in that fuselage. It's a lot bigger than it looks.

Once the wing area is selected, wing loading can be figured. For sport flying, 20 oz./sq.ft. is a nice number for reasonable performance. Multiply the wing area in sq.ft. by the wing loading in oz./sq.ft. for the total weight in ounces. This tells the kind of weight the airplane should weigh in order to give the handling you're after. All of this is related to take off speed, stall speed, landing speed, and minimum speed to stay airborne. There are other factors, but wing loading is the most important.

the most important.

If you don't always just want to be flying around level and want some aerobatic performance - roll, loops, etc., these mild aerobatic maneuvers need 50 to 60 watts per pound. If you want good aerobatics - pattern capabilities - you need 70 watts per lb. for outside maneuvers, knife edge, etc. Pylon racers are up over 100 watts per lb.

Multiply the performance level you want in watts per lb. times the weight of the airplane to establish the required power.

A 3 sq.ft. winged plane, at 20 oz./sq.ft., is a total of 50 oz. - just over 3 lbs. That means, at 50 watts/lb., 200 watts gives the airplane those characteristics - mild aerobatics.

How we create the watts needed. (Watt = Volts x Amps)

Our battery packs are fixed in size. If we want a red hot flight, it's a short one, because the current is high, but you get higher performance. The question is how long do you want the thing to fly at full power - this is your peak power, your vertical performance. This power level sets your peak current. For most reasonable airplanes - not biplanes or huge fuselages or 18 zillion rocket pods - with reasonable drag coefficients, and a current draw of 20 amps out of a 1200 mAh pack, you're going to get a 5 to 6 minute flight. If you run 30 amps, it's more like 3 minutes.

Watts are current times voltage. If we want 200 watts at 20 amps for a 5 minute flight, we need 200/20 - 10 volts. Because we get about 1 volt per cell at this current draw, we need 10 cells. A motor chart shows that a cobalt 15 is in about the right range. With 12 cells you could drop the current down to, say, 16 amps, but now, because you're at 16 amps, you might go to 900 mAh cells, save more weight and have the same flight time.

With a draggy airplane, the rule of thumb is to use a geared motor. Dealing with a pattern type airplane with no loading gear and a hand launch, or sleek fuselages or pylon racers, those are obviously direct drive. There is very little drag and the plane is better off with a smaller prop, getting the horsepower that way.

A lot of European motors offer different windings instead of gearing. They don't like gear boxes. They do everything with windings and change the windings more or less to change the "gear" the motor runs in. A motor can be set up for all torque and low rpm and turn a great big prop. If a different armature is put in it, the motor screams at a high rpm but can't use a big prop. Over there, they pick the armature, while we use gear boxes or direct drive.

There are other things to be considered. For a really good aerobatic airplane, leave the landing gear off. The good aerobatic airplane, leave the landing gear off. The landing gear causes a tremendous amount of drag. I've found the optimum power for a good aerobatic airplane is a 15 size. As far as vertical performance, per weight, per aerobatic, per flight time, it is very good. The bigger airplanes have more impressive vertical, but their maneuvers are bigger and it takes a lot of time for each one. Big planes give fewer maneuvers per flight compared to the 15.

For the 15 size aerobatic airplane, the wing area should be about 350 sq. in. If you want an off the shelf airplane and you don't mind re-engineering the fuselage a little, the Great Plane ElectroStreak with a cobalt 15, twelve 900SCRs and a light radio is one heck of an airplane. Talk about holding the airplane vertical to launch. You get about 3 minute flights at full throttle, maybe 5 minute flights with throttle use.

By the time you add a take off and landing, you're making a really aerobatic airplane a real challenge. You're dealing with nothing short of a cobalt 60 with 30 to 35 cells and lots of bucks, just to get the same performance you can get out of a hand launched 15.

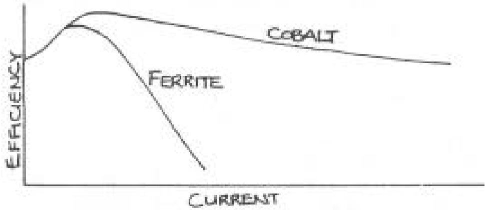
When dealing with scale airplanes, to be able to do nice take offs and landings, touch and goes, and modest aerobatics, virtually any size motor will do it. 05's will do it if you're careful, geared 15's will do it, which is a really nice size for a lot of scale airplanes. If you're trying to get some good aggressive flight characteristics, take offs and landing, maybe retracts, you need a 40. A 60 motor is a hard motor to make good use of. It is capable of putting out 1.5 hp, but the problem is that we don't have any ni-cads that can feed if for very long. 1.5 hp out is 1500 watts in. That means that if you are using 30 cells, you're drawing 50 amps! The motor can create it, but the battery pack can only deliver it for about a minute or so. Unfortunately, there is all this horsepower, but it's hard to feed it and keep the flight time. The best way to use this motor is to run wild amounts of horsepower for the vertical rolls, then pull the power back and use 1/4 power the rest of the time. Only when doing the vertical rolls, the figure "M"s and the outside maneuvers do you need full power. 60's are very expensive and it's hard to make good use of them. The only time I use them is when I want to turn a huge prop or when I need a lot of raw horsepower for a high airspeed. The sport 60 in the Mew Gull runs for about 4 minutes at full power at about 100 mph, way above scale speed.

I've actually found that the geared 40 is just about optimal for matching ni-cads to power to performance. A geared 40, running on 20 - 21 cells is about the best route to go. The geared 40 provides achievable power with flight time; with flight speed; with good aggressive performing scale aerobatic flight.

aggressive performing scale aerobatic flight.

Motors and motor efficiency:

Most cobalt motors run about 75% efficient and the rules of thumb quoted here assume this figure. Most cobalts stay at 75% efficiency as far out as 40 to 50 amps. Ferrite motors, in particular little ferrite can motors, at a little over 20 amps, are down to 40% efficiency. Dropping 200 watts in the front end is only yielding the equivalent of about 80 watts out. That's power like a cobalt 035. The can motor is screaming its guts out, getting red hot and you're getting a 2 minute flight. The cobalt 035 will give the same power for 5 minutes. Be very careful with ferrite motors as their efficiency to power is:



If you push a ferrite motor hard, it never comes back. The magnet is cooked, or the armature, or the commutator, or the brushes, then they fall apart. Remember, buy cheap, buy twice.

I feel that the reason cobalt motors aren't used in car racing is that if they used a lot of cobalt motors, the manufactures of the ferrites would go out of business. They are the ones supplying the events and writing the rules. That's why they don't allow cobalts. You buy one cobalt and run it for 10 years. You can't sell everybody motors 5 times a year or once a race or whatever. End of soapbox message.

Once the power needed is determined, weigh the power plant, battery, and the radio. Work backwards to see how much the structure has to weigh. Look at the airplanes you've built and weigh the structures to see if you can get some idea of the weight of the structures you build. Just a note; if you want a WWII fighter with full skin, all rivets and panel lines, you're not going to make it! The airplane will suffer in terms of performance. With that kind of detail, it will take off, it'll fly around level and look nice, but it won't have any kind of fighter-type aggressive performance.

I prefer performance rather than real detailed scale. I don't mind cheating here and there, using stringers, and building optical illusions for details. I'd rather have the performance. You can't see rivets and panel lines in the air.

Once the motor is chosen, look at the structure and figure out if you can do it. If there's no way, go back to square one and try a different size plane and see if something comes out the way you want.

After a while, you get used to this process and you can predict the motor needed for most airplanes, then you can reverse the procedure and go backwards. You

you can reverse the procedure and go backwards. You can think; I have a geared 15 and I want 60 watts per pound. That means that I need this wing area for this wing loading, then you can size the airplane for them.

Until you're used to that trick, you can end up with strange results, way over or under horesepowered. It never works out right. When I'm playing around with a new airplane, I always go in the forward direction, because occasionally I get fooled on how much power I need.

Props:

In those write ups, (MB & MAN), there is a discussion about how to choose your props for test flights. I'm not going to get into that here. How to modify props is a little beyond most people. I'll say, at the least, that Rev Up props are, in general, very good. APC props work - I don't think they work as well as Rev Up, but other people rave about them. Maybe they've only used Zingers or Master Airscrew fixed blade props which don't work well for our purposes. The little Master Airscrew props, the 5" and 6" ones are great for small clean airplanes, but the big ones are not. The APC's are reasonable, the Rev Ups are my favorites, the Zingers can be reworked into decent props, but you need to do it correctly. The Master Airscrew Electric Props work well.

I sometimes spend four hours reworking a prop until

I get the results I need and, if it's not right, I buy another one and try again. Once I get one working the way I want it to, I go out and buy another, make a back up, and put it in the flight box so that I have a replacement. A lot of my props are like this.

The single best thing you can do to improve the performance of an electric airplane is to play with the prop. You can change the performance by 30 to 40% with the same watts input. Many times it's just a case of buying a bunch of props and trying out each one. They could all be 10x6's. One of them will probably work a whole lot better than the others. You won't believe the difference. I can't tell you which prop to use because it depends on the airplane. A lot of times, it's just cut and try and experience. I tried to give some outlines in the he MAN article; how to get into the right size and shape prop, so that you are starting with a dozen props rather than 500.

A note on Twins:

In general, twins should be run in series for efficiency, unless you are running tiny 5 and 6 cell motors. They can be run in parallel because they probably only pull 5 or 6 amps each for an 11 amp total. If you try to run two cobalts in parallel at 20 amps each, the total draw on the battery is 40 amps. It's a very short flight time and the rpm will be lower, as the voltage drops at that draw.

voltage drops at that draw.

Batteries:

Everything, and I mean everything, I fly is with Sanyo SCR's. The reason is that the SCR's are the only batteries that I have found that give me consistent performance and tolerate a relatively casual charge-discharge cycle. They are like a fuel tank, you put electrons in, you take electrons out.

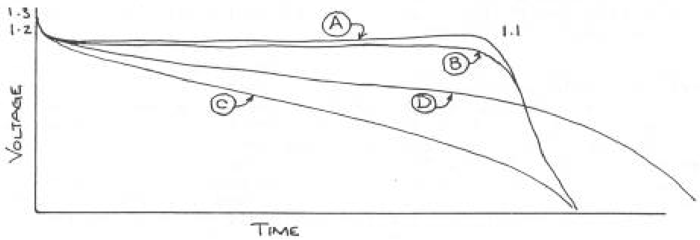
There are several reasons I like the SCR's. They have very low output impedance. That means that when I ask for current out of the battery, in addition to getting the current I want, the battery, which starts out at 1.2 volts per cell, only drops to 1.1 volt per cell, even if drawing 40 or 50 amps. I'm losing only a very little bit, (this is what heats up the battery). Sanyo SCR's do very well in this situation - very little loss.

Something like SCE's, because of their impedance at high amperage draws drops about .6 of a volt per cell. It's like throwing half the cells out. About all they're going to do is keep the fuselage hot.

Wiring:

You get horsepower, yielding performance, with voltage and current. To keep the voltage up you can't have small diameter wiring, high resistance switches, inefficient speed controllers, or high impedance ni-cads. If you are using 10 cells and put a volt meter on the back of the motor and see 8 volts, something is very wrong. A good rule of thumb is 1 volt per cell at the motor at full power. If you don't get this absolute minimum voltage, start looking for where the problem is. Either you have wire that is too small, the wrong switch, the wrong connectors, or something.

In addition to the output impedance, every battery has a voltage profile. That is what the chemical voltage looks like over time as you discharge. At very low currents, virtually every battery curve looks like (A).



Many battery maintenance instruments, like the Ace Digipace cyclers, are set to shut off at 1.1 volts per cell. As we pull current out the battery, we are going to lose a little voltage because of the higher current. The curve will drop a little, (B). SCR's do a pretty good job. They basically stay flat all the way down to the end. It's just like turning a switch off. You know it's time to land when the plane falls out of the sky! With cells like the SCE's and some of the cheaper ni-cads, the profile looks more like (C). You may find the plane landing before you get to the "knee". Even at full power, there just isn't more like (C). You may find the plane landing before you get to the "knee". Even at full power, there just isn't enough voltage times current to fly the airplane. When I fly an airplane with SCE's, the first minute I'm smiling, the second it's okay, the third it's boring, and then I'm scrambling to see how much more I can stay airborne before I have to land. Even then there's still lots of unusable power left over. This applies to high performance airplanes.

With an Amptique-type of airplane, where the current drain is 8 to 12 amps, the discharge curve isn't so bad, (D). Not quite as good as the SCR’s but okay. Because the SCE has more capacity for its weight, you do get a longer flight. If putting around, with ungodly long motor runs, slow fly bys, touch and goes, etc. is what you want, the SCE's aren't bad. They are a little finicky to charge. They aren't really as tolerant of over charging. They also have some funny characteristics.

Charging SCE's should be done carefully, at no more than 3 amps. I don't have a lot of experience with them, but that's what the people I know using them charge at. SCR's could care less about how fast you charge them. You can charge at 6 or 7 amps as long as you don't over charge.

AE's are even worse than SCE's. They droop pretty badly. They're the 1250 Magnum size. I won a pack of 7 x 1250 Magnums and took out my Amptique, which normally has 7 x 800 AR's. I did the same flight, took off, flew around, did touch and goes. With the he 800's, I was getting, typically, 30 touch and goes and 12 minutes of flight time. With the 1250's, which are supposed to have much more capacity, I could only do 25 touch and goes before I couldn't get it back into the air. If I had altitude, I could have cruised for some time, but the cells didn't have the voltage to get the airplane off the ground. It's also a little disconcerting to land and the pack is so hot I can hardly touch it. That was in an Amptique which is a low power design. I just don't have too many good things to say about the so called "extended flight" cells.

For carefree ni-cads - simple charging and go fly - it's pretty hard to beat SCR's. Plus they can deliver almost as much power as you need without really effecting the characteristics of the ni-cad.

Charging radio batteries versus power system batteries.

Radio ni-cads should be stored charged. Motor packs should be stored discharged. At the end of the day, I run my packs right down. It's just like running the fuel out of the tank. I don't wait for the prop to stop but I can clearly tell when they are down.

The problem with storing radio batteries flat is that there are micro crystalline growths. With SCR's, it's very unlikely, particularly when given a 5 amp charge.

very unlikely, particularly when given a 5 amp charge. It blows out any growths and the cell acts normally.

I've never had much luck trickle charging radio batteries. I prefer to charger a couple of hours once a week rather than trickle charge.

Balancing Batteries

I never worry about cell reversal because I've never seen it in an SCR. I ONLY use SCR's, so they are all I can address. I never balance packs. I buy the cells in boxes of 20. Whenever I've done tests, there is never anymore than 5% variation. They are all the same, no real bad cells and no real good cells. I don't know where some people are getting their numbers. Maybe someone has already gone through all the cells I get, but I don't think so.

I don't worry. I have yet to replace a SCR and I've been flying them since 1986. Maybe I've had to change one or two of the earlier SC cells, but not the SCR's. When I've had hundreds of flights on high performance airplanes and I cycle my packs, I still get 1.2 amp hours. These are good cells.

Catapult Launches:

Use 10 feet of heavy surgical tubing and 10 - 20 feet of heavy fishing line and some sort of ring. Set the launch ring hook on the line between your vertical center of gravity and where a high start anchor would be. It will be way out in the nose of the airplane. It shouldn't be back where a high start hook would go or the plane will go straight up! The catapult is used just to accelerate the plane. If you pull it back too far, by the time you launch and you're back on the stick, the plane is gone and off the line. If the hook is a little far forward, the plane will drop a bit but it's not much of a problem. Launch with the prop turned off.

About a foot ahead of the hook, put a piece of cloth to make sure the ring drops. When I see it drop, I know that I'm off the line. Its a really nice way of launching almost anything. If you don't feel you can launch carefully or your arm is tired, it's the way to go.