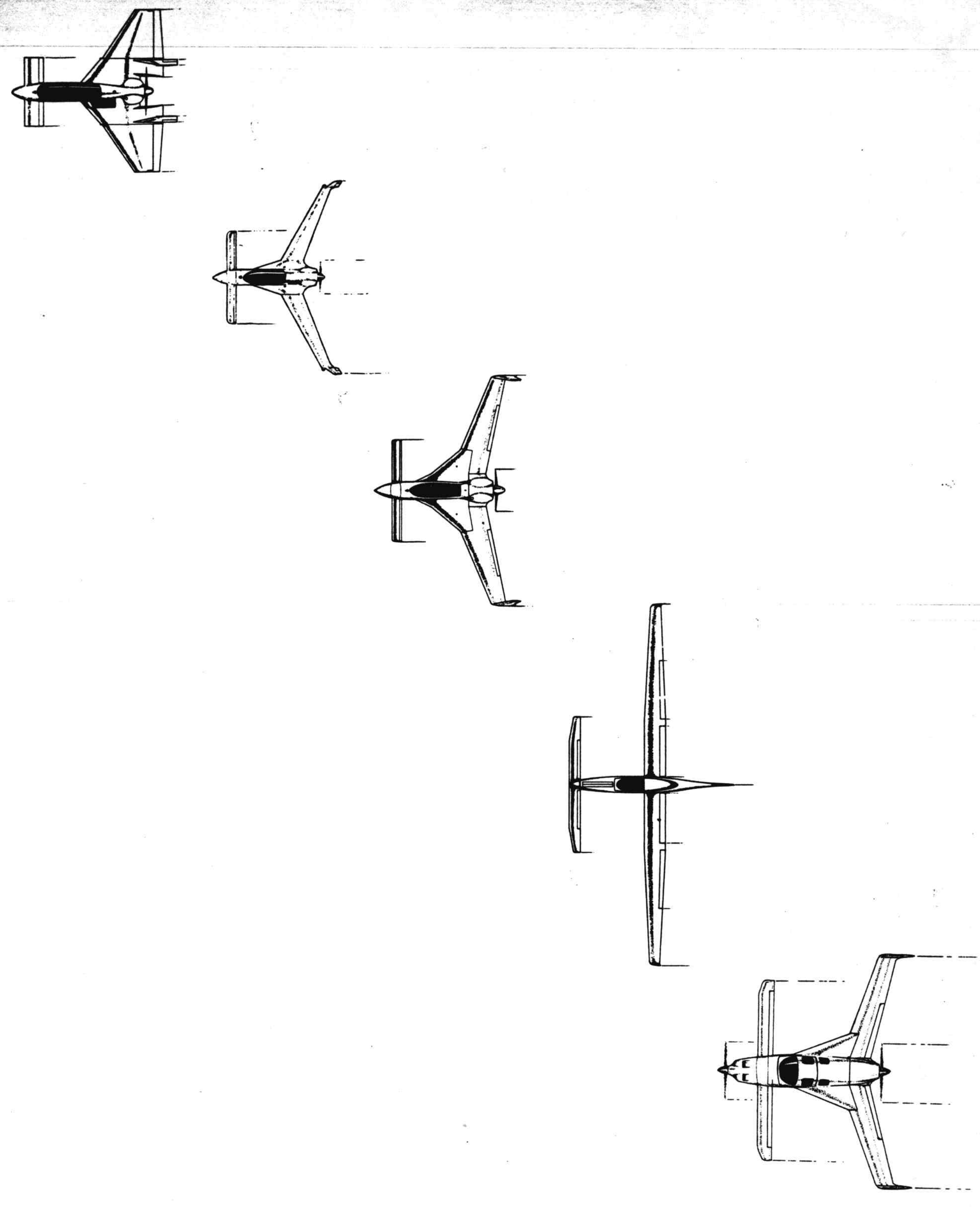


MOLDLESS COMPOSITE HOMEBUILT SANDWICH AIRCRAFT CONSTRUCTION

3rd EDITION — SEPTEMBER, 1983

MOLDLESS COMPOSITE SANDWICH
HOMEBUILT AIRCRAFT CONSTRUCTION

3rd EDITION - - AUGUST 1983

This booklet is intended to give you a complete education on the use of the materials for building a glass/foam/glass aircraft structure without molds. These are the structural methods and materials used in building the VariEze, Long-EZ and Solitaire homebuilt aircraft. It should be clarified that this booklet covers the use of the materials in building an aircraft, not the design methods for design of composite structures. Composite structural design is an involved engineering discipline beyond the scope of this booklet.

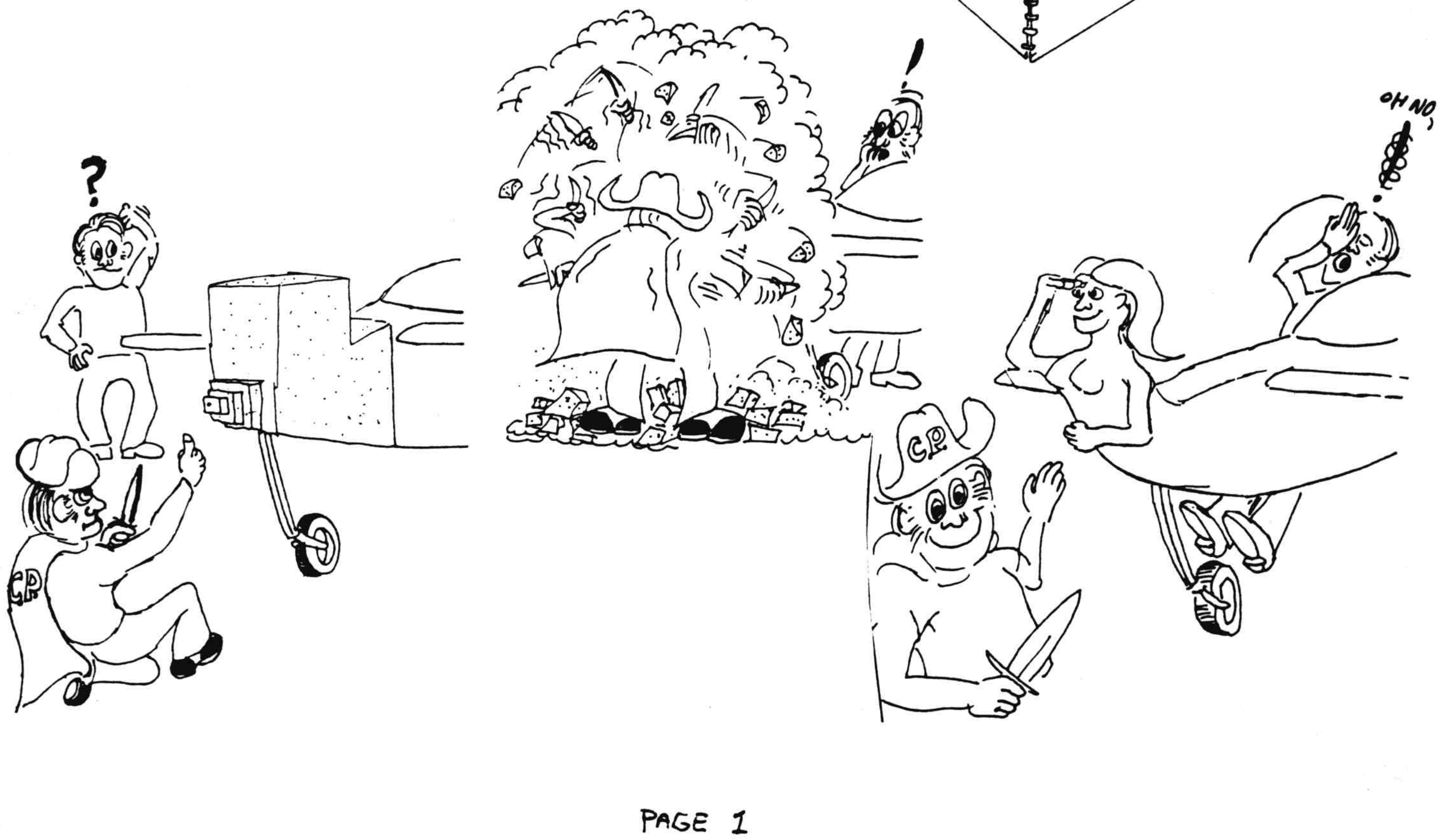
The booklet consists of three parts. The first is a bill of materials, listing the sample composite materials intended to be included with this booklet. The second part shows several items we recommend you build with the materials, to develop your workmanship and to display inspection criteria. The third part is Chapter 3 from the plans for the Solitaire. This is the educational chapter that prepares Solitaire builders for construction of their airplanes. This chapter is a very complete document covering materials description, required tools, hot wiring, foam shaping, glass layup, inspection, repair etc.

The recommended way to use this book is to first read and study Part Three, the education chapter and inspection requirements, then build the tools and composite sandwich parts shown in Part Two. After you have done this you should have developed the skills required to build a VariEze, Long-EZ or Solitaire. Also, you should have answered the question, "Do I enjoy working with these materials?" and "Is my workmanship adequate to build an airplane?" After you are done, you will have some material left over, so have fun and invent something to build.

BILL OF MATERIALS
COMPOSITE INTRODUCTORY PACKAGE

Booklet - "Moldless Composite Sandwich Homebuilt Aircraft Construction".

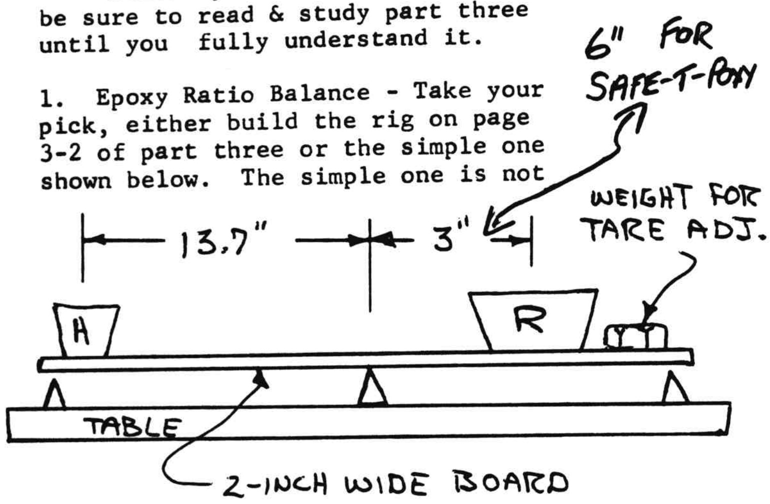
Urethane foam 2 lb/ft^3 density	2 bd ft
Styrofoam 2 lb/ft^3 density	4 bd ft
Bi-Directional fiberglass (BID)	2 1/4 yds
Unidirectional fiberglass (UND)	1 1/4 yds
Epoxy Kit (resin and hardener)	1 quart
Microspheres	2 oz
Flox	1 oz
Peel Ply 1" wide	6 feet
Stainless safety wire .032 dia.	5 feet
Bristle brush 1" wide	4 each
8 oz and 3 oz mixing cup	5 each
Mixing Stick	6 each
Sandpaper, 36-grit	1 sheet



PART TWO- THINGS TO BUILD WITH THE INTRODUCTORY PACKAGE

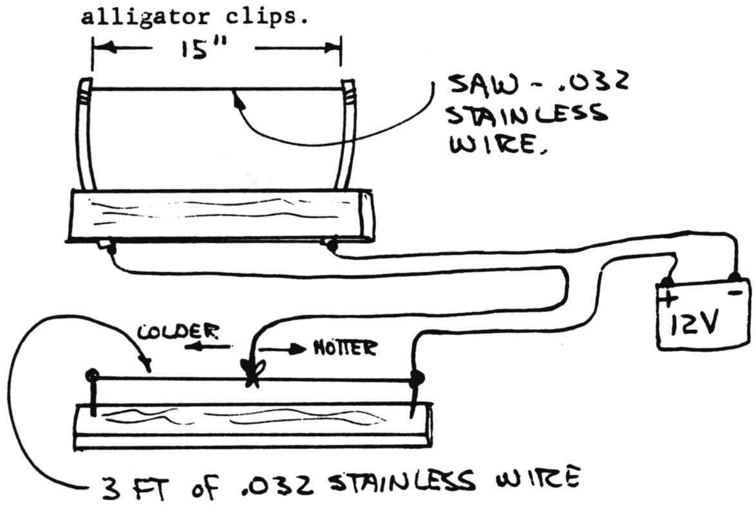
Before you start on these items, be sure to read & study part three until you fully understand it.

1. Epoxy Ratio Balance - Take your pick, either build the rig on page 3-2 of part three or the simple one shown below. The simple one is not

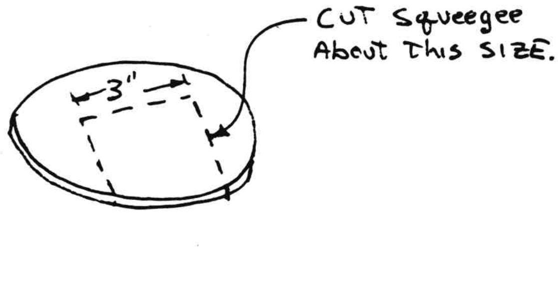


accurate enough for aircraft parts but adequate for the practice items. Use the wet-hardner-cup method when using the balance.

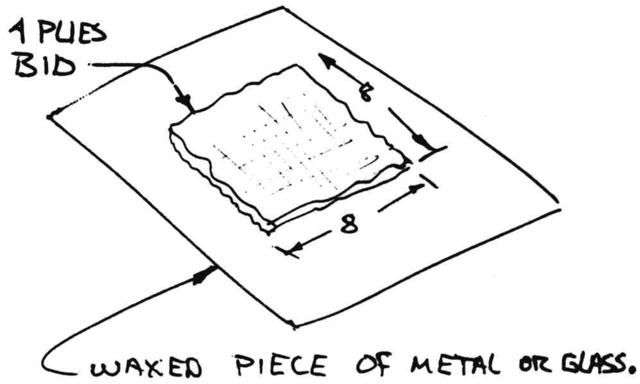
2. Hot Wire Saw- The saw for the practice parts is only 2 ft long, so you will only need one 12 volt charger or car battery. Rig it up as shown to give adjustment for wire temperature. The .032 stainless wire is included in the kit, the other wire can be from an old extension cord. Radio Shack has alligator clips.



3. Squeegee - You will need a flexable plastic squeegee to use on the layups. Cut this as shown from the plastic lid found on coffee cans or other food cans.

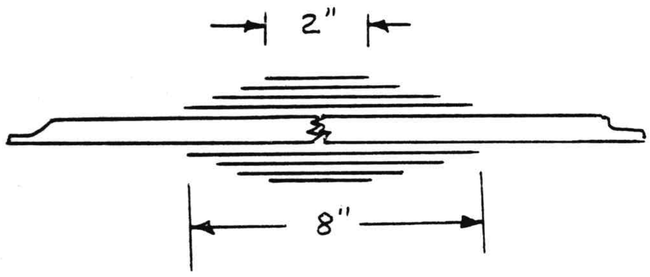


4. Glass Layup - The first items to layup are three pads of fiberglass. Lay them upon wax paper or a piece of waxed metal so they can be removed after cure. Each pad is 4 plies BID, layed up in squares, 8 inches on a side and later trimmed to a 7-inch square. On the first one, lay it up by painting on too much epoxy on each ply and not doing enough squeegeeing to remove excess epoxy. This pad, then is intentionally made too wet. Make the next one too dry, by not bringing in enough epoxy, and by not stippling out the voids. Squeegee it too hard also, this can leave it with air showing. When you are done with the layup it should have flecks of air visible, indicating a too-dry layup. Layup the third one like you should, ie., by stippling in a little more epoxy than required, then, using many light strokes with the squeegee, removing all excess epoxy without leaving any trace of air. The 3 pads will require about 4 oz. of epoxy. Make two 2 oz batches as you need them. At knife trim time, trim them to 7-inch squares. After cure weigh each one and carefully inspect them.



The correct layup should weigh 2.25 ounces. If the heavy one weighs 2.55 ounces, this difference will add 35 lbs. to a VariEze if this workmanship is done throughout the structure of the airplane. Study the dry sample under a good light. Note the appearance of the air. Your ability to identify this air is very important so you can properly inspect your aircraft. A very-dry layup can appear 50% white, ie, 50% of the surface area is white flecks. Ten percent is maximum allowable on a critical aircraft part.

5. Strength/Confidence Layup - The next item to make is the beam shown on Page 3-13 of Part Three. Build it and test it according to the instructions. Then cut it in half, or break it in the center. Now taper the glass back and repair it, using the standard repair procedure shown in Part Three, ie. sand dull and layup the material being replaced (2 BID plus 2 UND) lapping 1" per ply from the failure. Cure 4 days again and then retest, to give you confidence in the structural repair procedure.



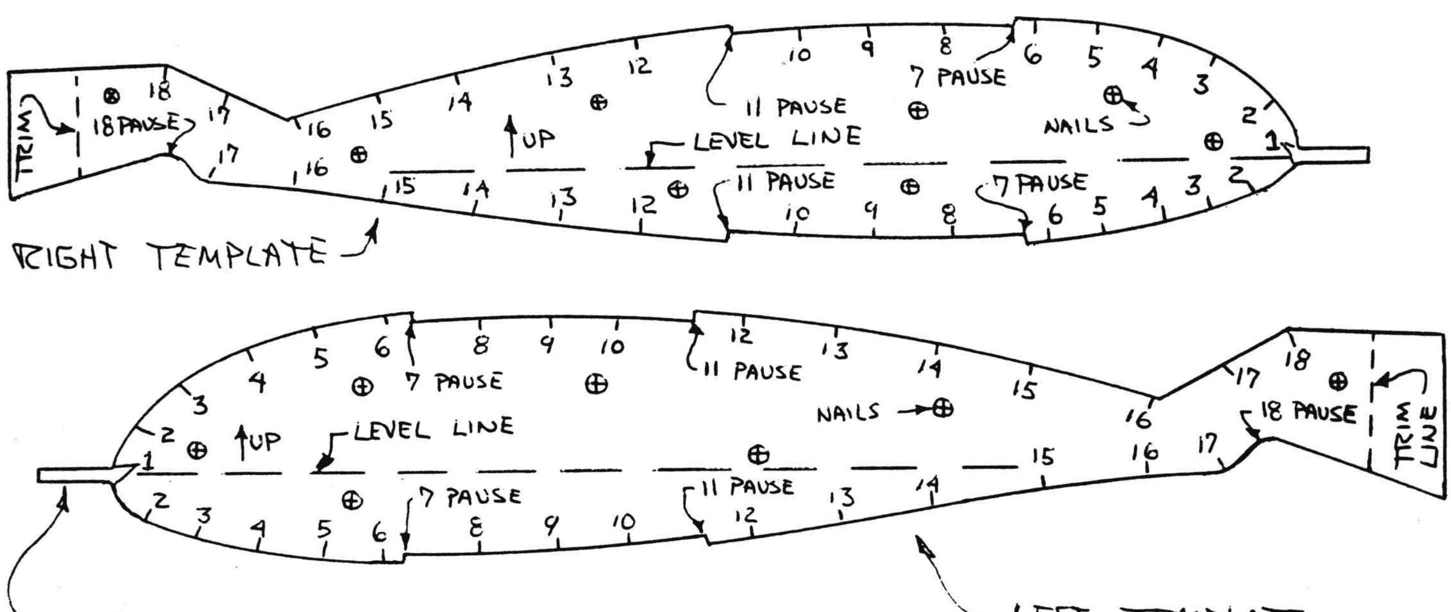
REPAIR - LAP ONE INCH/PLY

6. Wing Section - Now for the fun part, the hot wiring. This item is a wing section ,built much like the wing of a VariEze, Long-EZ or Solitaire. It will test your skills with the hot wire, leading and trailing edge treatments, spar cap flagging and skinning over blue foam. The finished product is a good representation of the actual wing, showing its surface durability and smoothness before finishing. You may want to do the finishing on it also, to practice on the use of fillers, primers and white paint. Finishing details are covered in individual plans.

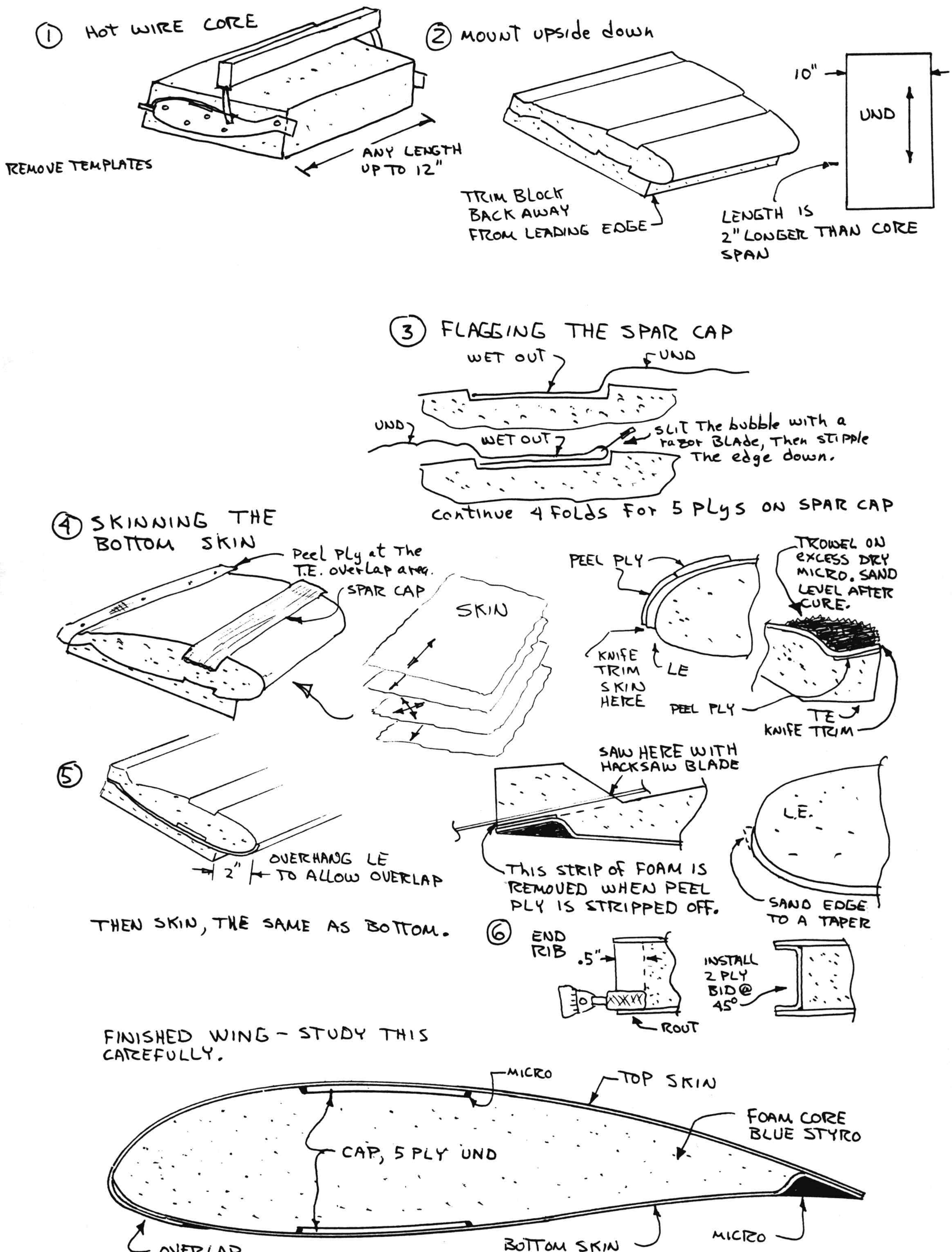
Cut out the templates below. Review the information on Page 3-7, 3-8 and 3-9. This practice wing can be made in any span or planform you wish. You may want to sweep it back, for example, which will require you to do the vertical hot wire cuts to sweep the planform of your wing before mounting the templates. Hot wire your core, being careful to follow all the rules (firm mounting of templates, nails out of the way, block weighted, correct tension and temperature, pauses etc).

Now, rest the core upside down in the trimmed core block as shown. Cut a strip of UND 10" wide and long enough for the span as shown. Be sure the fibers run spanwise. Mix epoxy, make a little micro slurry and slurry the spar trough. Layup the UND as shown (3). Wet out the 2" wide strip, fold the cloth and wet out again, then use a sharp razor blade to lightly slit along the bubble at the fold. After a light pass with the razor blade, stipple the fold down and the bubble will disappear. Repeat if necessary. Continue wetting, folding, slitting, stippling, until you have a spar cap that is 5 plies thick. Run the squeegee spanwise from the center out toward each tip to straighten the fibers and remove excess epoxy. The spar cap should now be flush with the adjacent foam surface. Trowel dry micro to fill any voids at the edges of the cap. Tack a strip of peel ply down in the trailing edge notch (4). Now, while the cap is still wet, layup the skin (1 ply UND with fibers spanwise, 1 ply BID at 45°, then 2 plies UND spanwise). Peel ply the leading edge with two strips of peel ply. The skin should be scissor trimmed all around to within 1/2" of the foam, then knife trimmed flush with the foam all around. While its still tacky, trowel some dry micro over the trailing edge notch as shown. Let this cure. Then turn it over and mount as shown, (5). Carve off the excess foam at the trailing edge with a butcher knife or hacksaw blade. Grab the peel ply and strip it off, (leading edge and trailing edge). Sand a good transition if necessary at the leading edge and trailing edge. Now, glass the top spar cap and skin the same as the bottom except it is lapped over the leading edge at least 1 1/2". Peel ply over this lapped edge to obtain a smooth transition (Page 3-14). Knife trim other edges flush. Let this cure. Now, using a rotary file in a drill motor, rout out the foam at the ends and layup a 2-ply BID rib into each end, knife trimming flush with the skin, (6).

This finished wing piece is a good example of how durable a composite wing can be made, while still being quite light. This wing also provides you valuable practice in many of the required processes.



THIS TIP IS TO REST THE HOTWIRE ON WHEN STARTING TOP AND BOTTOM CUT. SEE PAGE 3-8 (WATERLINE NAILS).



7. Book End- The bookend from part three involves many of the corner treatments, foam carving & difficult layup tasks found in airplane construction. Build it & judge yourself. If you can build the bookend pretty enough so the wife will use it in the living-room bookshelf, you probably will build a beautiful airplane. If your bookend looks ragged, bubbly & delaminated, you should probably not consider building an airplane.

DO NOT SKIP THIS SECTION. Every hour you spend in this preparation section will save you five when you really start building your aircraft.

GENERAL

In this section you don't build any part of your airplane. What you will do is learn how to build your airplane the right way. This construction technique is radically different from anything you've done before (including building boats, surfboards, airplanes and gocarts), and you should assume there is only one correct way to do it. We've discovered lots and lots of wrong ways of doing things and have written the plans to keep you from repeating our mistakes. We insist that you do things our way. If you have a better idea, send it to us, we'll test, and if it really is a better idea we'll publish details in the "Canard Pusher".

This section will teach you all of the techniques required to build your airplane, show you what special tools you need and how to use them. The educational samples that you will build in this section are designed to give you experience and confidence in all of the techniques that you will use in the construction of your airplane. The steps in construction of each sample are arranged in sequence (as are the steps in construction of the actual aircraft parts) and you should follow the sequence without skipping any steps. You will learn the basic glass layup technique used throughout the aircraft, special corner treatments, foam shaping/cutting and joining methods. A summary of these techniques is provided on yellow paper for you to tack up on your shop wall.

Our video tape titled "Building the Rutan Composites" is very helpful in developing your technique. It is generally shown on Saturdays at RAF, or can be purchased from RAF.

TOOLS

There are certain tools which are necessary to complete the aircraft. Three lists of tools are provided here. The first is the absolute bare minimum required, sacrificing efficiency; the second is a recommended list for the best compromise of cost and work efficiency; the third is a list for the "Cadillac" of shops where ease of construction is more important than money. The non-common items are stocked by the Solitaire distributors.

1. Basic Required Tools

Common household butcher knife.
Coping Saw.
Small open-end wrenches.
Sandpaper 36-grit, carborundum Aloxite Fastcut (50 sheets), also 220-grit, 320-grit and 400-grit (20 sheets each).
1 12" long #12 drill bit.
2" dia drum sander (coarse) for 1/4" drill.
Coarse rotary file bit for 1/4" drill.
Pliers.
1" putty knife.
Hacksaw.
Blade and Phillips screwdrivers.
Box of single-edge razor blades.
24" carpenter's level.
Carpenter's square.
Felt marking pens.
3-ft. straight edge.
200 eight-oz paper cups.
50 3-oz paper cups (unwaxed).
12-ft decimal steel tape (Stanley #61-112).
1/4" electric drill with #3, #10, #12, #21, #30, #40 and 1/4" drill bits.
#10-32 and 1/4-28 taps.
Roll of grey duct tape.
1" and 2" paint brushes (100 each).
6" plastic or rubber gloves.
Scissors.
Wire Brush.
Pop rivet puller.
Homemade balance for ratioing epoxy.
Wall thermometer 50 to 100°F.
1/4" hand drill.
Sears universal Protractor #9KT3995.

2. Recommended Tools (in addition to those listed above)

Dremel-type miniature high-speed hand grinder with saw and router bits.
6" and 9" disc-type hand sander.
Set of 1/4", 1/2" chisels (wood).
Small set of X-Acto knives.
1/2" dia 100° counter sink (piloted for #11, #21 and #40).
6" machinist steel ruler.
X-Acto razor saw.
Box of wood tongue depressors to mix epoxy.
6-ft straight edge (piece of aluminum channel)
Cheap holesaw set or flycutter.
3/8" variable speed hand drill.
12" long drill bit 1/4".
Hand broom and brush.
Large commercial 12" scisors (Wiss #20W).
Sabersaw.
Bench-mounted belt sander.
Stanley sureform plane.
Square and half round files.
Several 6" C-clamps.
Vacuum cleaner (shop type).
10" 18 tooth/inch hand saw.
Approx 150 lb. of small weights*.
Hair blow dryer.
Epoxy ratio pump (Michael's Engineering dispenser).
90° Drill adapter.

3. For the First Class Shop (in addition to those above

Drill Press.
Vernier Caliper.
Air compressor with blow nozzle.
Orbital sander.
Drill sets #1 through #60 and 1/16 through 1/2 (1/64 increments).

Items Used Only Occasionally and Can Be Borrowed

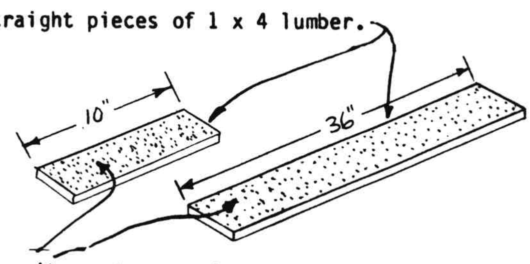
Nicropress Sleeve Tool.
1 dozen 1/8" clecos.
Hotwire voltage control.

Weights. 25 lb lead shot bags are very useful to hold down foam cores and to help hold parts in position for cure. They are expensive but almost anything heavy can be used, Clorox bottles filled with water, lumps of scrap iron, sand bags, sand filled milk cartons etc.

The following tools are ones you make:

Sanding Blocks
These are required in many areas during construction and for finishing. You may also use a "soft block", which is a block of the blue styrofoam wrapped with sandpaper.

Straight pieces of 1 x 4 lumber.



36-grit sandpaper glued to both sides with rubber cement.

Long Straight Edge

A long straight edge is not required but is handy to have. You can use a chalk line or string but this requires two people. There are several types of straight edges that you can use. You can buy a 6 foot level but that is perhaps in the "Cadillac" shop. You can buy aluminum channel at the hardware store or you can use wood. If you use wood you can go to the lumber yard and eyeball the boards until you find one that is straight. Another method is to buy a piece of 3/4" plywood sighting the edge to be sure it is straight and cut a 4" strip off the sheet. This will give you a stable straight edge (for wood) and you have enough wood left over to build a cloth cutting table. If you use a board, 1" x 4" redwood or fir, check it for straightness after the weather changes.

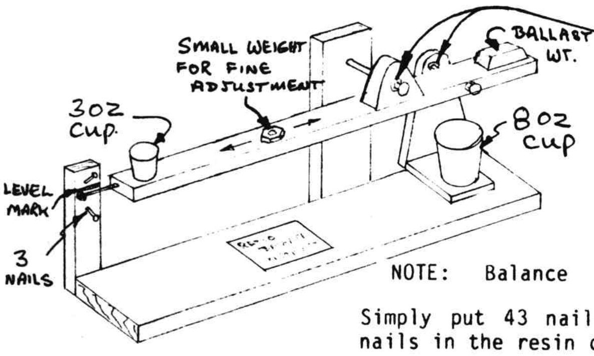
Epoxy Balance

Devices which automatically ratio the correct amount of resin and hardener and dispense it with the pull of a lever are available from Solitaire distributors for approximately $150. These save time and epoxy. You can ratio the epoxy the way we did in building N7EZ and N4EZ by building the following simple balance: (see drawings)
Cut out the 5-step instructions and glue to your balance - don't skip steps! Follow each step exactly every time you mix epoxy.

RATIO BALANCE FOR RESIN/HARDENER

1. Place both empty cups as shown. Wet the hardener cup.
2. Adjust ballast weight to level mark.
3. Fill resin cup with desired amount of resin - 1 to 6 oz.
4. Add hardener to hardener cup to balance scale on level mark.
5. Pour the hardener into the resin cup and mix.

Cut the instructions out and glue them to your balance.

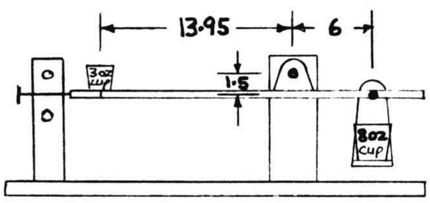


Pivots - metal tube bushings in wood. Loose fit on nails. The 1/8" diameter brass tube available at hobby shops is excellent for the bushings. Must be friction-free.

NOTE: The metal tube for the pivot bushings can be cut from an empty ballpoint pen.

NOTE: Balance accuracy check.

Simply put 43 nails in the hardner cup and 100 nails in the resin cup and check for level.



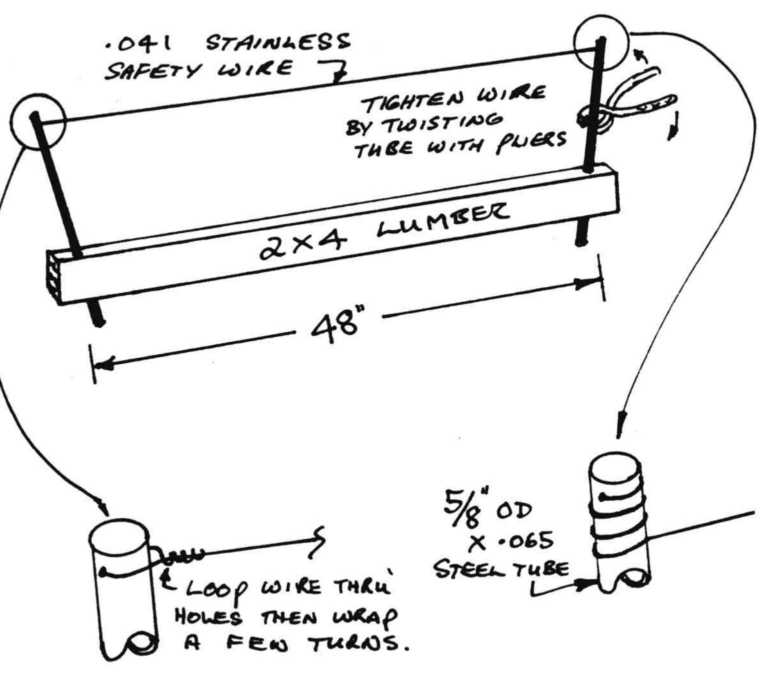
Safe-T-Poxy resin to hardner ration is 100 parts to 43 parts by weight. By volume it is 7 parts resin to 3 parts hardner.

Hot Wire Cutter

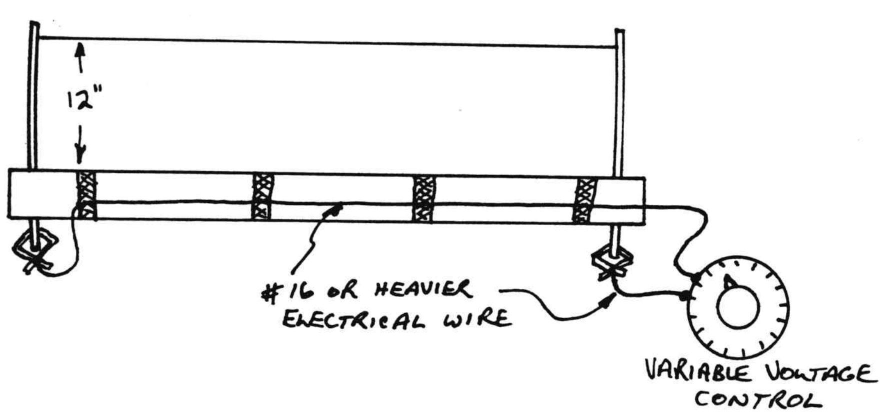
You will need a hot wire cutter to carve all the foam cores for the canard, vertical stabilizer and wings. Refer to sketch.

The Variable voltage control can be obtained from a Solitaire distributor or you can substitute any controllable power supply to include the 14 to 20 volt range with at least 4 amp capability. An alternative is to borrow two 12-volt battery chargers or auto batteries and lash up the following device. The "A" blocks represent either a battery or a 12-volt DC battery charger with 4-amp capability.

THE CUTTER SHOULD ONLY BE USED ON THE BLUE OR WHITE STYROFOAM. A HAZARDOUS GAS IS EMITTED IF YOU TRY TO CUT URETHANE.

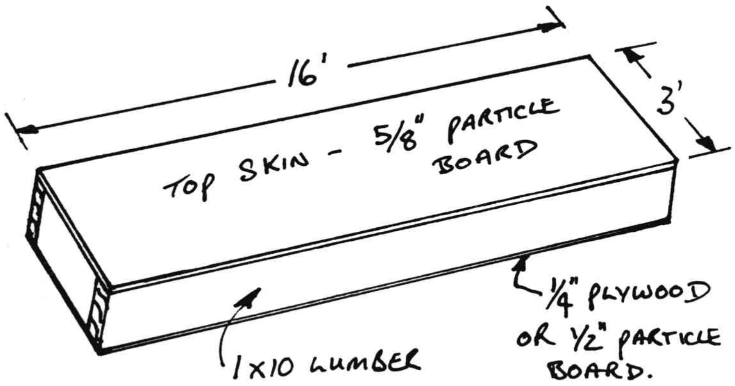


Adjust the current to obtain a wire temperature which will allow the wire to cut the foam at a rate of one inch every four to six seconds when pulled with a light load (less than 1/2 lb). This can be checked with a small scrap of foam. If temperature is correct, foam will have a smooth hairy surface. A cratered surface means too much heat. If the wire is too cold, the cutter will have to be forced hard, causing the wire to lag. Lag should not exceed 1/2" over the top and bottom of the wing and not over 1/8" around the leading edge. If the wire is too hot, it will burn away too much foam, making the part too small and will result in ruts in the foam if the wire is inadvertently stopped during cutting. The wire should be tightened until the wire starts to yield. Check this by tightening the wire while plunking it listening to the sound. The pitch will increase until the wire yields.



JIG TABLE

You will need a table to jig and build the wings and canard. It should be at least 3ft by 16ft. Use a little care in making a flat, untwisted surface. The following is a sketch of the one we made and it works fine. The box design makes it stiff in torsion. Set it up with the top 35 to 39 inches above the floor. Don't get carried away with surface finish, since you are going to be gluing blocks to it with Bondo and chiseling them off several times.



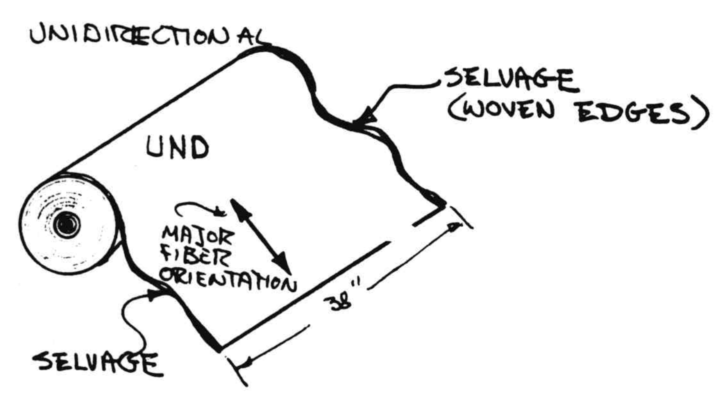
MATERIALS

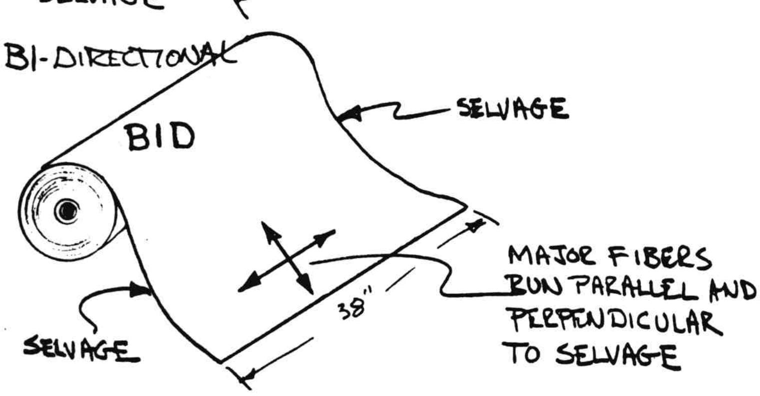
The materials, processes and terminology used in the construction of the Solitaire may be new to you unless you have built a moldless composite homebuilt in the last several years. This section is devoted to familiarizing you with the language, materials and techniques used in these plans. This information is basic to the construction of your airplane. You should study this section and be sure that you understand all of it before continuing.

There are five basic materials that you will be working with: fiberglass cloth, epoxy, microspheres, flox and foam. Each material, its properties and uses will be discussed in detail. Basic processes using these materials will also be discussed.

GLASS

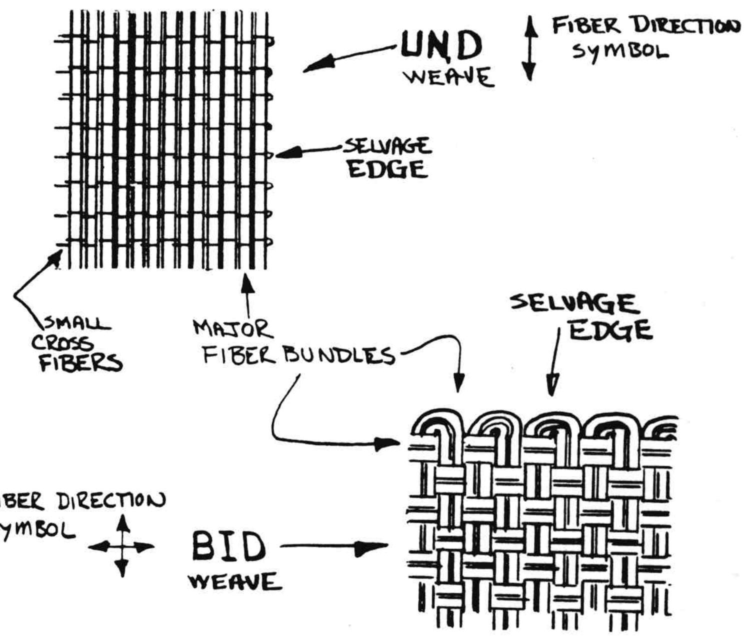
The most basic structural material in your Solitaire is glass cloth. Glass cloth is available commercially in hundreds of different weights, weaves, strengths and working properties. The use of glass in aircraft structures, particularly structural sandwich composites, is a recent development. Very few of the commercially available glass cloth types are compatible with aircraft requirements for high strength and light weight. Even fewer are suitable for the hand layup techniques developed by RAF for the homebuilder. The glass cloth used in the Solitaire has been specifically selected for the optimum combination of workability, strength and weight.





The glass cloth in your Solitaire carries primary loads and its correct application is of vital importance. Even though doing your glass work correctly is important, this does not mean that it is difficult. Good workmanship is a must, though, to achieve the design strengths.

Two types of glass cloth are used, a bi-directional cloth (RA7725BID) and a unidirectional cloth (RA7715UND). (Use the full part number for ordering your cloth, but for simplicity, the plans will use only the BID and UND designations). BID cloth has half of the fibers woven parallel to the selvage edge of the cloth and the other half at right angles to the selvage, giving the cloth the same strength in both directions. The selvage is the woven edge of a bolt of fabric as shown in the accompanying sketch. UND cloth has 95% of the glass volume woven parallel to the selvage giving exceptional strength in that direction and very little at right angles to it.



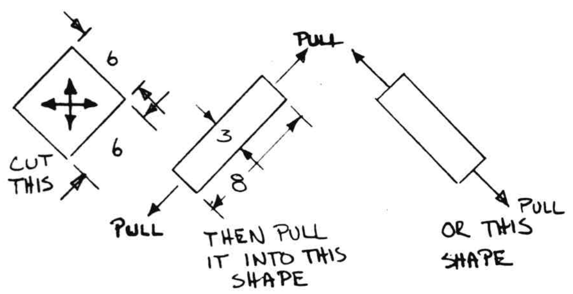
BID is generally used as pieces which are cut at a 45° angle to the selvage and laid into contours with very little effort. BID is often applied at 45° orientation to obtain a desired torsional or shear stiffness. UND is used in areas where the primary loads are in one direction and maximum efficiency is required, such as the wing skins and spar caps. Correct orientation of fibers is extremely important.

Multiple layers of glass cloth are laminated together to form the aircraft structure. Each layer of cloth is called a ply and this term will be used throughout the plans.

Marking and cutting the plies of glass cloth is a job that you will repeat often in the construction of your Solitaire. Glass cloth should be stored, marked and cut in a clean area with clean hands and clean tools. Glass contaminated with dirt, grease, or epoxy should not be used. If your cloth roll ever gets water spilled on it, it must be discarded and not used on an aircraft structure. A clean, smooth surface is needed for marking and cutting. The area used for storing and cutting glass cloth should be separated from the aircraft assembly area because it will be exposed to foam dust, epoxy and other things which can contaminate the cloth. You will need a good sharp pair of scissors, a felt-tipped marker, a fairly straight board and a tape measure for marking and cutting. The small amount of ink from marking and numbering plies has no detrimental effect on the glass cloth.

In each step, the size, type and fiber orientation of each ply is given. Take the list to your glass cutting table, roll out a length of the appropriate cloth, straighten the selvage, mark all of the plies and cut them.

Now is a good time to stop reading long enough to go and cut a square ply of BID and see how easy it is to change its shape by pulling and pushing on the edges as shown in the sketches. Cut a square with the fibers running at 45° and pull on the edges to shape the piece.



It helps if you make fairly straight cuts but don't worry if your cut is within 1/2 inch of your mark. As you cut BID it may change shape, just as the square ply that you are experimenting with does when you pull on one edge. Plies that distort when cut are easily put back into shape by pulling on an edge. Rolling or folding cut plies will help keep them clean and make it easier to maintain their shape. If several plies are called for, it may help to number them before cutting. Save your clean scraps and make an effort to use them for smaller plies. If the cloth is spotted with epoxy, throw it way.

When cutting long strips or larger pieces of 45° BID, always roll or fold it so it keeps its shape when handled. When its applied it can be set on one end of the part and rolled onto it. If you pick up each end, it will distort and not fit the part properly.

The fiber orientation called for in each materials list is important and should not be ignored. UND is characterized by the major fiber bundles running parallel to the selvage and being much larger than the small cross fibers which run at right angles to the selvage. In BID the cross fibers are the same size as those running parallel to the selvage, giving BID an even "checker board" appearance. BID is commonly used for plies cut at 45° to the selvage. Your tailor would call this a "bias" cut. The 45° cut also makes it possible to make a ply slightly longer than originally cut by pulling on the ends or wider by pulling the sides. The 45° orientation is not critical; you do not need to measure it. Your eyeball of a rough diagonal (45° ± 10°) is adequate when either cutting or laying up the cloth.

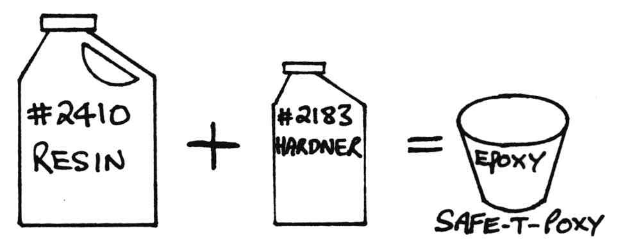
There is a difference in the way BID and UND are joined. When joining the edge or the end of BID and a BID ply it is necessary to overlap it one inch onto the ply it is being joined to. When joining UND across the major fibers it is lapped 1" per ply but when joining UND along the major fibers it is butted next to the piece it is joining, not overlapped. Also with UND it is not necessary to remove the selvage (edge of cloth) when making a wide layup such as a wing layup at 30°. Lay the first piece on with the selvage at 30° and butt the selvage of the next piece to it. With BID the selvage is always removed.

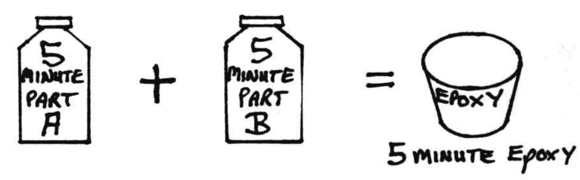
EPOXY

In recent years the term "epoxy" has become a household word. "Epoxy" is a general term for a vast number of specialized resin/hardener systems, the same as "aluminum" is a general term for a whole family of specialized metal alloys. Just as the "aluminum" in the spar of a high performance aircraft is vastly different from the "aluminum" pots and pans in your kitchen, the "epoxy" in your Solitaire is vastly different from the hardware store variety.
Epoxy is the adhesive matrix that keeps the plies of load-carrying glass cloth together. Epoxy alone is weak and heavy. It is important to use it properly so that the full benefits of its adhesive capability are obtained without unnecessary weight. A large portion of your education in composite structural work will be spent learning how to get the full strength of an epoxy/glass mixture with the minimum weight. This section will discuss the terminology and techniques for working with epoxy resin and its hardener.

An "epoxy system" is made up of a resin and a hardener tailored to produce a variety of physical and working properties. The mixing of resin with its hardener causes a chemical reaction called curing, which changes the two liquids into a solid. Different epoxy systems produce a wide variety of solids ranging from extremely hard to very flexible. Epoxy systems also vary greatly in their working properties, some are very thick, slow pouring liquids and others are like water. Some epoxy systems allow hours of working time and others harden almost as fast as they are mixed. A single type of resin is sometimes used with a variety of hardeners to obtain a number of different characteristics. In short, there is no universal epoxy system; each has its own specific purpose and while it may be the best for one application, it could be the worst possible in another use.

The Safe-T-Poxy epoxy system used in the construction of your Solitaire is tailored for the best combination of workability and strength, as well as to protect the foam core from heat damage and solvent attack. These systems are also low in toxicity to minimize epoxy rash.





The working and strength characteristics of an epoxy system are dependent on the resin, the hardener and on the amount of each in a given mixture. Epoxy systems are engineered for a specific ratio of resin and hardener. It is quite important that the proper mixture be obtained. An accurate balance or ratio pump must be used to accomplish this. A drawing of an inexpensive ratio balance is included in these plans, page . The mix ratio accuracy is important with Safe-T-Poxy. The 5 minute can be adequately ratioed by merely pouring a blob of Part A in a cup and adding a blob of Part B that looks the same volume before mixing. Never eyeball estimate Safe-T-Poxy, always carefully use the balance or pump.

Epoxy resin and hardener are mixed in small batches, usually 6 ounces or less, even in the largest layup. The reason for small batches is that, in large batches, as the hardening reaction progresses, heat is generated which speeds the reaction, which causes even more heat, which ends up in a fast reaction called an exotherm. An exotherm will cause the cup of epoxy to get hot and begin to thicken rapidly. If this occurs, throw it away and mix a new batch. The small volume batch avoids the exotherm. For a large layup, you will mix many small batches rather than a few large ones. With this method you can spend many hours on a large layup using epoxy that has a working life of only a few minutes. If the epoxy is spread thin as in a layup, its curing heat will quickly dissipate and it will remain only a few degrees above room temperature. However, in a thick buildup or cup, the low surface area to mass ratio will cause the epoxy to retain its heat, increasing its temperature. This results in a faster cure causing more heat. This unstable reaction is called an exotherm. Exotherm temperatures can easily exceed the maximum allowable for foam (200 degrees F) and damage the foam-to-glass bond. The Safe-T-Poxy system has been designed to minimize this problem and in thicknesses of less than 1/8 inch, there is no danger of exotherm. However, do not try to fill a void inside a wing by pouring Safe-T-Poxy in a small hole to fill a large void, it will exotherm and cause a larger hole.

Unwaxed paper cups are used for mixing and ratioing resin and hardener. Convenient 8-oz. cups for resin are available from Solitaire distributors. The hardener cups are the 3-oz. unwaxed bathroom paper cups available at any grocery store. Do not use waxed cups; the wax will contaminate your epoxy.

If you are using the homebuilt balance, follow this procedure. Place the resin (8 oz.) cup on the right cradle. The resin cup can be either a new clean cup, one with a little uncured epoxy left in the bottom, or a clean cup from a previous layup with hard epoxy in the bottom (smooth, not lumpy). Now, take a clean 3-oz. hardener cup - pour a splash of hardener into it then scrape the hardener back into the container. This gives the hardener a wet surface, so its remaining hardener will not be counted in the balancing. Now, place the wet hardener cup on the scale, check that it swings freely and balance it perfectly by moving the small weight. Epoxy is then poured into the 8-oz. cup (6-oz. or less). Hardener is then poured into the 3-oz. cup at the other end of the balance until the arm is level. When ready to mix, pour the hardener into the resin cup and mix completely. If you have the ratio pump, you simply put one cup under the spout, pump out the amount that you want and mix.

Mixing is done by stirring with a stick, being careful not to spill any. If you spill part of an unmixed cup, the ratio of resin and hardener may be inaccurate and it should not be used. Mix each cup for a least one minute. You should spend 80 % of your mixing time stirring the cup and 20 % scraping the sides to assure complete mixing. Do not mix with a brush. The bristles can soak up the hardener, changing the ratio. Use a tongue depressor or wood stick.

The working temperature has a substantial effect on the pot life and cure time. Very hot conditions will cause the cure to speed up. In cold working conditions the cure will be delayed and if it is cold enough, epoxy may not cure at all. Working temperatures must be between 70° and 100° F. A range of 75° to 85° is best. Be sure to get a wall thermometer (approximately $1.50 at any general store) to check the temperature of your work area. At 75° F, 5 minute must be used within four minutes, Safe-T-Poxy must be used within 20 minutes and in a cup the working time will go down as a mild exothem starts.

Cold epoxy results in increased time required to do a layup, since it takes longer to "wet" and to squeegee the cloth. A layup at 70° F may take almost twice the time as at 80° F. On most layups (except for joining foam cores) it is best to have 75° to 85° F room temperature and 90° to 100° F epoxy. Resin and hardener can be kept warmer than room temperature by keeping it in a cabinet with a small light bulb on. DO NOT store your resin or hardener on a cold floor if you plan to use it within the next several hours. If you let your shop get cold between working periods, keep some resin and hardener in the warmest place of your house for use on the next layup.

Sometimes Safe-T-Poxy hardner will have solids form in the bottom of the bottle. If this happens do not use the hardener. All of the hardener must be liquid before it is used. To use this hardener it is necessary to heat it up and stir or shake it slightly. To do this heat some water on your kitchen stove in a large pan with the hardener in the pan of water. Move the bottle around to be certain not to melt the plastic container. When the water has just started to boil pull the hardener out and slosh it around. This should disolve all of the sediment in the bottom. If not put it back in the water for a few minutes and then shake it again.

Save your mixing cups, as they can be used as a quality check of your epoxy. After a day or two take a sharp knife point or scribe and scratch at the face of the epoxy in the cured cup. If the epoxy cured properly the scribe will make a white scratch mark. If the epoxy has not cured, the scribe will make a dull ridge, indicating a soft surface. If this occurs the epoxy is not cured, either due to inadequate time or temperatures, or bad mixing or bad epoxy.

Temperature is very important in working with Saf-T-Poxy. If you are working in a garage in the winter, the room must be heated up well in advance of the start of your layup. The foam blocks are a very good insulator and so it can take as long as four hours for the foam to warm completely to room temperature. Start heating your work area and all materials well in advance of starting your layup.

A hair dryer is also very helpful to use during a layup. If you are working toward the bottom of the temperature range you can speed the wetting of the cloth with a few light passes of your hair dryer while running a squeegee across an area of the layup. Care must be taken when using this technique so as not to get an area too hot. Also, when you have heated the epoxy up the squeegee will remove it easier, therefore it is possible to get the layup too dry. But the conservative use of the hair dryer can be very helpful.

MICROSPHERES

Microspheres are a very light filler or thickening material used in a mixture with epoxy. Micro, as the mixture is called is used to fill voids and low areas, to glue foam blocks together and as a bond between foams and glass skins. Only 3M 1323, 500 glass balloons are usable in the Safe-T-Poxy. This type will be supplied with your kit and can be ordered separately from your Solitaire distributor. Quartz Q Cell balloons if used with Safe-T-Poxy will slow the cure time by as much as three days. When the cure is complete, the structural integrity is satisfactory but the time required is not. Micro balloons must be kept dry. If moisture is present it will make them lumpy. Bake them at 250 degrees then sift with a flour sifter to remove lumps. Keep the microballoon container covered.

Micro is used in three consistencies: a "slurry" which is a one-to-one by volume mix of epoxy and microspheres, "wet micro" which is about two-to-four parts microspheres by volume to one part epoxy and "dry micro" which is a mix of epoxy and enough microspheres to obtain a paste which will not sag or run (about five parts-to-one by volume). In all three, microspheres are added to completely mixed epoxy.

You do not have to accurately mix the microspheres; just dump them in until the desired consistency is obtained. Micro slurry is used to paint over foams before glass cloth is applied over them. Slurry is almost the same viscosity as the pure epoxy and is runny enough to apply with a brush. However, the easiest way to apply slurry is to pour it onto the surface and spread it out evenly using a squeegee. When skinning pour-in-place urethane foam use a full thick coat of slurry. Inadequate slurry on urethane can result in a poor skin bond. Wet micro is used to join foam blocks and while it is much thicker than slurry, it is still thin enough to sag and run (like thick honey). Dry micro is used to fill low spots and voids and is mixed so that it is a dry paste that won't sag at all. In all three micro types, you do not measure, just add microspheres until the desired consistency is obtained. Use micro only as specifically shown - never use micro between glass layers.

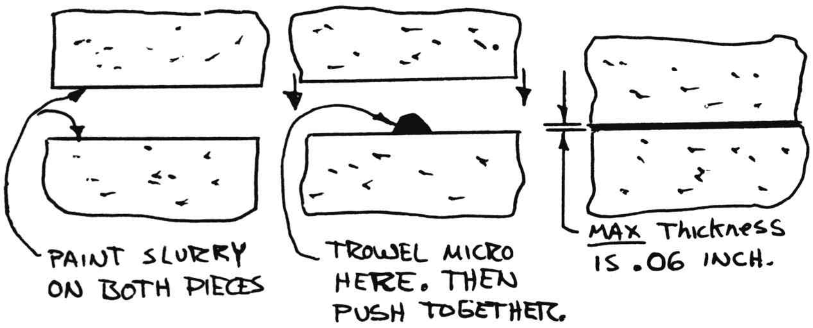
Joining Foam Blocks with Microspheres/Epoxy

Always use the following method to join foam blocks. This is extremely important. Always use Safe-T-Poxy.

1. Check that the foam blocks fit closely together. If there are voids over 1/16 inch, sand to fit, or fill the void with a sliver of foam.

2. Paint a light coat of micro slurry on both surfaces. If joining foam to fiberglass, paint pure mixed epoxy (no microspheres) on the fiberglass surface and micro slurry on the foam surface.

3. Refer to the sketch and trowel wet or dry micro in the center of the joint. Thus, when joined the micro is pushed outward expelling (rather than trapping) air. If the fit is excellent use wet micro. If it is open enough and vertical such that epoxy may run out, use dry micro.



4. Push the two pieces together, wiggling each to move the micro toward the surfaces. Be sure the micro is no thicker than 0.1 inch at any place, to avoid exotherm. Wipe off any excess. Do not be concerned if the micro does not completely reach the surface. That void can be filled immediately before skinning the part.

FLOX

Flox is a mixture of cotton fibers (flocked cotton) and epoxy. The mixture is used in structural joints and in areas where a very hard durable buildup is required. Flox is mixed much the same as dry micro, but only about two parts floxs to one part epoxy is required. Mix in just enough flox to to make the mixture stand up. If "wet flox" is called out, mix it so it will sag or run.

When using flox to bond a metal part be sure to sand the metal dull with 220 grit sand paper and paint pure mixed epoxy (no flox) on the metal part.

A flox corner is a structural joint which is in the shape of a triangle from the end view and the side length will be called out. If only one side length is called out assume the other to be the same. When removing foam to install a flox corner be very careful not to cut the skin but you must remove the micro that was slurried onto the foam when the skin was applied. There are two places where this type of joint is used. First when there is a 90° corner and second at the top trailing edge of the rudder and elevator where you are trying to make a very tight wrap over the top. A flox corner will give the corner some extra strength.

BONDO

Throughout these plans the term "Bondo"is used as a general term for automotive, polyester body filler. Bondo is used for holding jig blocks in place and other temporary fastening jobs. We use it because it hardens in a very short time and can be chipped or sanded off without damaging the fiberglass. Bondo is not used for contouring or filling because of its heavy weight.
Bondo is usually a dull gray color until a colored hardener is mixed with it. The color of the mixture is used to judge how fast it will set. The more hardener you add, the brighter the color of the mixture gets and the faster it hardens. This simple guide works up to a point where so much hardener is added that the mixture never hardens.
Follow the general directions on the Bondo can for fast setting Bondo. Mixing is done on a scrap piece of cardboard of plywood (or almost anything) using a hard squeegee or putty knife. A blob of Bondo is scooped out of the can and dropped on the mixing board. A small amount of hardener is squeezed out onto the blob and then you mix to an even color. You will mix the blob for about one minute. You will then have two to three minutes to apply it before it hardens.

Be sure to clean the board and putty knife off before the Bondo is completely hard. MEK will clean Bondo off your putty knife and squeegee if it is not completely hardened.
Throughout these plans you are asked to Bondo boards to cured epoxy such as wing skins. When joining fixture at 90° to your skins it is better to use several small dabs than one large one. These should be about 1/2" x 1/2" forming a triangle as shown. When joining a layup to a flat table or board it is best to use an amount that when fully squeezed between the parts, spreads to about the size of a quarter.

R.T.V. Silicone Rubber

This product is used to hold things in place that generally are subject to heat up to 450° F, or vibration. R.T.V. sticks well to sanded steel or aluminum and sanded fiberglass parts. The general use of this material is to hold down fuel lines or stick parts to an engine. We have tested GE brand in clear or white. Product # GE2567-012 or GE 361. Caution: Silicone will dissolve in fuels.

FOAM

Three different types of rigid, closed-cell foam are used in your Solitaire (and several densities). A low density (2 lb/ft^3), light blue or white styrofoam is used as the foam core of the wings, vertical stabilizer and canard. The styrofoam is exceptional for smooth hotwire cutting of airfoil shapes.

The large cell type used provides better protection from delamination than the more commonly used insulation-grade styrofoams. This styrofoam also has greater peel strength than the standard blue styrofoam sold by some insulation distributors. Do not confuse styrofoam with white expanded polystyrene. This is the material white foam ice chests are made from and its properties are not accceptable. The blue foam used in your flying surfaces was selected for a combination of reasons, hot wire cutting ability was an important factor. Never hot wire other types of foam, urethane will give off poisonous gases. Buy your foam from a Solitaire distributor and you will receive high quality materials that have been tested to do the job.

Devincel Poly Vinyl or PVC is used in the bulkheads of the fuselage if you make them yourself. The weight of the foam used in the bulkheads is 2.9 lb/ft^3 (type H45) and the thickness is .25". This foam has very good peel strength and compression strength. Again PVC foam comes in many types and densities. Be sure you order from a Solitaire distributor so you receive products which are recommended for the job.

Pour in Place Urethane foam. This is a two part liquid which when mixed together will foam up into a solid at 2 lb/ft^3 liquid. X-40 foam is the brand we have tested. This foam is a strong skin sensitizer so it is imperative that gloves be used when working with this material. Read the label and follow mixing instructions. X-40 foam cures with heat so it kicks faster on a hot day. Mix small batches the first couple of times you use it to get the feel for how fast it goes off and how much to use. Successive layers can be used one after the other before curing or after cure to get a full build. Watch when trying to fill an area that you leave room for the excess to escape. Scrap pieces of styrofoam can be used as dams to contain the X-40. When you are building a shape such as in the wing root fairing you can glue pieces of styrofoam together using X-40. After mixing the X-40 apply with a brush to the foam blocks and set them in place. This foam when cured can be worked with standard wood working tools. Sanded with standard sandpaper and cut with a knife or saw. Never, however, use this foam in any application that will be hot wire cut as this will emit a poisonous gas.

HOT WIRE CUTTING

The airfoil-shaped surfaces of your Solitaire are formed by hot wire cutting the blue styrofoam of 2lb/ft^3 density. The hot wire process gives airfoils that are true to contour, tapered and

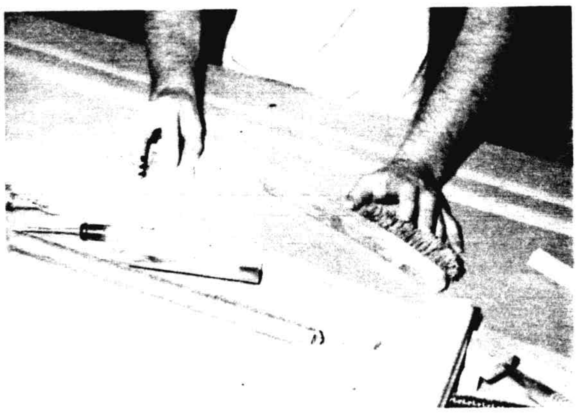
URETHANE FOAM SHAPING

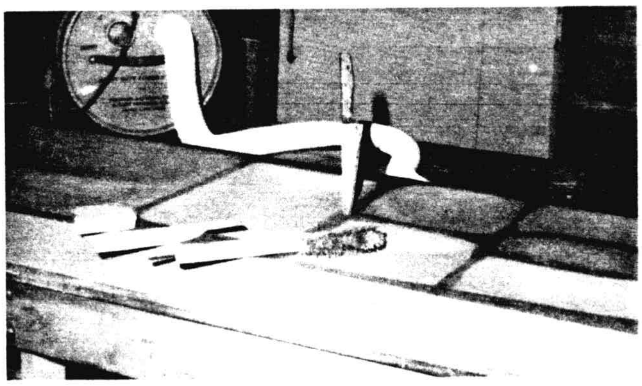
One of the real treats in the construction of your airplane will be shaping and contouring urethane foam. Urethane is a delightful material that shapes with ease using only simple tools. A butcher knife, old wire brush, sandpaper and scraps of the foam itself are the basic urethane working tools. A vacuum cleaner is convenient to have handy since working urethane produces a large quantity of foam dust. The knife is used to rough cut the foam to size. The knife needs to be kept reasonably sharp; a sander or file is an adequate knife sharpener since it is a frequent task and a razor edge is not necessary. Course grit sandpaper (36-grit) glued to a board as shown on Page 3-1 is used for rough shaping outside contours.

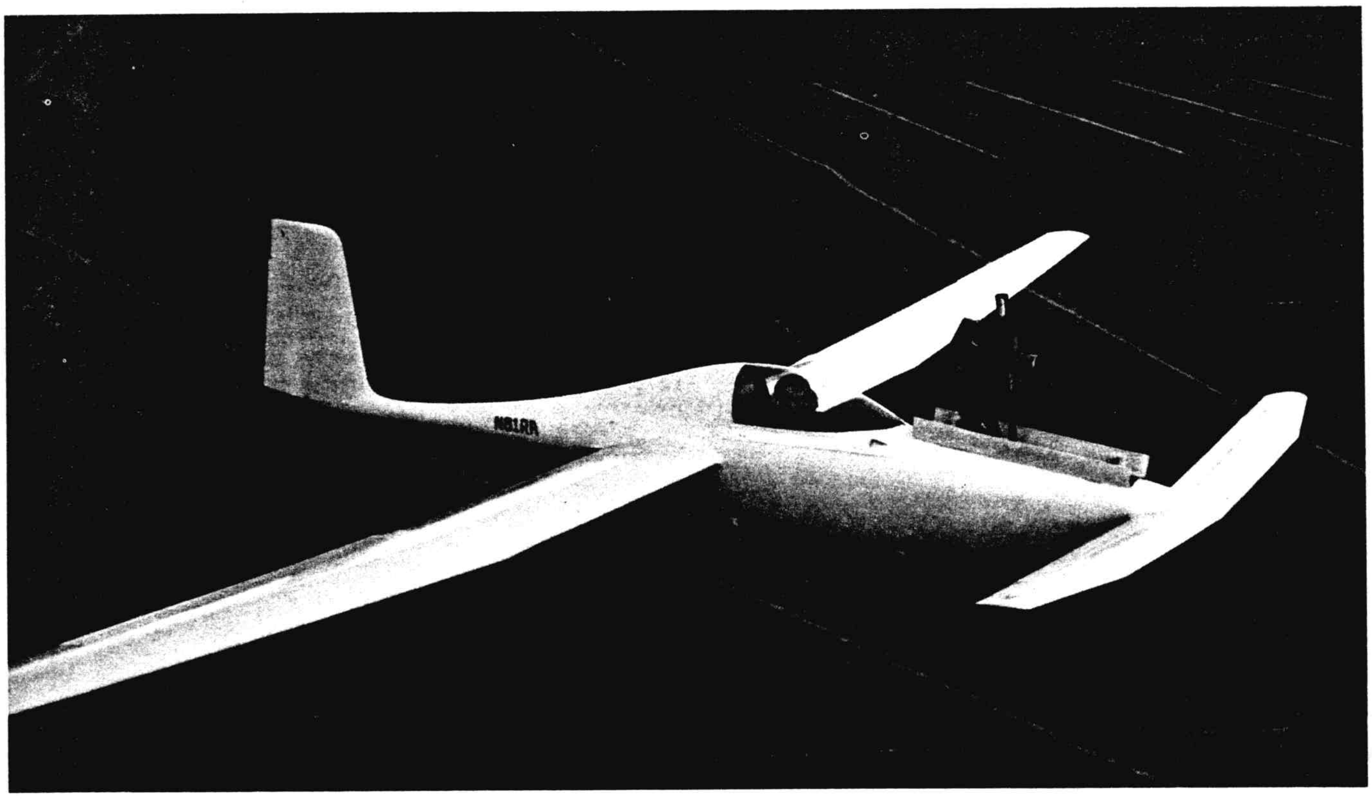
Inside contours or "dishing" is done by using a ragged old wire brush to rough out the bulk of the foam and following up with a scrap foam piece to smooth the surface. The foam scrap conforms to the shape of the surface resulting in a very smooth contour.

Outside contours are roughed out with a sanding block and finished using a foam scrap. Dry micro and flox are used to fill voids and pot fasteners in a number of places. All foam shaping should be finished before any micro filling is done, because the filler is much harder than the foam and this makes smooth contouring very difficult. Your best carving template is your eyeball; an occasional check on the depth of a contour is about the only measurement necessary.

Keep your shop swept reasonably well. The foam dust can contaminate your glass cloth and your lungs. Use a dust respirator mask while carving urethane. Try not to aggravate the family by leaving a green foam dust trail into the house.







HOT WIRE CUTTING

The airfoil-shaped surfaces of your Solitaire are formed by hot wire cutting the blue styrofoam of $2 lb/ft^3$ density. The hot wire process gives airfoils that are true to contour, tapered and properly twisted with a minimum of effort and the simplest of tools. The details for making your hot wire saw were shown on page 3-2.

The hot wire saw is a piece of stainless steel safety wire, stretched tight between two pieces of tubing. The wire gets hot when an electrical current passes through it and this thin, hot wire burns through the foam. By making smooth steady passes, the hot wire gives a smooth, even surface. The foam offers little resistance to the hot wire's passage. A variable voltage control is used to supply the electrical current that heats the wire.

To get a smooth accurate cut, a hot wire template is needed. Hot wire templates can be made from 1/16 to 1/4 inch plywood, formica, or masonite or .032 to .064 sheet metal. It is important to have smooth edges on the templates. A rough edge may cause the wire to hang up and burn into the foam excessively. Templates are required on both ends of the foam being cut. The size, shape and orientation of the two templates is varied to taper and twist the foam core as required. The plan form (span and sweep) is set by squaring up the foam block before the templates are used. In general, the trailing edge of the wing is the reference; a "trim line" on the templates is lined up on the trailing edge.

Full size template drawings are provided in the plans. To make your templates, just glue the template drawings to a piece of plywood or sheet metal and trim to the contours shown. There are a number of markings on each template which aid in the alignment and cutting of the foam core. These templates can also be purchased from a distributor.

Each template has a waterline (W.L.) marked on it which is used to align the twist of the foam core. Each template's waterline is leveled using a carpenters bubble level. This assures that the relative twist at each template is correct. The template is then nailed to the foam block to obtain the correct plan form; a foam trim line is provided near the trailing edge of each template which is lined up on the foam edge before cutting. It is necessary to check the straightness of the trailing edge of the foam block. This edge must be straight.

Each rib template has numbered marks running from the trailing edge around the leading edge and back to the trailing edge. These are called "talking numbers". When the foam cores are cut into their airfoil shape, the talking numbers are used to assure that each end of the hot wire is co-ordinated to obtain the correct, tapered airfoil. The person calling the numbers should be at the largest template. A typical cut would sound like this: "Resting on the tab at the foam, moving forward, entering foam now - one, half, two, half, ... 34, half, 35, half, 36, coming out of the foam and pausing on the tab, wire's out". As the cut is made, the person on the small rib follows the numbers, passing over them as he hears them called out. Pause marks are indicated in places where it is necessary to pause for a couple of seconds and let the hot wire's center lag catch up with the ends.

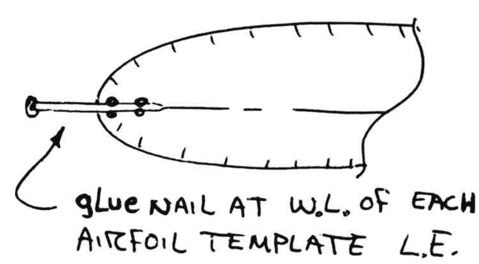
Preparing a foam block for an airfoil is begun by trimming the rectangular foam block to the basic dimensions for the correct plan form. These "trim" cuts are made using two straight edge trim templates. The best way to get straight edge trim templates is to buy a 36" aluminum yard stick and cut it in half. Drill holes to fit your nails every inch. You do not need to nail this every inch but it is good to have lots of places to nail it.

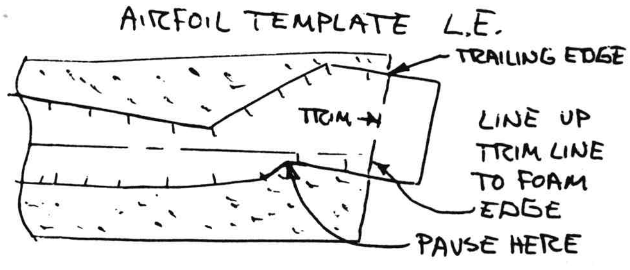
The templates are held against the foam by nails through the template into the foam. Enough nails should be used to hold the template firm so that it won't move when the hot wire is held against it.

The use of the hot wire saw is a simple thing if your equipment is set up properly. Proper wire tension and wire temperature should be maintained for good cutting. The wire tension should be tightened after the wire is hot by twisting one tube with a pair of pliers. The wire should be hot enough to cut one inch of foam in four to six seconds without having to force the wire. A wire that is too hot will burn the foam away excessively. To cool an over-heated wire, simply turn your voltage control to a lower voltage setting. If you use a battery charger, you will have to add length to the wire. To warm up a cool wire, just increase the voltage setting or, with the charger shorten the wire.

When the wire is heated away from the foam it will become hotter than when it is in the foam. To avoid excessive burndown at the start of a cut rest the wire against the foam on the part of the template which is sticking out of the foam. Then turn the wire on and with light pressure in the direction of the cut wait until the wire starts to melt into the foam. Although the foam offers only mild resistance to the hot wire, a long cut will cause the middle of your wire to lag behind the ends. Wire lag can cause problems in tight curves like the leading edge of an airfoil. To reduce lag there, the cutting speed is reduced to about one inch in 8 to 10 seconds. The airfoil templates have notations in the areas where reduced speed cutting is necessary to allow the lag to catch up completely.

The most common hot wire error is wire lag which causes a bow in the leading edge. The following method solves this problem and thus we recommend you use it for cutting the canard, wings and vertical stabilizer. Instead of making one cut all around, glue nails on the templates at the waterline at the leading edge as shown. Now, cut the core in two passes: one from the leading edge up over the top to the trailing edge, the other from the leading edge (under the nail) down under the bottom to the trailing edge. The thin "flash" of foam left on the leading edge due to the thickness of the nails is easily removed with your butcher knife. The result is a perfectly straight leading edge. Care must be taken to assure that both ends simultaneously approach the template at the leading edge. Use the following vocal commands "wire is moving toward the nail, now resting on the nail 1/2 inch from the template (confirm both ends in that position), moving toward template 1/4 inch away, 1/8" away, on the template, moving up X (talking number) , Y (talking number)....". When approaching the trailing edge overlap notch (see sketch) slow down and pause 3 seconds in the notch to assure a full, sharp , accurate surface for the skin overlap.





The hot wire should be guided around the templates with light pressure. Pushing too hard against the template may move them or flex the foam block which results in an under cut foam core.

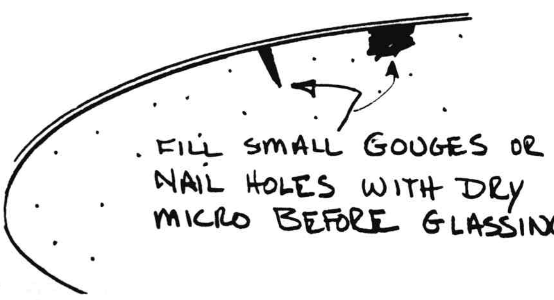
The correct set-up is just as important as using the correct tools and materials. Foam is a fairly flexible material and an improper set-up can cause deflection. The foam block should be well supported at each end, so that it does not sag and does not move around while being cut.

You need clearance for the hot wire cutter to pass by the table and the weights used to hold the foam steady.
When applying weights, set the foam core on your table and weight both ends near the hot wire templates. We use lead shot bags, 25 lbs. on each end of each core. Once you have nailed a set of templates on a foam block do not move the templates and weight on the foam blocks, until the core is

completely cut out. If you cut the top of a core then move the block and then cut the bottom, you will not necessarily have a core that is the right shape.

Foam is manufactured in sizes that are often too small to get a solid core from a single block. If it is necessary to use two foam blocks to get the size required for cores, these blocks have to be joined using an epoxy/microspheres mixture. The hot wire won't cut through the micro joint, so all of the hot wire cutting is done with the blocks temporarily joined. Nails or blobs of 5-minute epoxy are used for temporary foam joints, but the hot wire won't cut through these. Thus they have to be placed carefully so that the wire doesn't have to pass through them.

Do not be overly concerned if you don't make perfect foam cuts: ridges on the foam core from inadvertently lifting the hot wire off the templates are easily faired in with a sanding block. A less-than-perfect leading edge can be blended in by sanding after the foam core is assembled. Gouges in the foam can be smoothed and filled with dry micro to contour after applying the glass skins. The foam is too expensive to throw away because of a minor gouge.



A finished foam core may warp out of shape after it is removed from the original block. This is due to internal stresses in the foam from the manufacturing process and is no cause for concern.

A warped core is simply weighted into the jig blocks and shimmed straight. Once the skin has been installed, the foam is held firmly in position.

GLASS LAYUP

The glass layup techniques used in your Solitaire have been specifically developed to minimize the difficulty that glass workers have traditionally endured. Most of the layups that you will do, will be on a flat horizontal surface without the molds, vacuum bags and other special equipment that are common in glass work. The layups that you do will all cure at room temperature; no ovens or special heating is required. If you have suffered through a project that requires you to build more molds and tools than airplane components, then you are in for a real treat.

The techniques that you will use are very easy, but they still need to be done correctly. 90 % of the work that you will do is covered in the next few paragraphs, so make sure that you read and understand this section very well. If you learn these basics, your airplane will be VariEze indeed. If you skip over this information, you will probably end up very frustrated.

Step I: Personal Preparation

Before you get started with a layup, plan ahead. Some major layups take several hours and before getting your hands in the epoxy, its a good idea to make a pit stop at the restroom.

Do not start a large layup if tired. Get some rest and do it when fresh. Its best to have three people for any large layup, two laminators and one person to mix epoxy. Be sure the shop is clean before you start.

Take the recommended health precautions (discussed later in detail) using gloves or barrier skin cream. Get your grubby, old clothes on or a least a shop apron. Make sure that your tools are clean from the last layup and ready to use. Your working area should be between 70° F and 95° F. Best results are obtained at 75° to 95° F. Below 70° the epoxy is thicker making it more difficult to wet the cloth. Above 85° F, the possibility of an exotherm is greater.

Step 2: Cut Fiberglass Cloth

The fine points of glass cutting have been covered earlier. Just remember that there is not any requirement to cut accurate dimensions. Cloth dimensions are given well oversize. You scissor trim them as you go, while laying the cloth up. It is a good idea to keep two pair of scissors: one clean and in the glass storage area and one in the shop that gets epoxy on it. After cutting, roll or fold the material; keep it clean and handy for the pump.

Step 3: Prepare Surfaces

The only difference between layups over different materials is in surface preparation. The layup over foam will be covered here since you will be doing more of it and other surface preparations will be covered separately.

The foam surface is prepared by leveling uneven areas with a sanding block and brushing or blowing any dust off the surface. Use compressed air or vacuum to remove dust.

Now is the time to accurately check that the foam core is the correct size, shape and contour. Refer to the section views of the part - be sure your core looks exactly like that on the section view. Lay a 12-inch straight edge spanwise on all critical areas of the flying surfaces (see sketches 3-10) and be sure you don't have any high or low places or joggles. Measure any areas that involve fiberglass buildups to check for correct depth. Build up is 0.009 inch per ply for UND and 0.013 inch per ply for BID.

Step 4: Mix Epoxy and Paint Surface

Mix epoxy only when needed, not before. Epoxy, micro and flox may be needed at various stages, so you may need several cups. If you are laying up over cured fiberglass, paint a liberal coat of epoxy on the surface. When laying up over styrofoam, PV foam or urethane foam, paint a liberal coat of micro slurry on the surface, before laying on the first ply. The slurry can be poured on the foam and spread thin with a squeegee or it can be brushed on with a brush. Squeegee excess slurry off the foam. You do not want the slurry to work up between the layers of cloth with stippling and squeegeeing. Then, fill any dings or gouges in the foam core with dry micro.

Step 5: Lay on the Cloth

To lay the cloth on, you need to know which direction the fibers of the cloth will run. You are told to lay them on usually 2 plies one at +30° to some named reference point such as a shearweb or T.E. and a second ply at -30° to the same reference.

Lay on the cloth in the specified orientation. Pull the edges to straighten the cloth out and to remove wrinkles. Maximum strength and stiffness is obtained if the fibers are not wavy or wrinkled. If the cloth is to be applied around and into a sharp corner, you will find the job easier to do if the fiber orientation is at 45° to the corner. Do not get depressed if the layup looks like a hopeless mess at this point. Press on with patience and things will work out fine. To remove wrinkles, study the direction of fibers, follow the fibers to the outer edge of the cloth and pull on the outside edge. Pushing a wrinkle off the part is incorrect. Once the part is free of wrinkles use a squeegee and make light passes from the center outwards to smooth the cloth.

The better you lay the cloth on the part the first time, the easier the straightening will be. Take extra care laying it on. If you are applying UND, have a helper hold the roll in position to one side of the part and you can pull the cloth off the roll over the part. Then you both set the cloth down on the part, come around and cut the cloth free of the roll leaving a little extra to trim later. Once you try this a couple of times you develop the knack and can lay the cloth on so it needs very little adjustment.

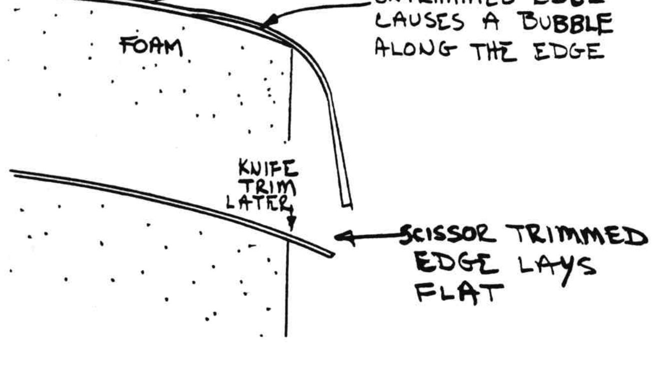
Step 6: Wetting out the Cloth

Once the cloth is on the part you will notice some of the epoxy in the slurry will wet out blotches of the cloth. Apply more epoxy on a larger layup by pouring a fresh mixed cup onto the part and squeegeeing it out to as much area as you think it might cover quickly. Get the epoxy spread out while it is still above room temperature.

On this first fast spreading of the epoxy do not take too much care to cover all the cloth, just get it spread out. Once you have the epoxy spread out come back and squeegee for the proper amount of epoxy over the surface, respreading to cover and wet out the area properly. If you start to work in a small area, working until that area is perfect and then onto another small area, you will never get the epoxy out of your cloth before it begins to cure, and you will never finish your first layer of cloth on the wing before it has cured. If this is a one ply layup, squeegee until a light pass will not run a ridge of epoxy in front of the squeegee as you pull it. Also look for air in the layup which can be seen as tiny flecks or bubbles. If you see this and squeegeeing does not help, try either fresh mixed hot epoxy or light strokes with a hair dryer. If this is a multiple ply layup you do not have to have all the excess epoxy up before the next ply goes on. Apply the second ply and squeegee the cloth to draw up any excess from below before applying fresh epoxy. If you use this method do not keep putting wet plies on and think you can draw it all up on the top ply. Dry each ply out by squeegeeing the new cloth then add new epoxy. If the epoxy comes through but does not wet the cloth out use light passes with a hair dryer. Remember that you only want to add 5 to 10° F to the surface temperature of an area of your core. Do not overdo it or you can dry it out too much. Do not squeegee to hard as this can starve the layup also. A brush is used to wet out small areas or curved areas where you cannot get a good stroke with a squeegee. A brush can be used to remove air from the layup by stippling.

This is a vertical light stabbing motion with the brush. This technique is useful for wetting out small areas and corners and perhaps a problem area on a wing. Do not try and stipple out a whole wing, it takes much longer than using light passes with a squeegee. A brush can be used to pick up excess epoxy in small areas or corners by drying the brush out as much as possible. Hold the brush on edge and run the brush down past the edge of the cup several times. Now the brush will pick up a small amount of excess epoxy. This is a very slow way to remove excess epoxy but useful in corners and tight areas. Another tool many people find useful is a stipple roller. This is used for spreading the epoxy and stippling out the air. It is however a good idea to check your layup with a squeegee for excess epoxy.

As you wet out each ply, scissor trim to within 1/2" of any overhang (trailing edge, etc.). This 1/2" will be knife trimmed after the layup cures. If an over hanging ply isn't trimmed, it lifts the edge up and makes a bubble. After scissor trimming, restipple the edges to be sure there are no voids. Wet the cloth beyond the trim line at least 1/4" to allow easy knife trimming later.



Step 7: Squeegeeing

Squeegee out excess epoxy. This involves drawing a plastic or rubber squeegee over the layup as shown. Plastic squeegees (scrapes) are available at any paint store. If excess epoxy exists, it will be pushed off the edge of the piece. Remember, excess epoxy is much better on the floor than on the airplane. It is possible to squeegee too hard and make the layup too dry. If this occurs, the surface will appear white, indicating the presence of air. If this occurs, wet the cloth by painting on a little epoxy and squeegeeing it down into the layup. The best quality layup is obtained if each layer of a multi-layer is squeegeed.

The finished layup should appear smooth and brown so that the weave of the cloth is clearly visible, but not so dry that any area appears white in color. If you've done an excellent job, the weight of resin will be about 1/2 of the weight of cloth used.

To check if there is too much epoxy in the layup, pull a squeegee across the surface, stopping before you reach the edge. Lift the squeegee up and look for a large "ridge" of epoxy where the squeegee stopped. The ridge under the top ply indicated that the layup is too wet and you should spend time with the squeegee to remove epoxy off to the sides.

Don't hesitate to use your stippling roller or brush on an area after squeegeeing. But resqueegee afterwards to check epoxy content. Some places are not suited to the use of a squeegee and the dry brush or roller can be used to expel the excess epoxy. On a given layup, about half of your time should be spent squeegeeing.

Step 8: General Inspection

After you have finished the layup, take a few minutes and give it a good general inspection for trapped air, dry glass, excess epoxy and delamination. It is much easier to correct these things while the layup is wet than to repair the cured layup. Also, have someone else inspect it, usually a different person can find air flecks or bubbles that are missed by one inspector. Carry a good light around for the inspection. Glance the light off the surface at various angles to look for air flecks. If any air is visible, stipple or squeegee it out.

Be sure the overlaps on the edges are perfect. If, due to a sharp corner etc., you have a problem eliminating an air bubble, use one of the following two methods: (1) Lift the cloth up off the foam, trowel some wet micro into the troublesome area, add more epoxy as you stipple the cloth back down. (2) Add excess epoxy over the bubble, cover the surface with Saran wrap (thin plastic wrap) then push firmly outwards to force the air out to the sides. The Saran wrap will seal the surface to keep air from being drawn in. This method will force the cloth to stay down even around a sharp corner.

Step 9: Preliminary Contour Fill

Certain areas, like over the spar and along the trailing edge (see cross section views) require a dry micro fill. It is preferred to apply this fill within 2-3 hours of finishing the fiberglass layup. However where the micro filler obscures the structure underneath, like over the spar cap, FAA inspection should be completed before dry micro filling. Areas like the trailing edge where the structure can be inspected from the other side should be filled while the layup is still tacky (within three hours of the layup). If you wait until the layup cures, you will have to sand the fiberglass surface to a dull finish before applying the micro. So, mix up a "dry" micro mix and trowel it into low areas while the layup is still wet, and save the work of sanding where feasible. On the trailing edge cover the dry micro with peel ply and squeegee the whole thing to contour.

Step 10: Cleanup

We generally use a cheap brush (approximately $2.00 to $4.00 per dozen) and discard them after use. Clean squeegees by wiping with a paper towel then wash the squeegee in soap or Epocleanse and water.

If you use skin barrier cream (Ply #9) the epoxy and cream will wash off easily with soap and water. When you get epoxy on unprotected skin, Epocleanse is used to remove the epoxy. Both of these products are available through Solitaire distributors and are listed in the bill of materials. Once you are sure your skin is clean, wash again thoroughly with soap and water, even if your hands were protected with plastic gloves. If you get epoxy on tools or metal parts, clean them with a clean paper towel then wash them in Epocleanse or soap and water.

The only good way to protect your clothing is not to get epoxy on anything that you care for. Use a shop apron and don't make layups in good clothing. A surplus flight suit or other cheap coveralls are a good investment.

You may feel that layups are real messy work after your first experience with them. However, after you've done several, you will have learned not to scratch your ears, eyes, etc. during the layup. If your tools and work area are clean and organized well and you are disciplined with the epoxy, the job can be a lot less messy than working with other materials.

Step 11: Knife Trim

When a layup is wet, you can only scissor trim to within 1/4 inch without disrupting the fibers in the ply. An easy clean trim can be obtained by waiting three to five hours after the layup. At this time, the laminate is firm enough to support the cloth from fraying, yet soft enough to cut easily with a sharp knife. This "knife trim" stage is the optimum time for edge trimming with ease and accuracy. Take a sharp, single-edge razor blade or X-Acto knife and trim the edges with a motion down ward toward the edge. Experience will help you determine the correct time in the curing cycle for optimum knife trimming.

In the plans when "knife trim" is called for, this assumes the three or four hour wait, even though not specifically stated. Don't fall apart if you miss the knife trim stage and have to trim the fully cured glass. If you wait until the layup is completely set, then saw along the edge with a coping saw, or dremel, bandsaw, saber saw etc. Smooth the edge with 36 grit sandpaper. When trimming a cured edge, be careful of the "needles" (sharp protrusions of glass-frayed edges supported with epoxy). The needles can be avoided by returning three hours after the layup to make the knife trim. Knife trim time varies with temperature: about 6 hours at 70 degrees and 1 hour at 90 degrees. A little heat applied with a hair dryer will allow knife trim if you arrive a little late. Caution: hair dryer heat can damage foam cores.

Other Surfaces

Surface preparation (Step 3 of the basic glass layup) varies with the material that you are laying up over. The layup over foam was covered in detail in Step 3. To prepare a cured glass surface for layup, the cured surface must be sanded to a completely dull finish with 36 to 60 grit sand paper. If any of the glossy surface remains, an incomplete bond results which is weak. Better yet, use peel ply as described later. Micro slurry should not be applied to glass surfaces being bonded, this weakens the joint. Wood requires no special preparation for bonding but should be free of grease, oil, paints and varnish. Sand wood surfaces with 36-grit sandpaper before layup. Metal bonding is not relied upon for strength but metal surfaces should always be free of oil and grease. Except for bolts, nuts and other fasteners, metal surfaces should be dulled by sanding with 220-grit sand paper and coated with epoxy before setting in place. Cured micro surfaces should be sanded dull but be careful not to obliterate surrounding foam surfaces while doing it. In practice you may be glassing over several types of material in the same layup and you will be using most of these surface preparation techniques together.

QUALITY CONTROL CRITERIA

One of the unique features of the glass-foam-glass composite construction technique is your ability to visually inspect the structure from the outside. The transparency of the glass/epoxy material enables you to see all the way through the skins and even through the spar caps. Defects in the layup take four basic forms: resin lean areas, delaminations, wrinkles or bumps in the fibers and damage due to sanding structure away in finishing. Resin lean areas are white in appearance due to incomplete wetting of the glass cloth with epoxy during the layup.

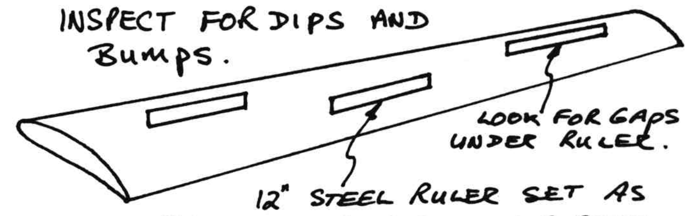
Dryness Criteria - Pick any 6" x 6" square in the layup in the critical area. Assess carefully if any evidence of air in the layup is present (white flecks, bubbles, air at the foam face). If the dryness evidence is more than 10 % of the area, the part MUST be rejected. Reject or repair any evidence of dryness or voids in the trailing edge or leading edge overlaps. Better yet, do an adequate inspection with a good light before cure when it's easy to fix. If in doubt on overlaps be sure to stipple in enough epoxy.

Delaminations in a new layup may be due to small air bubbles trapped between plies during the layup. The areas look like air bubbles and are distinctly **visible even** deep in a cured layup. Small delaminations, or bubbles up to 2-inch diameter, may be filled with epoxy by drilling a small hole into both ends of the bubble and filling the void with epoxy.

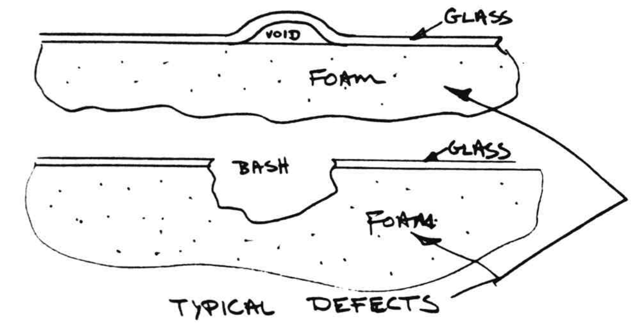
When making a layup, do not be concerned if the brush occasionally sheds a few bristles - these do not need to be removed. If the bristle count exceeds about 20 per square foot, change your brush and remove bristles.

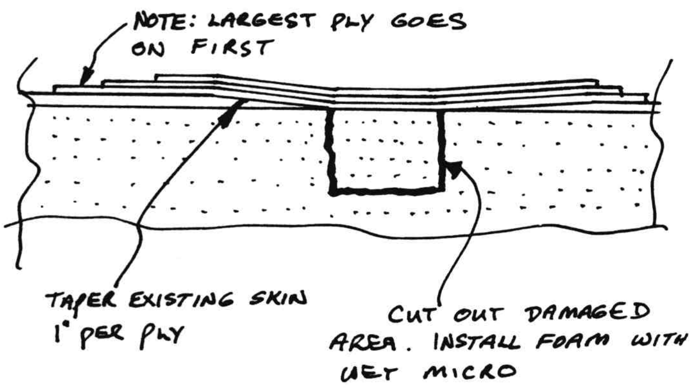
Occasionally sanding through the first weave on multiple ply layups is not cause for rejection of the part. If the sanded through area is less than the size of a quarter it may be left as is, but areas larger than a quarter must be repaired by putting back the ply with a 1 inch overlap. An excess of resin (wet) will make your airplane heavy and does weaken the layup, but usually not enough to reject the part for strength reasons.

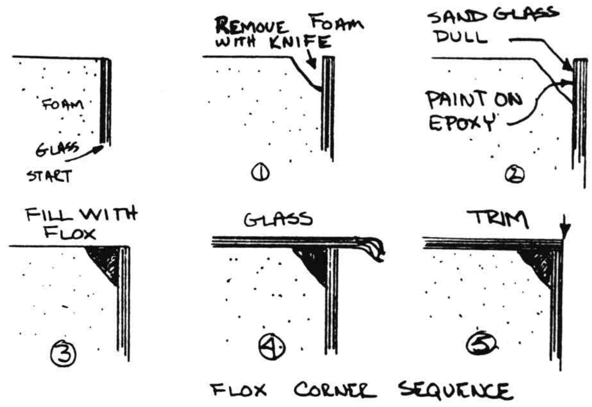
Bump/Joggle/Dip Criteria - The best way to check this is to lay a 12 inch straight edge on the part spanwise. Move it all over the surface in the critical areas. If you can see 1/16" gap in any area, the part must be repaired. It is best to repair or beef up lumpy areas even if they meet this criteria. Better yet, do a good job in core preparation and use your squeegee well in the layup to avoid the lumps in the first place.



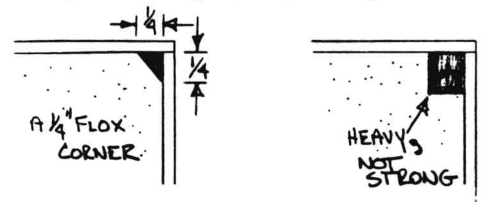
Major wrinkles or bumps along more than 2" of chord are cause for rejection in the wings, canard and winglets, particularly on the top (compression side). This does not mean you have to reject the whole wing - anything can be repaired by following the basic rule: remove the rejected or damaged area and fair back the area at a slope of 1 " per ply with a sanding block in all directions. By watching the grain you will be able to count the plies while sanding. Be sure the surface is completely dull and layup the same plies as you removed. This will restore full strength to the removed area. Use this method to repair any area damaged for any reason - inadvertent sanding through plies during finishing, taxiing a wing into a hanger, etc.







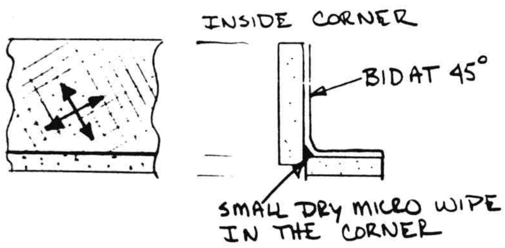
If a specific size of flox corner is desirable, an approximate dimension may be given as shown. Don't make your flox corners square. The extra flox only adds weight, not strength.



Corner Treatments

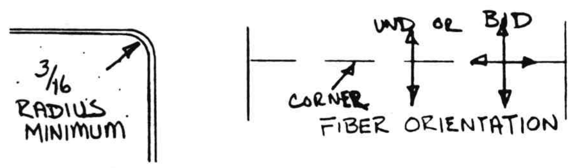
A variety of structural corners are employed in the construction of your Solitaire. There are two basic types of corners: one where the glass fibers are continuous around the corner and the other where a structural filler is used and glass is bonded to the filler. The corner with the glass fibers running completely around it is used where maximum strength is required.

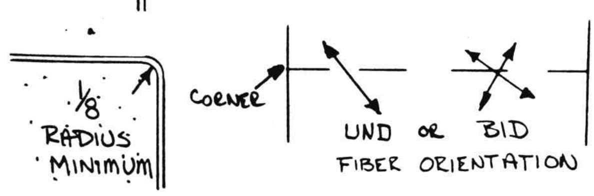
Inside corners can be laid up quite abruptly and only a very slight wipe of dry micro is needed to get the glass to lay into it. When applying micro



into an inside corner use a finger wipe or regrind a stirring stick to a 1/8" radius. This is used when putting the bulkheads into the fuselage.

Outside corners require a radiused edge. Where the glass fibers run directly around the corner a minimum radius of 3/16" is required. Where the fibers run at an angle to the radius, only a 1/8" radius is needed.



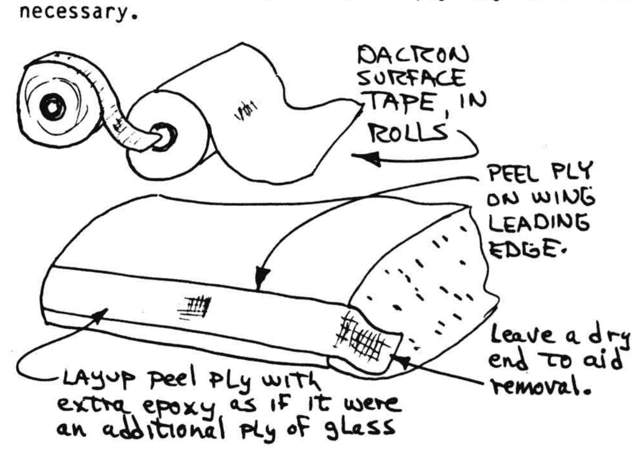


In some areas a sharp corner is desirable and maximum strength is not required. In these areas a flox corner is used. A simple unsupported glass corner has very poor strength. To strengthen this corner a triangle of flox is used to bond the glass plies together. The flox corner is done just before one glass surface is applied for a wet bond to one surface. The other glass surface has to be sanded dull in preparation as shown.

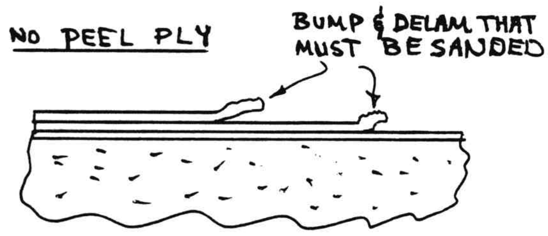
PEEL PLY

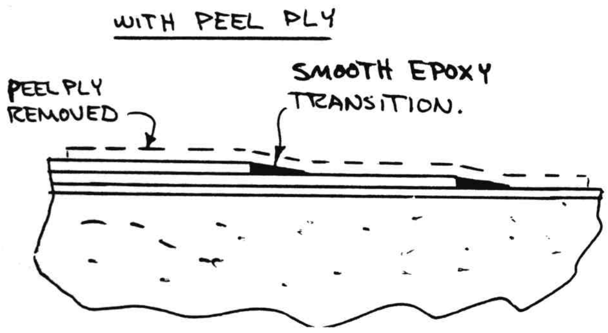
Peel ply is a layer of 2.7 oz. dacron fabric which is layed up over a fiberglass layup while the fiberglass is still wet and is later removed by lifting an edge and "peeling" it off. The most convenient form of dacron to use is "surface tapes", normally used in covering fabric aircraft. These are available in rolls. You will need several rolls, 1", 2" and 4" wide. Peel ply is used for two purposes: (1) Peel ply any area that will later be structurally attached to another fiberglass layup. Once the dacron is peeled off, the surface is ready for another layup without sanding. If you do not use peel ply you will have to sand the surface completely dull (no shiny spots). This sanding is hard, itchy work and ruins the strength of the outer ply of fiberglass.

So remember to peel ply the following areas. Main wing spar caps, canard leading edge and shear web. The edges of all the bulkheads and all places where a future layup will join to an existing layup. Peel ply is needed at the trailing edge of control surfaces and wing outboard panels when the trailing edge comes to a point. In this application it is put under the layup on the foam. (See the section on trailing edge treatment). Pg. 3-17
The thing to remember is that peel ply is never left in the finished product either between or under layups. Peel ply on foam is only used when that foam will be removed later and glass to glass bonding will take place. If you are about to put peel ply in a place where you cannot get to it later or do not understand why it should be in the middle of your part, read ahead in the plans, find out when it will be removed. If it is not possible to remove it later, you have probably misunderstood the plans. Another thing to remember is that peel ply adds weight. It fills the weave 100% with epoxy so it should only be used where it will serve its purpose of bonding or transitioning plies. Do not get carried away and peel ply any more than necessary.



(2) The second use for peel ply is to transition the area where the top ply of a layup terminates on the fiberglass surface. These are found at the wing to outboard wing panel junction, canard spar cap plies and on all corner tapes inside the fuselage. Refer to the adjacent sketches. If the top ply edge is laid up bare it results in a rough edge that can delaminate if a little dry. Sanding the rough edge is hard, itchy work and usually results in damaging the adjacent surface. If the edge is over laid with a strip of dacron during the layup (lay on the dacron and wet out by stippling or squeegeeing) it will make the edge lay down flat and will form a wedge of epoxy to smoothly transition the edge. After cure, peel off the dacron. The result is a beautifully transitioned smooth edge with no delamination tendency. Use this method in all places where a cloth edge terminates on the surfaces.





HEALTH PROTECTION

Anyone working with epoxy needs to become aware of the fact that it is possible to develop an allergic reaction to the material. Safe-T-Poxy has been developed especially for hand layups by non-professionals. This epoxy has the lowest tendency towards allergic reactions of any that we are aware of. Sensitivity can come from two areas. Contact with the epoxy and breathing the fumes. To avoid contact wear latex rubber gloves with cotton liners or use Ply-9 hand cream protectant. After a layup wash up with soap and water and apply a hand cream with lanolin. If you are using Ply-9 wash your hands and reapply the cream a couple of times during a long layup. To avoid problems with breathing the fumes, have some ventilation in the work area where you are doing the layup. A small fan will usually do an adequate job of moving air in or out. When you are finished with the layup but still need heat for the cure, shut off the fan as you leave. Becoming sensitized to epoxy is usually a progressively worsening situation with small and smaller exposures necessary to cause a reaction. The number of people that have developed a reaction to Safe-T-Poxy is small and often the reaction is not to the epoxy but the Ply-9 or the gloves or people using M.E.K. or lacquer thinner to clean brushes. If you thin epoxy by cleaning brushes in MEK, that combination will go through the skin into the body more easily than the thick epoxy by itself. Keep Acetone, MEK, lacquer thinner or toluene out of your shop, it will increase your chances of an epoxy reaction. The common reactions to epoxy systems are breaking out on the hands, arms or face, a rash in the same areas or swelling in the same areas. We have taken the space to reprint a study that was done by the epoxy manufacturer to inform you of the possibility of reaction <u>not</u> the likelihood.

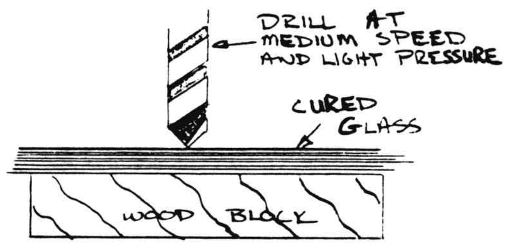
Use good work habits and you will probably avoid any reaction.

Dust Protection

Sanding or grinding fiberglass and foam creates dust that can be harmful to your lungs. Use a dust respirator mask for their operations. Disposable dust masks are available at most paint stores.

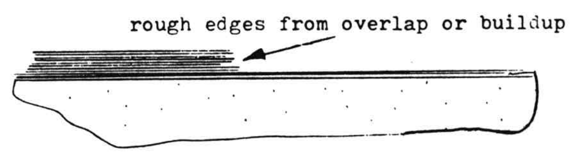
DRILLING, GRINDING AND SAWING

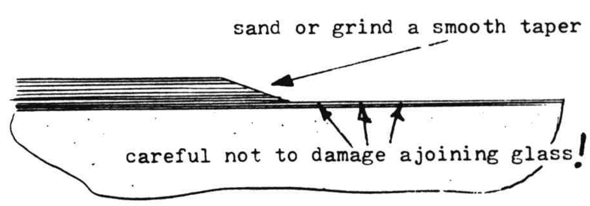
Drilling through cured glass tends to tear the surface plies on the back side. Backup a glass layup with a wood block for drilling as shown and drill at medium speed.



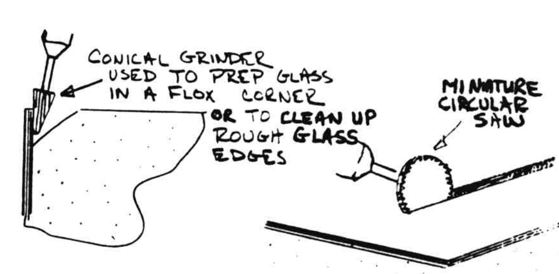
Using a small hone, grind the cutting edges of your drill bit flat as shown (not undercut). This will keep the drill from grabbing into the glass. Don't over do it, just make a couple of light passes with the hone.

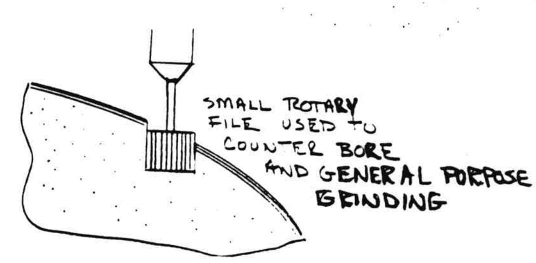
In several places rough cured glass surfaces occur where overlaps or thick buildups are done. These rough edges should be smoothed as shown using a grinder or sanding block.





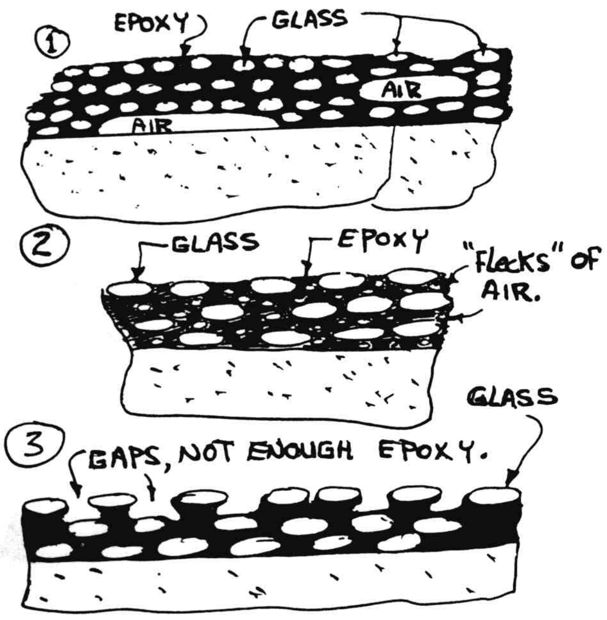
The Dremel (Moto Tool) or Home Shop (Weller) is a very versatile tool with many uses in the construction of your Solitaire. The kits usually have a nice selection of bits, cuts, grinders, stones and mandrels for every conceivable use. Several types that are not in the kit are very useful. Dremel makes a 1/8" carbide bit with a round end, this is very good for cutting holes in glass sandwich panels. Merrit Abrasives makes 1.5" disc sander heads that will fit the Dremel with snap lock discs. The coarse discs will do an excellent job sanding cured fiberglass. Don't throw the others out, your buddy next door might be able to use them on his radio controlled golfball project.





RECOGNITION OF A DRY LAYUP

One of the most important things you must know is how to inspect for the presence of air within a layup. Air leaves somewhat crystal-like flecks of white areas, noticeably different than the white color of the micro balloons. The presence of air is shown in the adjacent sketches in 3 forms: (1) A bubble or large void at the foam surface or within the laminate, (2) small bubbles of air scattered throughout an area, or (3) inadequate filling of the outer ply. Make a layup of 3 ply BID in a 6" square over a scrap piece of foam, trying to achieve these 3 types of dryness. Let it cure with the defects. This will be a handy sample to use to instruct others who will help you inspect.



GENERAL HINTS

You can generally tell the quality of workmanship just by looking at his shop. Clean up and sweep up after every step. Keep your tools organized and clean. Dirt in or under a layup will increase weight and decrease strength. A clean shop will reflect on your airplane and will make construction more pleasant.
A key to good glass layup is preparation.
Copy the check list below and post in your shop.

BEFORE ANY GLASS LAYUP

1. Tools cleaned and available
   - Squeegee — Cups
   - Brushes — Scissors
   - Rollers — Ply-9 or Gloves
   - Sticks
2. Workbench clean
3. Glass cut and rolled
4. Surface to be glassed -
   - correct shape and smooth contour
   - sanded dull
   - dust blown or vacuumed off
5. Temperature of room and epoxy 70 to 90 degrees F.

Protection of foam during layups

If you get raw foam contaminated with epoxy it will cure and be very difficult to remove without damage to the foam. During a layup where there is raw foam that will not be layed up onto, protect it with grey tape or tape and newspaper. This is the case on the Solitaire when applying the spar cap to the foam block for the wings.

ATMOSPHERIC CONDITIONS

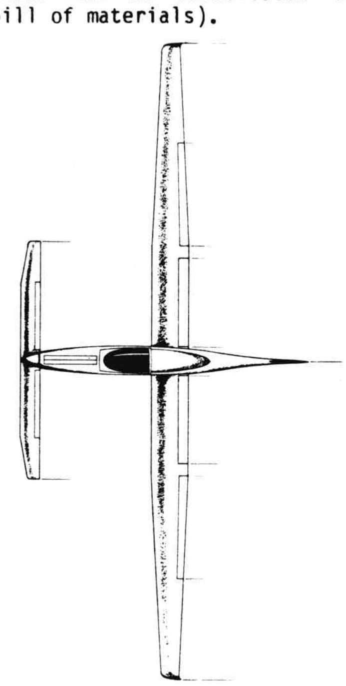
Temperature has the greatest effect on the working properties of your epoxies. 77° F. is an ideal temperature. The range from 75° to 95° is acceptable with the precautions mentioned in the section of EPOXY. Humidity has a lesser effect on these materials than it does on aircraft dopes and some paints. Humidity will only create problems if it is over 75%. Don't undertake a layup if it is pouring down rain outside or, if you notice a cloudy "blush" on the wet epoxy surface, or any evidence of whiteness in the epoxy due to moisture.

In high humidity areas keep your cloth in a low humidity environment, ie. in a warm house in the winter or an air conditioned house in the summer. You can build a cabinet for storing the cloth rolls as shown and use a light bulb with a thermostat to raise the temperature of the cloth and thereby lower the humidity.

Heat Deformation and Creep

Several builders have had flying surfaces warp or bend due to being poorly supported until fully cured. Do not hang or support them at each end for long periods as they may "creep" or slowly deform. Store them leading edge down with support in at least three places. Your surfaces can be better protected against "creep" if you post-cure them. Sailplane manufacturers do this by putting the entire airplane in an oven at 160° F. You can do as follows: after you have painted on the black primer, put the wing/winglet or canard out in the sun. Be sure it is well supported in at least three places along its span. At noon a black surface can reach 140° to 180° F. giving it a relatively good post-cure. After the post-cure, the structure is more stable for warping or creep. If you have a wing or canard that is twisted wrong, apply a twisting force in the opposite direction before and during the post-cure (weights applied to boards can be used). Remove the force only after the surface has cooled. A 200 ft/lb torque (50 lb. weight on a 4 ft. arm) applied twice, once while the top surface is post-cured and once for the bottom surface, can twist your canard over one degree. The twist correction will be permanent and will stay as long as the surface remains cool (below the post-cure temperature). This is generally referred to as the heat-deformation characteristic of the epoxy. If it is room temperature cured only, it will soften above 140° F. But if post-cured it will not soften until over 160° F. Heat for post-curing or for intentional deforming can be applied by other means such as heat lamps, hair dryers or electric radiant heaters (household type), however this is generally not recommended, since it is too easy for the homebuilder to get the part too hot and ruin the part. The blue foam is damaged above 240° F. If you want to use these heat sources, do so by applying the heat very slowly and checking the temperture often by placing your hand on the surface. If you can hold your hand on the surface five seconds without pain, the temperature is okay - three seconds is too hot.

A pneumatic riveter is not required to build your Solitaire. The few hard rivets used can be set with a hammer, using your vise as backup. The 'pop-type' rivets are pulled with a low-cost hand puller available at any hardware store. Note that Cherry rivets can be substituted for the Avex rivets. (bill of materials).

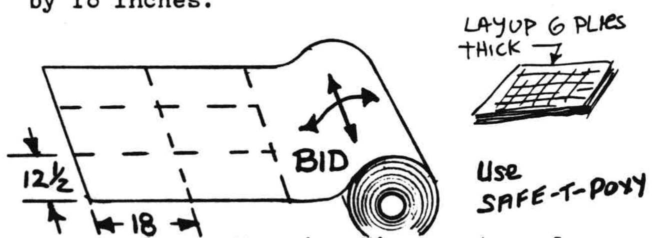


PRACTICE LAYUPS

Flat Layup

The first practice layup that you will make is a layup of six BID plies onto a flat surface. This is inteneded to give you experience in the techniques of glass/epoxy work and to give you a check on your workmanship. You should be able to complete this layup in about half an hour.

Protect your work bench by taping waxed paper over an area about 24" by 24", (or, find a piece of metal and wax its surface). This will keep the epoxy from bonding to the table top. Cut six plies of BID that are about 12-1/2 inches by 18 inches.



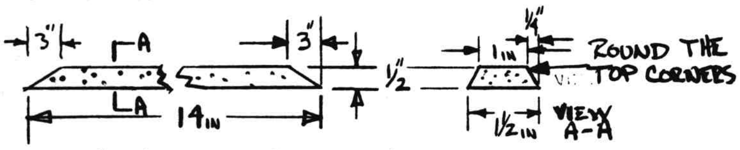
Laminate the six plies on top of the waxed paper. Try to do your best job of stippling and squeegeeing so that the plies are completely wetted but not full of excess epoxy. Let the layup cure to knife trim, about four hours. Carefully mark a 10-in by 16-in rectangle and knife trim the layup to that size using a sharp razor blade or trim knife. Allow the layup to cure completely. If you forget the knife trim, cut the cured piece with a coping saw or band saw.

Take the cured 10"x16" piece to your post office, or any accurate scale, and ask them to weigh it for you. Your laminate should weigh between 10-1/2 and 12-1/2 ounces. A 10-1/2 ounce layup is about as light as can be done without voids (white areas). A 12-1/2 ounce layup has too much resin, and if you make all of the layups in the airplane this wet, your Solitaire may be as much as 40 pounds over weight. An 11-ounce layup is just about perfect. Save this piece; it will be useful material later on.

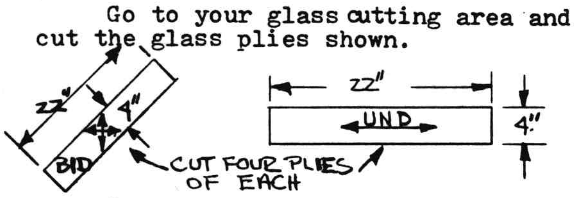
Confidence Layup

The second practice layup is one intended to give you confidence in the strength of your work. This layup is a sample of composite sandwich structure and is typical of the load carrying structures in your Solitaire. When this layup is finished and completely cured, you will subject it to a simple load test and thus demonstrate the strength of your workmanship.

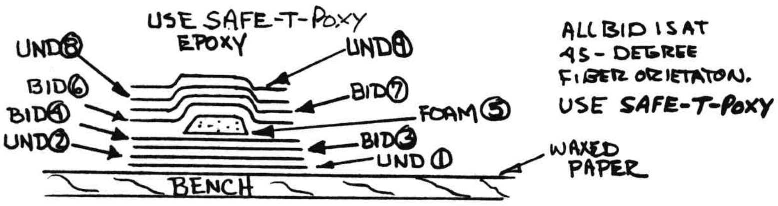
First, tape a piece of waxed paper about 30 inches long to the top of your work table. Shape a piece of green foam as shown.



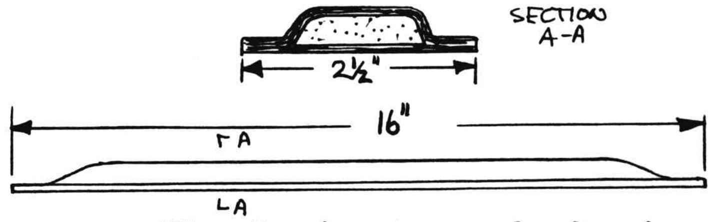
Go to your glass cutting area and cut the glass plies shown.



Lay up two plies of UND, two plies of BID, paint the foam with micro slurry and press it in the center. Then lay up the other BID and UND plies.

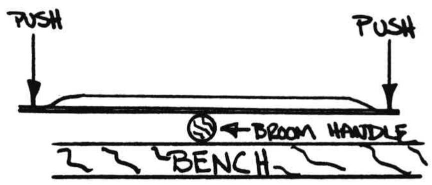


Be careful to work all air bubbles out of the corners. The best way is to stipple with the brush. The glass is oversized so that it can be trimmed to exact dimensions later. Trim to the dimensions shown after curing 24 hours. Using a coping saw or band saw.



Allow the piece to cure for four days at room temperature before the load test.

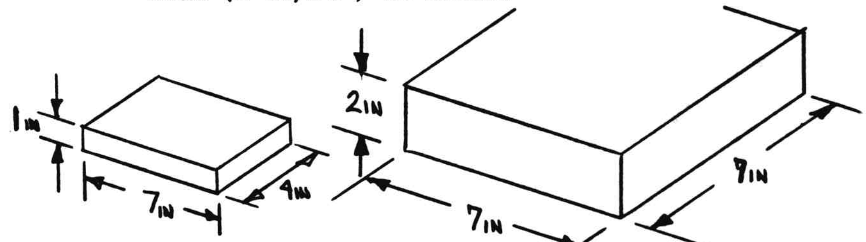
Now for the test: lay a broom handle or piece of tubing on the work bench and try to break the sample by putting all of your weight on the ends. A 200 pounder will stress the sample more than any part of your airplane is stressed at 10 g's!



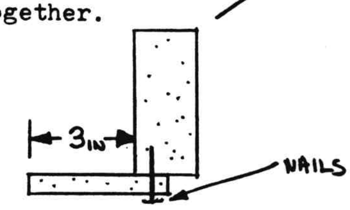
Book End

The last practice part that you will make before starting on your airplane is a book end. It takes three layups to make the book end and involves most of the operations that you will need to learn, to build your airplane.

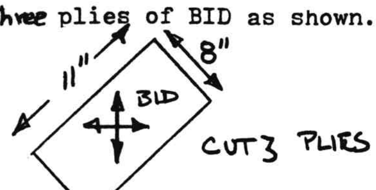
Cut the two blocks of green urethane foam (2 lb/ft^3) as shown.



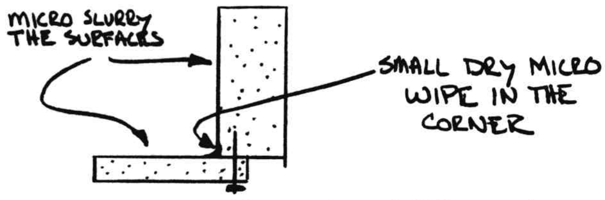
Nail them together.



Cut Three plies of BID as shown.

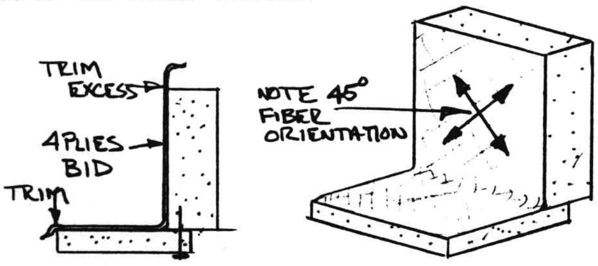


Mix 4 oz of SAFE-T-POXY using about 1 oz, make a small batch of micro slurry and coat the foam as shown. Make dry micro from the leftover slurry and make a small radius with it as shown.



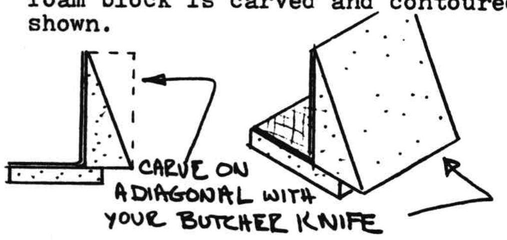
Lay up the first ply of BID as shown.

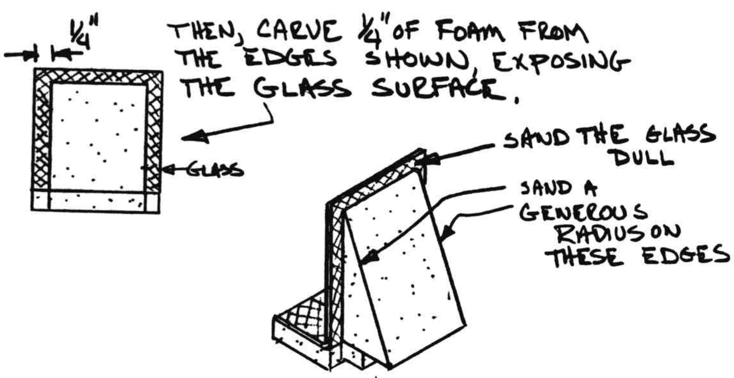
Using plain epoxy (no micro) lay up the other Two plies and allow to cure. Note how the 45° fiber orientation allows the glass to lay down completely into the small radius.



Knife trim along the foam edges.

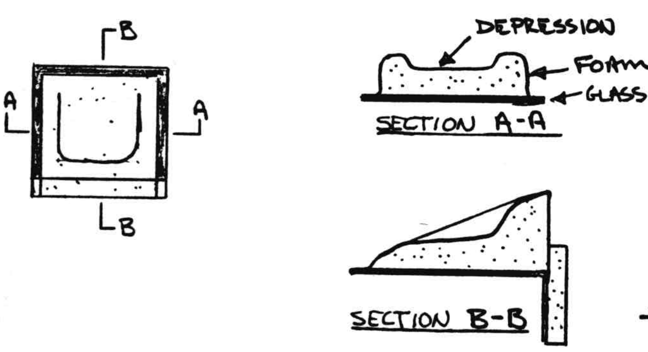
After the first layup has cured and the edges have been trimmed, the thicker foam block is carved and contoured as shown.



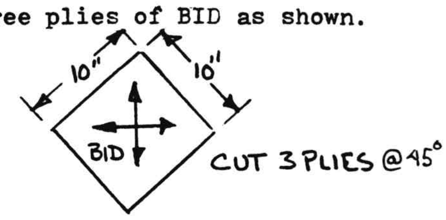


Put a generous radius on the foam edges and sand the 1/4" wide glass edges dull for glass to glass bond. Use your wire brush to rough out a depression in the middle of the block.

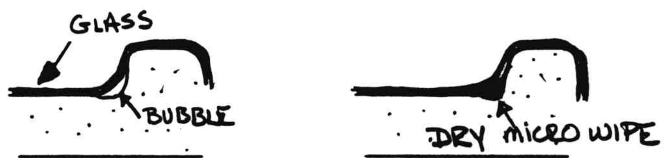
Finish smoothing the depression by rubbing it with a scrap of green foam. Radius the corners of the depression. Blow or brush all of the foam dust off the surfaces.



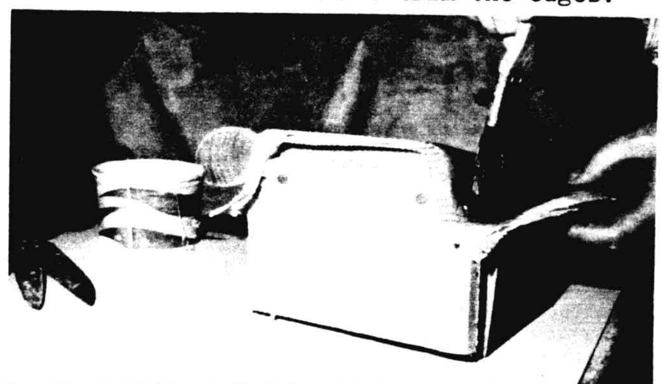
Cut three plies of BID as shown.

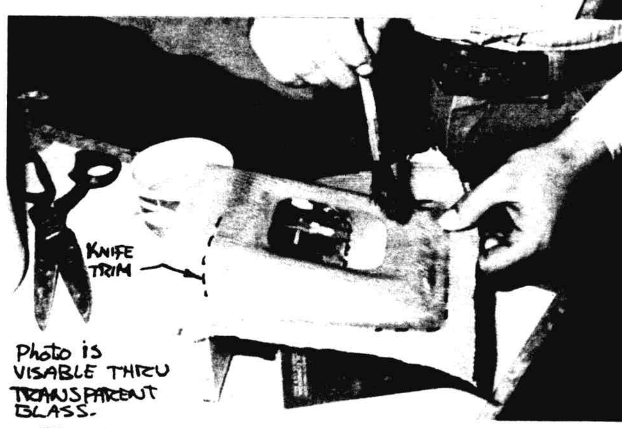


MIX SAFE-T-POXY make a small batch of slurry and save the remaining epoxy. Slurry the foam surface LIGHTLY and apply two plies of BID to the contoured surface. Start the layup in the center and work out toward the edges. If you have trouble getting the glass into the depression corners without bubbles, lift the plies and wipe in a little dry micro. You will then find that it will lay smoothly in without voids (see sketch). This depression is sharper than any in your airplane and is intended to give you a feeling of how sharply you can form the cloth.



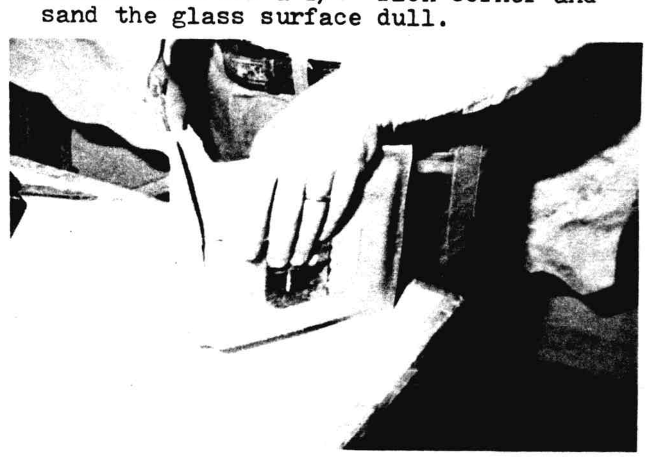
Before laying the third BID ply down, place your favorite photo in the depression, and then lay the third BID ply over it. Scissor trim the excess glass cloth. Allow to cure and knife trim the edges.

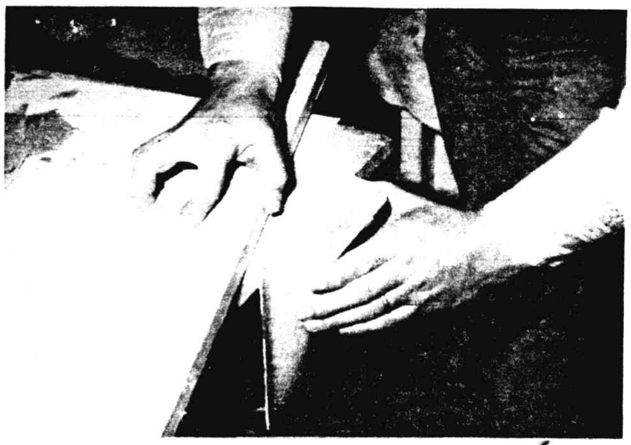


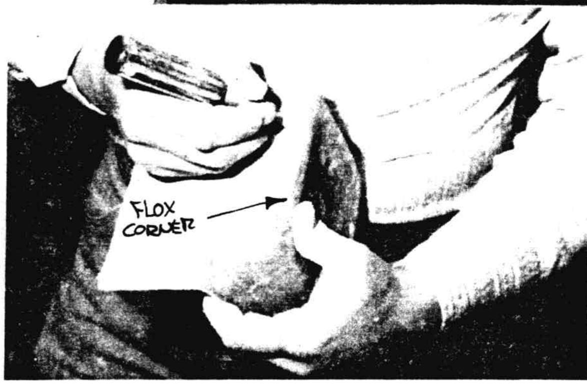


The lower edge is trimmed flush with the bottom of the foam block.

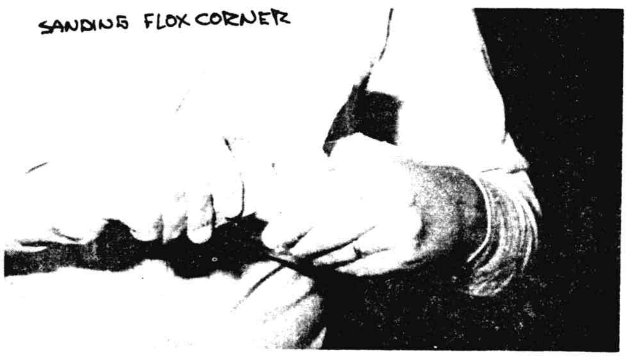
Wait until the second layup is fully cured. Remove the 1 IN foam block with a butcher knife and sanding block. Remove FOAM for a 1/4" flox corner and sand the glass surface dull.

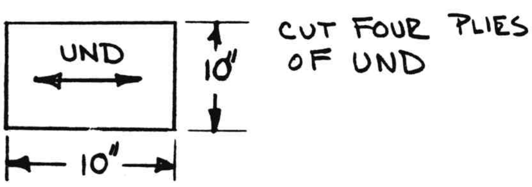




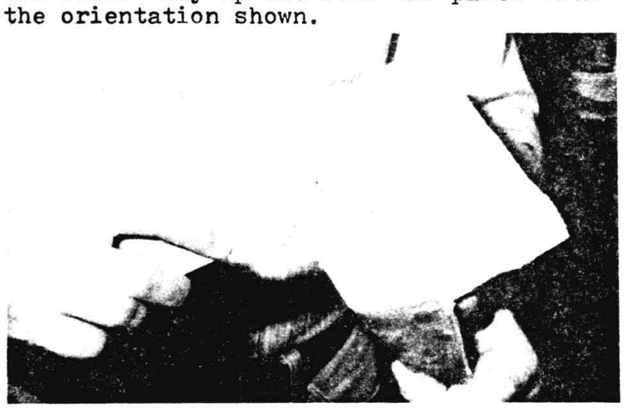


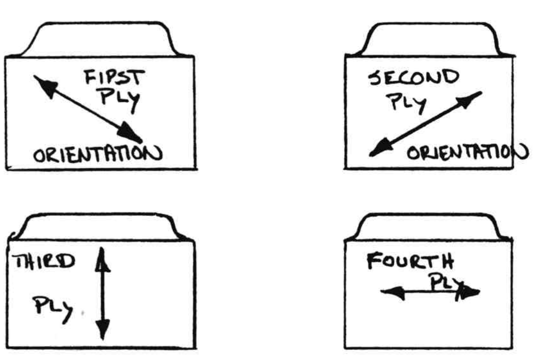
SANDING FLOX CORNER



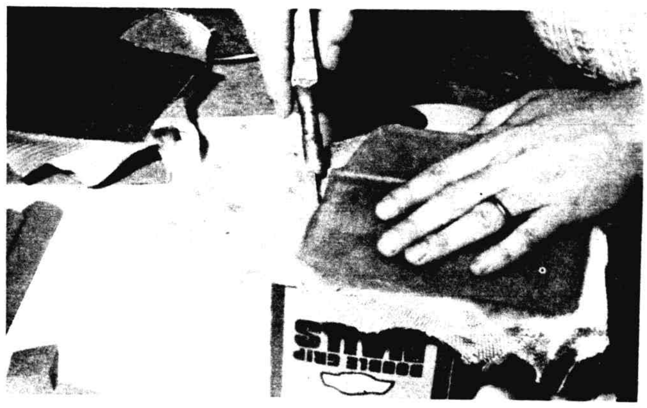


MIX SAFE-T-POXY, a small batch of flox, and a small batch of micro slurry. Fill the corner with flox and slurry the foam. Lay up the four UND plies with the orientation shown.





Knife trim the edges. After 12-hour cure, sand the edges with 100-grit sandpaper as required for smoothness and good appearance.

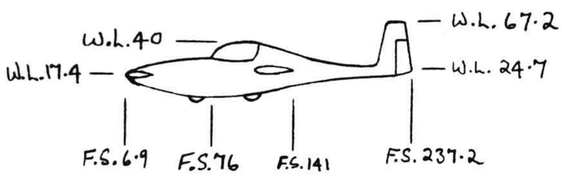


It may at this time seem a bit ridiculous to use three layups, about four hours work, and two days cure, just to make a book end! But remember, this book end was not designed for ease of construction; it was designed instead, to let you get a first hand exposure to the following operations before starting on your airplane: glass cutting, foam preparation (slurry), BID and UND layups (flat surfaces, corners, and compound curves , flox corner, knife trim, concave and convex foam carving, glass to glass surface preparation and sanding edges. So, use this experience to your best benefit and spend the curing time studying the plans. Even if you're experienced in glass layups, the book end is a worthwhile project to get familiar with the workability of this BID and UND weave cloth.

AIRCRAFT MEASUREMENT REFERENCE SYSTEM

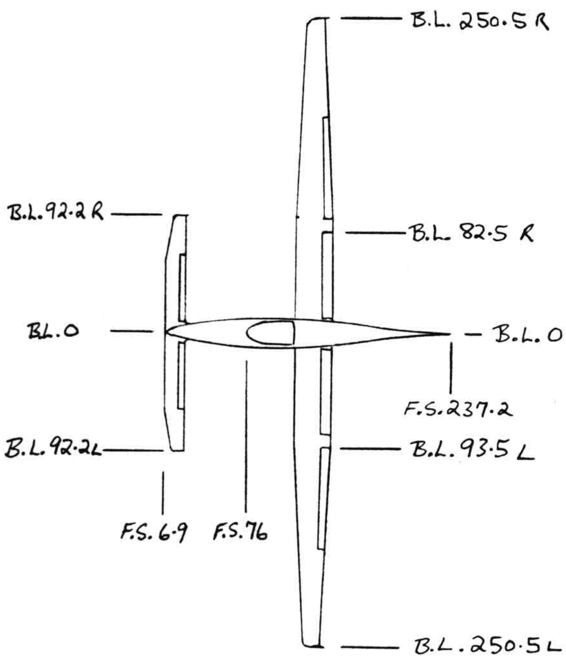
To ease the engineer's task of defining where things go in these odd-shaped gadgets called aircraft, a fairly standard system of references has been developed. Fortunately the Solitaire is so simple that an elaborate measurement system is not necessary. It is, however, convenient to use the standard terminology for reference occasionally and you should be familiar with its meaning.

The three basic references are called butt lines, fuselage stations and water lines. Don't blame us for the absurd names, we didn't set the system up. All three are given in inches from some arbitrarily chosen references so, fuselage station 100 is found 100 inches away from fuselage station 0 and similarly for butt lines and waterlines. Being as lazy as anybody else, we abbreviate these as F.S., B.L. and W.L. We use these abbreviations with periods, F.S. not FS, so that they aren't confused with part numbers like CS, which do not use periods. Fuselage stations (F.S.) are used to define the location fore and aft on an airplane. To make things easy, fuselage station 0 is generally located near the nose of an airplane and measurements are made aft. Fuselage stations are the most commonly used of the references and later on you will make a reference mark on your airplane to use as a permanent F.S. reference point.



Waterlines (W.L.) are used to define vertical locations. Waterline 0 is generally found near the ground and measurements are made up from W.L. 0. Waterlines are utilized in many places to position components or templates relative to each other by leveling reference waterlines with a carpenters level.

Butt lines (B.L.) define positions inboard and outboard. Butt line 0 is the vertical centerline of the airplane and measurements are taken to the left and right of B.L. 0. Since left and right depends on which way you are facing, it is standard practice to define left and right as the pilot would, while seated in the cockpit.

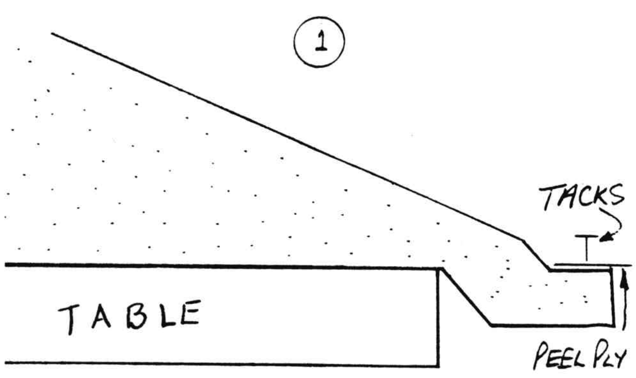


Using these three references, any point in an airplane can be described with a fuselage station, butt line and waterline.

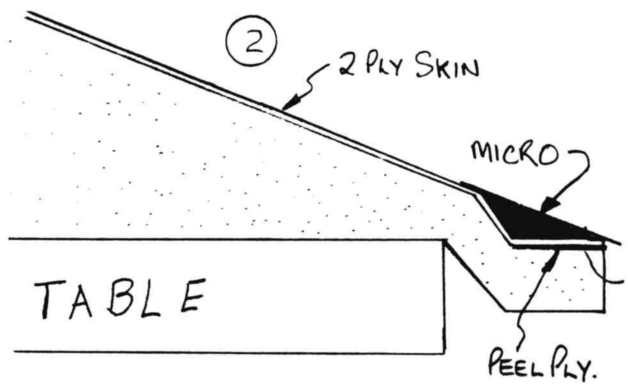
TRAILING EDGE TREATMENT

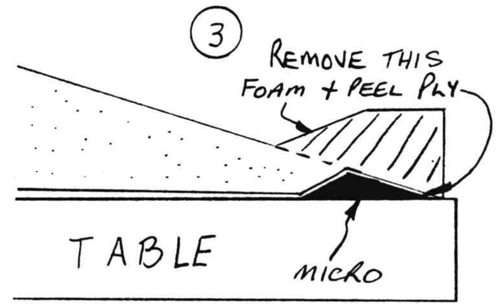
There are two types of trailing edge treatments used in these plans. They are used whenever two skins come together at a narrow angle, ie. the trailing edge of the spoil flaps, the elevators, the ailerons and the outboard section the canard and main wing. In these plans the trailing edge is abbreviated as T.E. and the leading edge L.E.

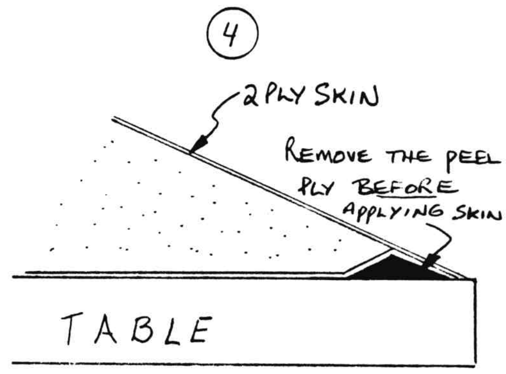
Taking the type of T.E. that is most common first, glue the part to your flat table and run peel ply along the T.E. holding it in place with tacks as shown in sketch (1). Micro slurry the cores and



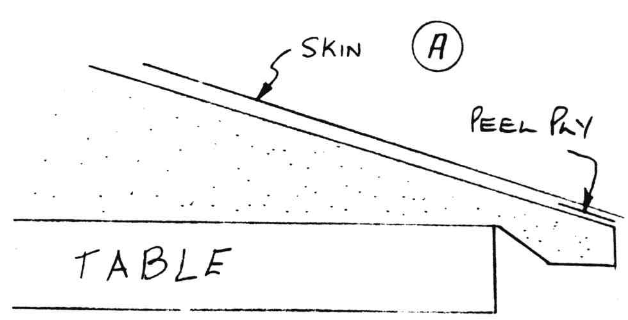
apply the skin usually 2 plies. Next fill the T.E. with dry micro and cover with peel ply then squeegee to contour as in sketch (2). When cured flip the part over and remove the excess foam at the T.E., pull the peel ply and sand to contour as shown in sketch (3). Layup the top skin after slurrying the core as in sketch (4).

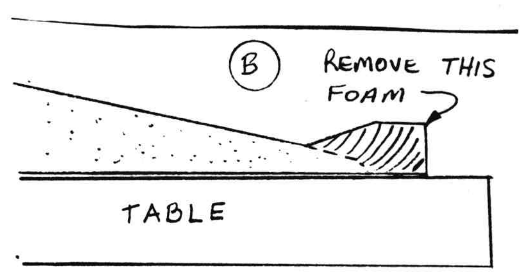


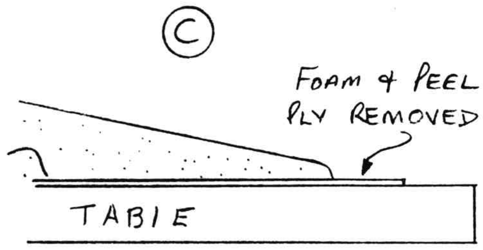


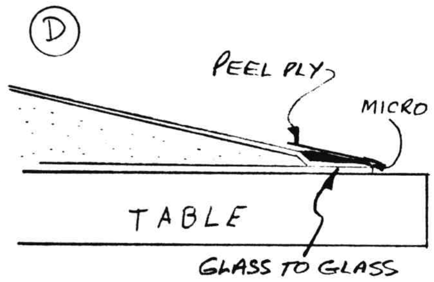


In the second type of T.E. apply peel ply to the flat side to extend into the layup 4", hold this in place with tacks and slurry the foam. Layup the called out skin. See sketch (A). Knife trim and









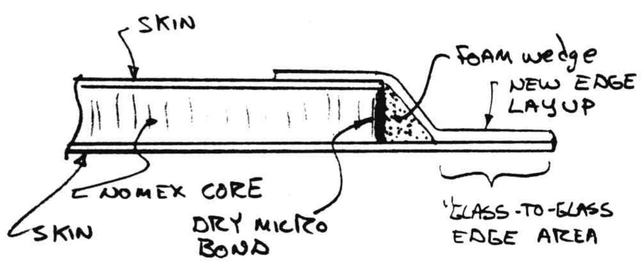
flip over when cured. Remove the excess foam and pull the peel ply. Sketch (B) and (C). Slurry the foam, layup the called for skin then apply dry micro cover with peel ply and squeegee to contour.

With both of these methods, take care to get the cloth into the corner and down onto the first skin. Do not forget the first peel ply because this is the only good way to get a strong T.E. bond.

Nomex Honeycomb Cores

Nomex Honeycomb is used as a core material on the fuselage of the Solitaire. This material cannot be used except with preimpregnated fibers. This means they are coated to the correct resin content by the manufacturer and kept under refrigeration until used and then cured in an oven.

The main advantage of the honeycomb is weight. The material it is replacing weighs 3 lb. per cubic foot and Nomex Honeycomb weighs 1.5 per cubed foot. While building the Solitaire, the different cores are treated the same way except when opening a hole to provide a "glass-to-glass" edge. It is necessary to install a piece of foam to taper the top skin to the bottom skin as shown. This is installed with micro, being careful not to get any micro between the glass to glass area.

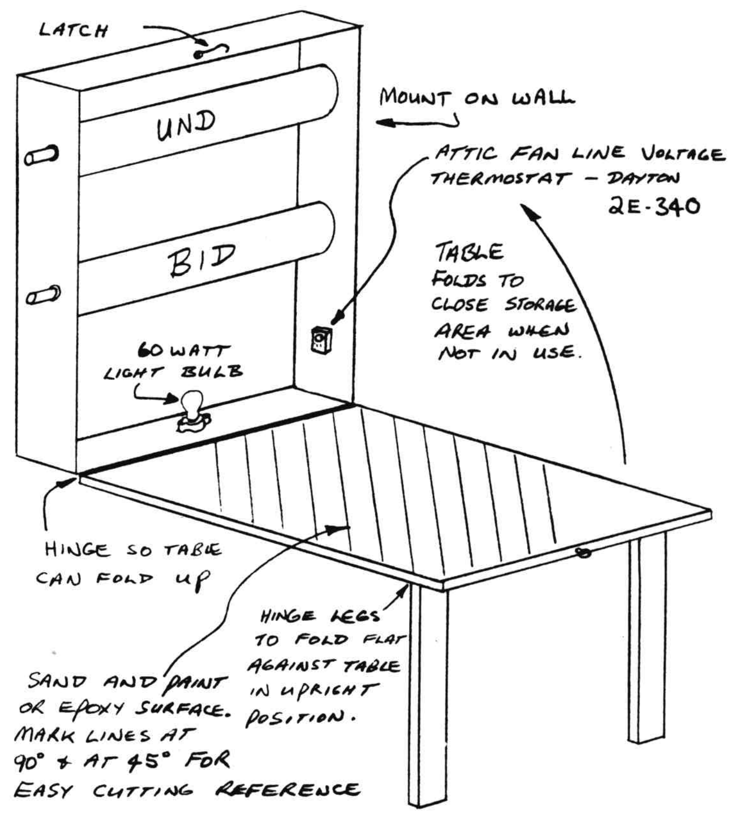


TIME MANAGEMENT

Time management is important with any project but it becomes critical with a foam and fiberglass composite sandwich structure. With other types of aircraft construction it is possible to stop at any point, come back later and pick up where you left off. With epoxy you have to finish a layup once you start. It can take the fun out of working on your project if you get stuck until 2:00 am on Monday night because you started a large layup at 8:00 pm. In these plans, times will not be given for every step. Most of the time is not spent doing layups, but is spent getting ready for the next layup. During these times it is possible to stop at any point.

We will attempt to warn you of any major layups but as the builder you should read ahead and understand where each step will lead to. To help you govern your time as well as the quality of your work you can judge the time in a layup as two minutes per ply per square foot. This does not include applying the micro slurry and peel ply after the last ply. To give an example, the vertical stabilizer is roughly 3.5 ft high and 1.5 ft average width which means 5.25 sq feet. Two plies gives you a total of 10.5 times two minutes per ply equals 21 minutes. The time between when you start the laminating until the final ply is wet out, should be no more than that per side. We have done this test on several different types of layups and this seems like a good average. If you are very much under or over this figure you are probably working inefficiently. Some parts with several cures or complicated inside layups can take longer but if you are glassing the vertical stabilizer and the times are off very much get someone with experience to look at your parts or better yet get someone to help you on your next layup to see if you are working properly.

Join your local EAA. This is a group of people whose purpose is to help each other build homebuilt aircraft. There is hardly an EAA chapter around that does not have someone in it that has not built or is building a VariEze or a Long-EZ. These people are using the same materials and techniques as the Solitaire. Last you can bring parts into Rutan Aircraft and we will be happy to inspect them. The thing to remember is that slower is not better.



An excellent method of storing glass on the rolls is to build a wall mounted closet as shown. The 'door' folds down to become the cutting table. A 60 watt light bulb will keep the humidity down and thus keep your cloth dry. If you want to get really sophisticated you can install a Dayton 2E-340 line voltage, attic fan thermostat to control the temperature in the closet. If you sand and paint varnish or epoxy onto the top surface of the cutting table, it wil not snag the glass. Marking 90° and 45° lines on the table every 6" will help when it comes to cutting the glass. When you are not cutting glass, fold the door up and latch it to keep dust from contaminating your rolls of glass. The table legs should be hinged to fold flat with the door closed.

AMATEUR-BUILT SOLITAIRE INSPECTION CRITERIA

1.0 Scope

This document has been prepared to assist inspection personnel by providing recommended acceptance criteria and acceptable repair practices for the Solitaire amateur-built composite sandwich structure.

2.0 Background Information

2.1 Design Criteria.
The materials, methods and practices employed by the amateur builder in the construction of the Solitaire type are new to light aircraft construction and may be unfamiliar to the inspection personnel involved with the licensing of amateur-built aircraft. Structural design criteria for the Solitaire exceed F.A.R. part 23 requirements. In-house component testing of the primary flight structure has been conducted to 200% of design limits. Detail documentation of test data is on file at Rutan Aircraft Factory Inc. The aircraft is considered to be a utility category aircraft. Solitaire builders are being supplied with a complete owner's manual which specifies all placards, operating limitations, normal and emergency operations, flying qualities, maintenance specifications, inspection procedures and initial flight test procedures.

2.2 Structural Approach.
The basic structure throughout the design is a composite sandwich of load bearing fiberglass skins separated by a lightweight foam core. While the materials and processes are tailored to the amateur builder, the structural layout is very similar to the honeycomb composite structures utilized in military and transport type aircraft and fiberglass sailplanes. Loads are carried by epoxy "E" type fiberglass lamina. Foams of various types and densities are employed as a form (upon which the load bearing material is shaped) and as local buckling support. In no instance are foams used to transmit primary loads, as is the case in some other amateur-built designs.

2.3 Inspection Techniques
The transparent nature of the fiberglass/epoxy material allows for visual inspection of primary structure from the outside prior to finishing. Defects in the structure, as described in paragraph 3.0, are readily visible even in the deepest laminate.

2.4 Inspection Sequencing
The external visual inspection capability provided by the materials allow inspection of all primary structures at any point before finishing. All primary structures are at the surface, eliminating the requirement for "pre-cover" or "closure" inspections. Opaque filler materials are used throughout the airplane in finishing. Inspection must take place before any areas are obscured. Some areas may have opaque materials applied to one surface where the structure is inspectable from the opposite side (wing trailing edge for example).

3.0 Defects

3.1 Voids.
Interlaminar voids in a new layup may be due to small air bubbles trapped between plies during the layup. These void areas look white and are distinctly visible even deep in a cured layup. Interlaminary voids up to 1 inch in diameter do not require repair, as long as they do not consist of more than 5% of the surface area.

Voids greater than 2 inches in diameter should be repaired as shown in paragraph 4.

3.2 Lean Areas
Areas where the epoxy/glass matrix is incomplete because of inadequate wetting of the cloth with epoxy (lean areas) are speckled whitish in appearance. The fully wetted laminate will have a consistent transparent greenish appearance. Epoxy lean areas are acceptable, as long as the white speckled area is less than 10% of the surface area. White to green ratios greater than 10% require rejection or repair as shown in paragraph 4.

3.3 Rich Areas
Resin richness primarily adds weight to the laminate. While some degradation of physical properties does occur, an overly wet (rich) layup is not grounds for rejection.

3.4 Inclusions.
Bristle paint brushes are used throughout the layup process. As a brush begins to deteriorate it will shed some bristles into the laminate. The bristle inclusions, up to 20 bristles per square foot, are not cause for rejection. Occasional inclusion of small woodchips or other small foreign objects is not ground for rejection.

3.5 Fiber disruption
In all instances, it is good practice to have the glass fibers laying flat and without wrinkles. Major wrinkles or bumps along more than 2 inches of chord are cause for rejection in the wings, canard and winglets, particularly on the upper surfaces (compression side). Disruptions greater than 2 inches require repairs per paragraph 4.

3.6 Finishing Damage
Damage to the external structure by sanding in preparation for surface fill and paint can occur. Occasional sanding through the weave of the first skin ply is not grounds for rejection. Sanding through areas greater than 2 inches in diameter completely through the first ply or any damage to interior plies must be repaired in accordance with paragraph 4. A damp rag passed over the sanded surface will make the plies show up to determine how many plies have been sanded away.

3.7 Service Damage
Damage to the glass structure will be evidenced by cracked paint, or "brooming" of glass fibers. Both of these indicators are clearly visible. If either type of indication is present the paint and filler should be sanded away, bare laminate inspected and repairs made per paragraph 4 as required. Where surface damage has occured it is also likely that local foam crushing has been inflicted.

3.8 Delaminations
Delamination of glass/epoxy lap joints is evidenced by physical separation of plies. These defects are easily visible and easily repaired. The leading and trailing edges of flying surfaces (wing, canard, winglets) should be free of delaminations.

3.9 Multiple Defects
Where multiple types of small defects occur in a laminate (voids, fiber dislocations and lean areas for example). They should not exceed a total of 10% of the surface area of the laminate, or 20% of the wing chord at any one spanwise position.

4.0 Repairs

There are seldom single defects so massive that a major component must be scrapped. The repair procedures described here may be applied throughout the Solitaire composite sandwich structure.

4.1 Small Void Repairs
Voids up to 2 inches in diameter may be repaired by drilling a small hole into the void and injecting the void full of epoxy. A vent hole opposite the injection point is required to allow air to escape.

4.2 Large Defects
Excessively large voids, lean areas, finishing damage, fiber disruptions, major fiber wrinkles, or service damage may be repaired using this procedure. Remove the rejected or damaged area by sanding or grinding and taper the glass laminate on a slope of approximately 1 inch per ply in all directions. The plies are visible as the sanding is done. The tapered glass edges and surrounding two inches of glass surface must be sanded completely dull. Damaged underlying foam should be removed and the void filled with a dry microsphere/epoxy mixture or a replacement foam piece. The damaged area is then laminated over using the same type and orientation of glass plies removed, each ply lapping onto the undamaged glass at least one inch. The whole repair area is covered with an additional bi-directional glass ply.

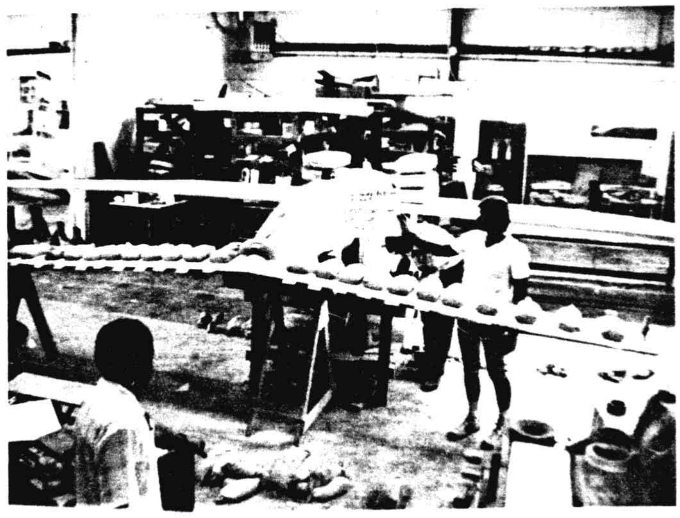
4.3 Delaminations
A delaminated joint should be spread, the mating surfaces sanded dull, gap filled with flox (epoxy/flocked cotton mixture), then clamped shut while it cures.

5.0 Materials

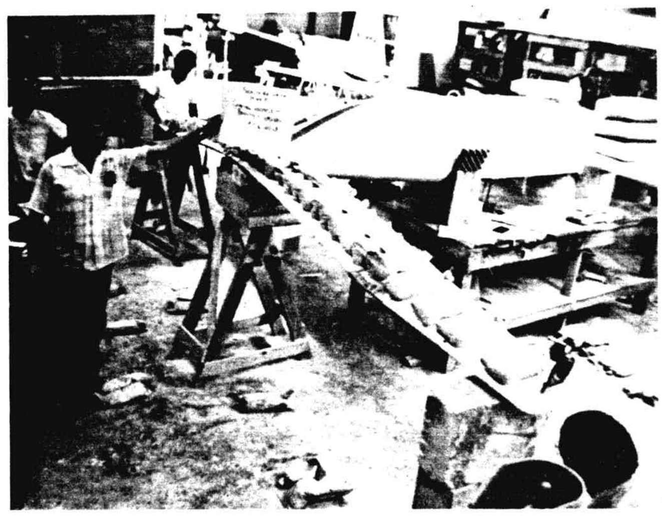
Since a wide range of similar appearing materials exist which exhibit substantial differences in physical (structural) properties, Rutan Aircraft Factory Inc. has established a distribution system to provide the amateur builder with proven acceptable materials. RAF strongly discourages the substitution of materials. Homebuilder substitutions for the basic structural materials constitutes major structural modification to the Solitaire design, and could adversely effect flight safety.

6.0 Applicability

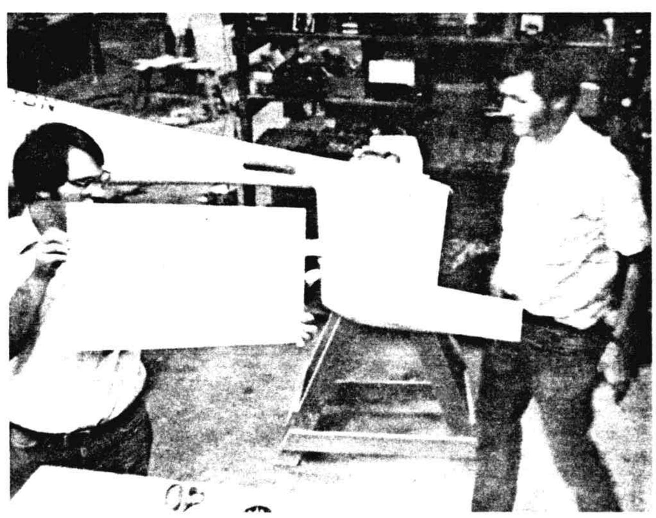
These acceptance criteria are different from and, in some cases, much looser than for similar structures found in sailplanes and other contemporary composite structures. These criteria apply only to the Solitaire structures. Design safety factors in excess of these enable somewhat relaxed acceptability criteria compared to other similar structures.



Canard at design limit, bending and torsion.



Canard at 1.5 x design limit in bending and torsion



Vertical tail at 1.5 x design limit.