



CHAPTER 3

EDUCATION

DON'T 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 won'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 go-carts), 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, suggest 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.

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 Long-EZ distributors.

1. Basic Required Tools

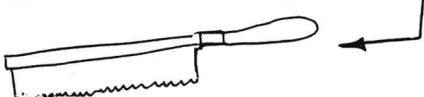
Common household butcher knife
Coping saw
1/4" drive socket set
Small open-end wrenches
Sandpaper 36-grit, carborundum
Aloxite Fastcut (50 sheets),
also 220-grit and 320-grit
wet or dry silicon carbide
(20 sheets each)
Dissston Abrader #401C - Tool for
carving fiberglass.
5/8" counterbore with 1/4" pilot, 10" long shank
12" long, 1" dia. drill bit.

Peel-MY

2" dia drum sander (coarse) for 1/4" drill.
Coarse rotary file bit for 1/4" drill.
Pliers
1" putty knife
Hacksaw
Blade & phillips screwdriver
Box of single-edge razor blades
24" carpenter's level
Carpenter's square
Felt marking pens
3-ft straightedge
200 eight-oz paper cups (Lily 8SN1)
50 3-oz paper cups (unwaxed)
12-ft decimal steel tape (Stanley
#61-112)
1/4" drill with #30, #3, #10, 1/4 "#3, 1/4 "#12, and 1/4 "#21 bits
#10-32 and 1/4-28 taps
Roll of grey duct tape
1" & 2" paint brushes (100 each)
6" plastic or rubber squeegees
Scissors
Wire brush
Pop rivet puller
Homemade balance for ratioing epoxy
Wall thermometer 50 to 100° F
1/4" hand drill

2. Recommended Tools (in addition to those above)

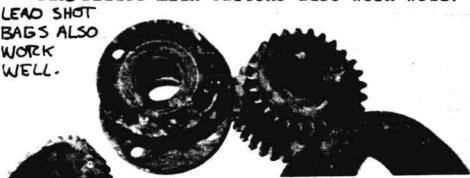
Dremel-type miniature high-speed hand grinder with saw and router bits.
6" to 9" disc-type hand sander
Set of 1/4", 1/2" & 1" chisels (wood)
Small set of X-Acto knives
Stipple rollers
1/2"-dia 100° counter sink (piloted)
6" machinist steel ruler
X-Acto razor saw
Box of wood tongue depressors to mix epoxy
6-ft straightedge
Cheap hole saw set or flycutter
3/8" variable-speed hand drill
12" long drill bits - #10 & 1/4"
Hand broom/brush
Large commercial 12" scissors (Wiss #20W)
Sabersaw
Bench-mounted belt sander
Stanley surform plane
Square & half round file
Several 6" C-clamps
Vacuum cleaner (shop type)
10" 18 tooth/inch handsaw (see sketch)
Approx 150 lb of small weights*



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

Drill press
18-inch bandsaw
Vernier Caliper
Epoxy ratio pump (Michael Engineering dispenser)
90° drill adapter
Air compressor with blow nozzle
Orbital sander
3/8" & 1/2" spotface
Drill sets #1 → #60 AND 1/16 → 1/2 (SAE in)
Items Used Only Occasionally & Can Be Borrowed
Nicopress sleeve tool
1 dozen 1/8" Clecos
hotwire voltage control

* Weights are used to hold various parts down while epoxy cures. They're best in 5 to 15-lb pieces. The items in the photo work great. We got them for 5¢/lb at a local scrap yard. Sand-filled milk cartons also work well.



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 1X4 LUMBER.



A lot of elbow grease is saved if you replace the sandpaper often.

Long Straightedge

This is not absolutely required, but is quite handy when jiggling or checking the straightness of flying surfaces. It is merely a 6-ft or 8-ft 1x3 or 1x4 piece of lumber that is hand-selected to be "eyeball straight." You can get it one of two ways: (1) Order it from Aircraft Spruce or Wicks - they plane them perfect from dry lumber. (2) Sort through the lumber (dry fir or redwood) at your local lumber yard until you find one that looks straight when you eyeball it from one end. Mark it and hang it on the wall so it doesn't end up as part of a shelf!

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 Long-EZ distributors for approximately \$130. 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: Cut out the 5-step instructions and glue to your balance - don't skip steps! Follow each step exactly every time you mix epoxy.

BALANCE IS ON NEXT PAGE

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.

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

Level Mark
Three Nails
3-oz PAPER CUP FOR HARDNER (UNWAXED)

HARDENER CUP.

SMALL BALLAST WEIGHT FOR FINE ADJUSTMENT

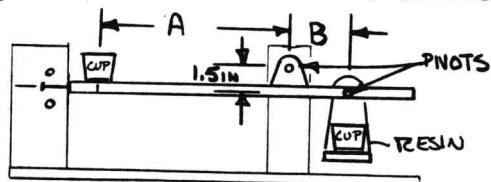
Pivots - metal tube bushings in wood. Loose fit on nails. The 1/8"-dia brass tube available at hobby shops is excellent for the bushings. **MUST BE FRICTION-FREE.**

Ballast weight

NOTE : THE METAL TUBE FOR THE PINOT BUSHINGS CAN BE CUT FROM AN EMPTY BALL-POINT PEN.

NOTE! BALANCE ACCURACY CHECK. Simply put 20 nails in the hardner cup and 100 nails in the resin cup, or for the new Safe-T-Poxy system, 43 nails and 100 nails.

Lily 8SN1 Paper Cup or Any 8-10 oz cup (UNWAXED)

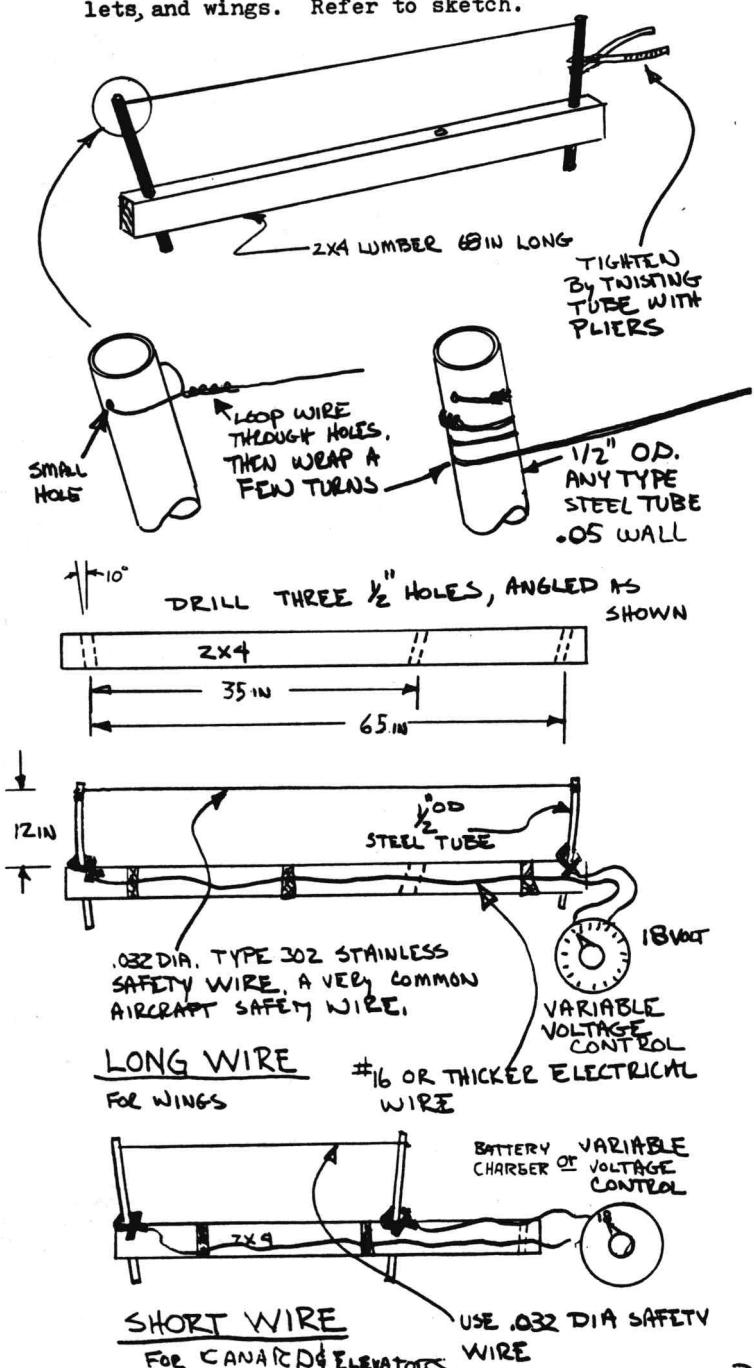


Balance Dimensions

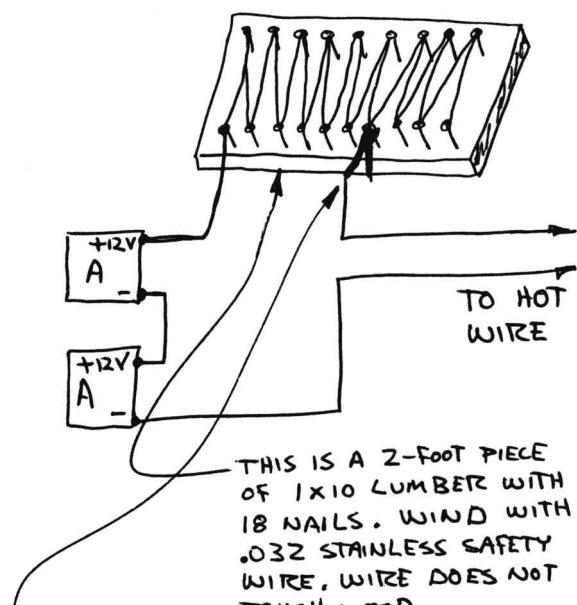
	A inch	B inch	Parts Hardner for 100 parts Resin
RAE System	13.7	3	22
SAF-T-Poxy	13.95	6	43

Hot Wire Cutter

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



The Variable Voltage control can be obtained from a Long-EZ 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-V battery chargers or auto batteries and lash up the following device. The "A" blocks represent either a battery or a 12-V DC battery charger with 4-amp capability.



Alligator CLIP. MOVE TO RT TO COOL THE WIRE, OR TO LT TO WARM IT.

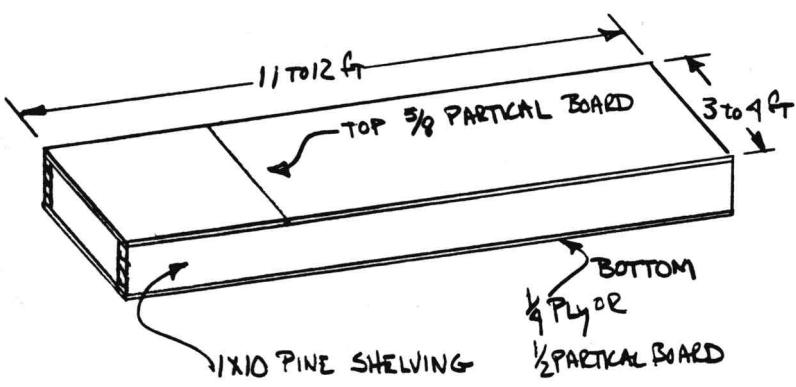
The cutter should only be used on the blue or white styrofoam. A hazardous gas is emitted if you try to cut urethane.

You can substitute .025 nicrome wire which can be run at a lower current (about 2 amp) but nicrome wire is difficult to find. 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 pound). 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 inch over the top and bottom of the wing and not over 1/8 inch 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 1 ft by 1 ft. Any larger than 4 ft by 12 ft will just get in the way. Use a little care in making a flat, un-twisted 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

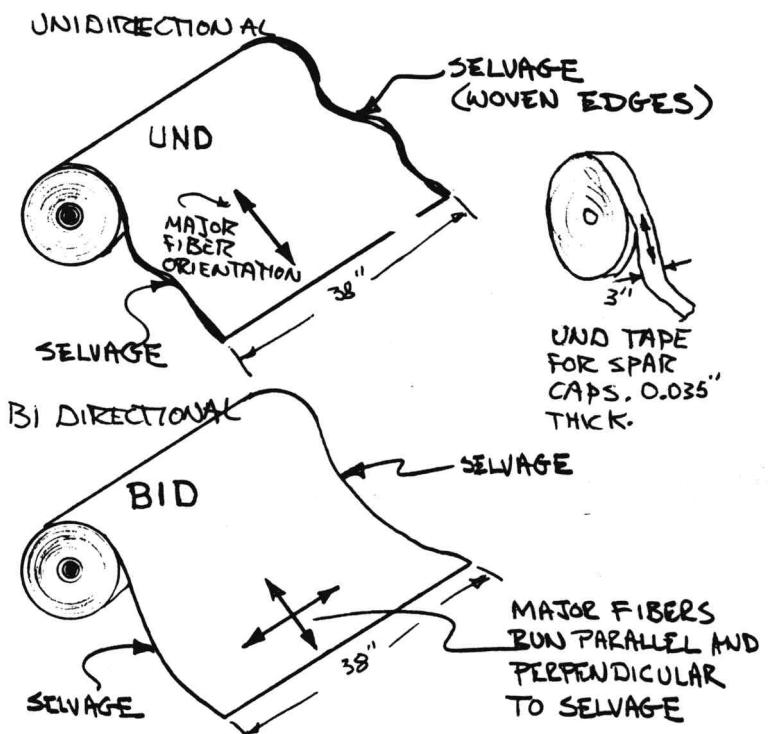
The materials, processes, and terminology used in the construction of your Long-EZ are new to homebuilding. This section is devoted to familiarizing you with the language, materials, and techniques used in these plans. This information is basic to the construction of your airplane. You should study this 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.

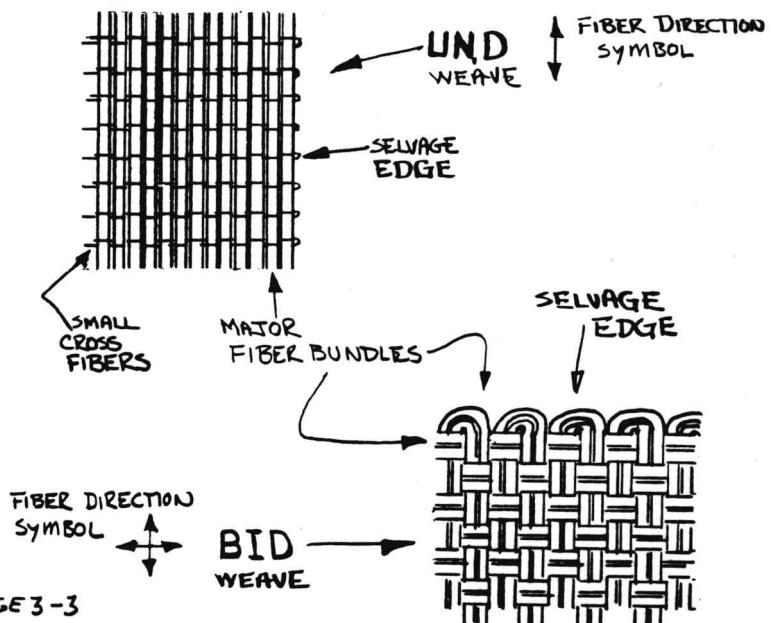
Glass

The most basic structural material in your Long-EZ 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 Long-EZ has been specifically selected for the optimum combination of workability, strength, and weight.

The glass cloth in your Long-EZ carries primary loads, and its correct application is of vital importance. Even though doing your glass work correctly is important, this doesn't mean that it is difficult; in fact it's VariEze!



Two types of glass cloth are used, a bi-directional cloth (RA5277BID), and a unidirectional cloth (RA5177UND). (Use the full part number for ordering your cloth, but for simplicity, the plans will use only the BID or 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.

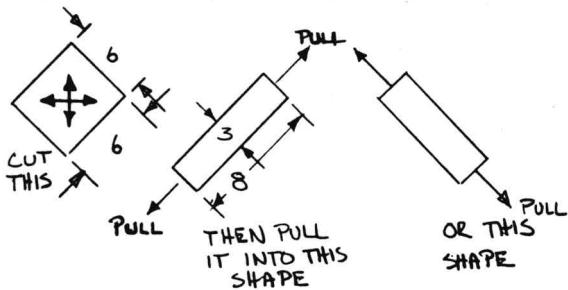
BID is generally used as pieces which are cut at a 45-degree angle to the selvage and laid into contours with very little effort. BID is often applied at 45-degree orientation to obtain a desired torsional or shear stiffness. UND is used in areas where the primary loads are in one direction, and maximum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

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 Long-EZ. 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. 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 effects 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 away.

When cutting long strips or large pieces of 45 BID, always roll or fold it so it keeps its shape when handled. When it's 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 shouldn't 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 makes it easy to work wrinkles out of a ply locally, without having to chase it to the far edge. The 45° cut also makes it possible to make a ply slightly longer than original by cutting on the ends or wider

by pulling the sides. The 45° orientation isn't critical; you don't need to measure it. Your eyeball of a rough diagonal ($45^\circ \pm 10^\circ$) is adequate when either cutting or laying up the cloth.

Epoxy

In recent years the term "epoxy" has become a household word. Unfortunately "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 Long-EZ 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.

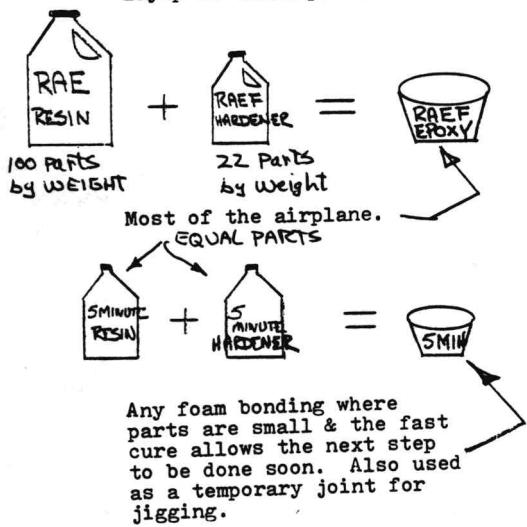
The RAE-type epoxy systems used in the construction of your Long-EZ are tailored for the best combination of workability and strength, as well as to protect the foam core from heat damage and solvent attack. These systems are also low in toxicity (SPL-2) to minimize epoxy rash. These epoxies are not similar to the common types normally marketed for fiberglass laminating. Three different systems are used in the Long-EZ for three different types of work: a slow curing system, a fast curing system, and a 5-minute system. The very fast curing (5-min) system is used much like clecos are used in sheet metal construction (or clamps in woodwork) for temporary positioning. Five-minute is also used in some areas where high strength is not required, but where a fast cure will aid assembly.

As an epoxy system cures, it generates heat and in some areas, the heat buildup of a medium or fast curing epoxy system is unacceptable. Where this is a potential problem, a slow curing system is used. Slow cure epoxy is always used with styrofoam, where heat can melt the foam away and ruin the joint. In other

areas where heat buildup isn't a problem and a faster cure is desirable, a fast curing system is used. Both the fast and slow cure epoxies will cure to a firm structure at room temperature within one day. Complete cure takes 14 days.

The RAF epoxy systems are called RAES (for slow curing), RAEF (fast curing), and 5MIN. Both the RAES and RAEF hardener use the same RAE resin.

NOTE! SEE PAGE 3-15 FOR NEW LOW TOXICITY SAFE-T-POXY.



Note: If working conditions are hot (85° to 90° F), RAES can be used where RAEF is called out. While this practice is allowable, the best results are obtained working between 70 and 80° F with the specified epoxy.

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, Pg 3-2. The mix ratio accuracy is particularly important with RAEF & RAES. The 5-MIN 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 RAEF or RAES, 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° F) and damage the foam-to-glass bond. This is why the slow epoxy system is used in joining foam cores as exotherm is impossible as long as epoxy joint thickness is less than $1/8"$.

Unwaxed paper cups are used for mixing and ratioing resin and hardener. Convenient 8-oz cups for resin are available from RAF distributors. The hardener cups are the 3-oz unwaxed bathroom paper cups available at any grocery store. Don't 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 shouldn't be used. Mix each cup for at least two minutes. 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 65° and 95° F. A range of 75 to 85° F is best. Be sure to get a wall thermometer (approx. \$1.50 at any general store) to check the temperature of your work area. At 75° F, 5-min must be used within four minutes, RAEF must be used within 20 minutes and RAES must be used within 50 minutes.

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 65° may take almost twice the time as at 75° F. On most layups (except for joining foam cores) its best to have 70 to 80° F room temperature and 80 to 90° 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 & hardener in the warmest place of your house for use on the next layup.

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 the surface of epoxy in the cured cup. If the epoxy cured properly the scribe will make a white scratch mark. If the epoxy hasn't 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 temperature, or bad mixing or bad epoxy. Refer to pg 3-15 for details on the new SAF-T-Poxy epoxy.

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. Several different types of microspheres and microballoons are available commercially. The quartz-type supplied by RAF distributors is lighter and cheaper than most common types. Microballoons must be kept dry. If moisture is present it will make them lumpy. Bake them at 250° F 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 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 don't measure, just add microspheres until the desired consistency is obtained. Use micro only as specifically shown - never use micro between glass layers.

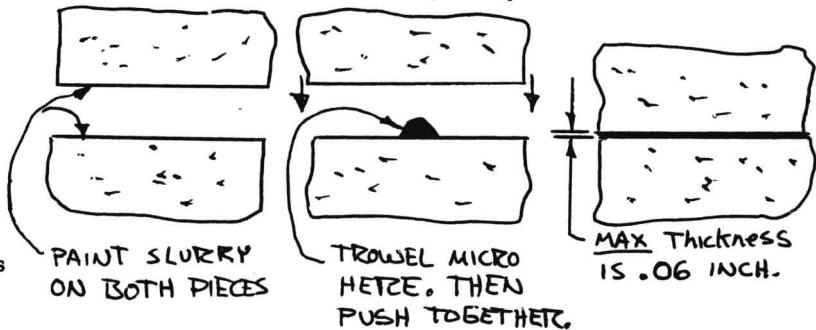
JOINING FOAM BLOCKS WITH MICROSPHERES/EPOXY

Always use the following method to join foam blocks. This is extremely important. Always use RAES or SAF-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 fiber (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 flock to one part epoxy is required. Mix in just enough flock 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 sandpaper and paint pure mixed epoxy (no flox) on the metal part.

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

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 or 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 isn't completely hardened.

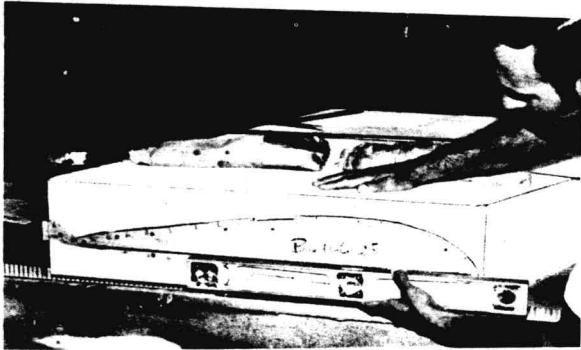
Foam.

Three different types of rigid, closed-cell foam are used in your Long-EZ (and several densities). A low density ($2 \text{ lb}/\text{ft}^3$), light blue or white styrofoam is used as the foam core of the wings, winglets, elevators 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.

Low density $2 \text{ lb}/\text{ft}^3$ green (or light tan) urethane foam is used only in non-structural areas, where its ease of carving is important (nose and canopy). Urethane foam is fantastically easy to carve and contour. The urethane used is U-Thane 210 or equivalent.

PolyVinyl, PV core foam in low, medium and high densities is used extensively. The dark blue color $3 \text{ lb}/\text{ft}^3$ type R45 is used in the fuselage and fuel tanks. It has excellent compressive strength (75psi), good laminate peel strength and is completely fuel compatible. The light-red color, $6 \text{ lb}/\text{ft}^3$ type R100 PV-core is used in the center section spar and canard inserts. Dark red color, $16 \text{ lb}/\text{ft}^3$, type R250 is used in several bulkheads in Chapters 4 and 13. Do not substitute other foams. The Styrofoam has greater peel strength than the standard blue styrofoam sold by some distributors. Also, we considered using the "fire resistant" BROWN urethane instead of the green or tan 2-lb urethane, but found it's physical properties to be much lower than U-Thane 210. Do not confuse Styrofoam with white expanded polystyrene. Expanded polystyrene is a molded, white, low density, soft foam, which has the appearance of many spheres pressed together. It's compression strength and modulus is too low.

All three types of foams, PV, urethane and polystyrenes are manufactured in a wide variety of flexibilities, densities and cell sizes. Getting the wrong material for your airplane can result in more work and/or degraded structural integrity. Sun damages foam. Keep it covered.



HOT WIRE CUTTING

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

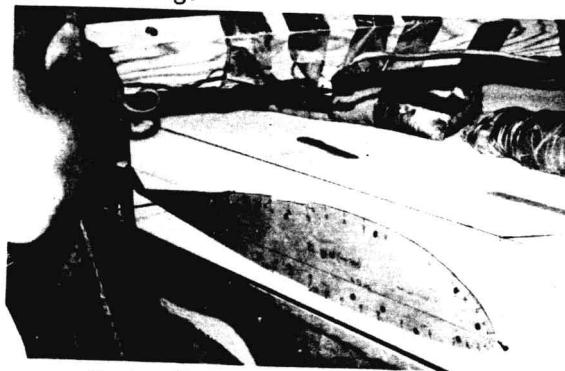
The hot wire saw is a piece of stainless steel safety wire, stretched tight between two pieces of tubing. The wire gets hot when an electrical current passes through it and this thin, hot wire burns through the foam. By making smooth steady passes, the hot wire gives a smooth, even surface. The foam offers little resistance to the hot wire's passage. To get a smooth accurate cut, a template is required. Templates are made from thin plywood, sheet metal, masonite or formica. A variable voltage control is used to supply the electrical current that heats the wire.

The blue foam used in your flying surfaces was selected for a combination of reasons and its hot wire cutting ability was one of them. Other types of foams are readily hot wire cut, but some (white expanded polystyrene) have poor physical properties and others (urethane) give off poisonous gases when hot wire cut. Use only the recommended materials!

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 planform (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.

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 carpenter's 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 planform; a foam trim line is provided near the trailing edge of each template which is lined up on the foam edge before cutting.



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 $1/4$ " from 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 cut is begun by trimming the rectangular foam block to the basic dimensions for the correct planform. These "trim" cuts are made using two straightedged trim templates. 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.



CUTTING
STRAIGHT
DOWN
ALONG
TEMPLATE
WITH
HOTWIRE.

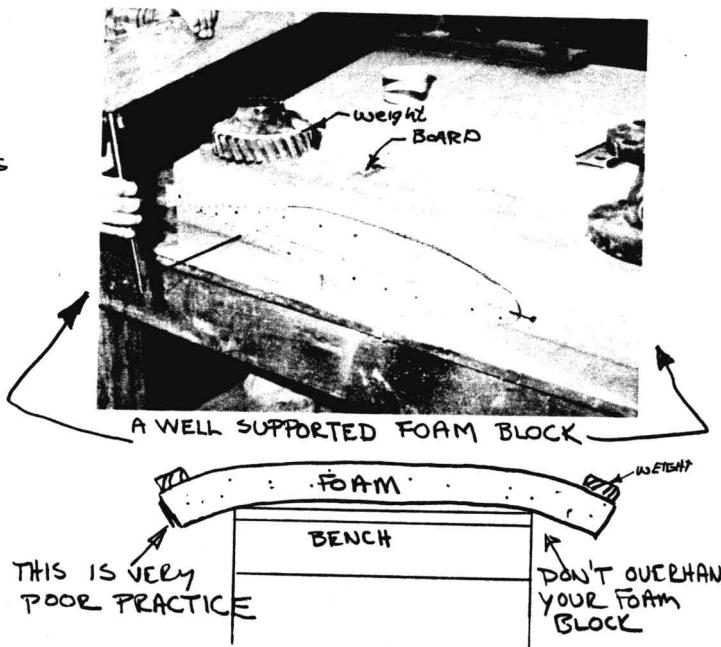
NOTE The diagonal CUT being MADE by correctly POSITIONING the VERTICAL Templates AND PASSING THE hotwire downward along Them



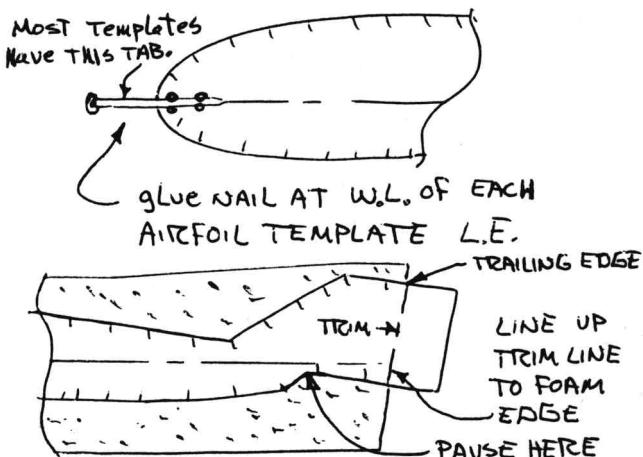
The use of the hot wire saw is a simple thing if your equipment is set up properly. Proper wire tension and wire temperature should be maintained for good cutting. The wire tension should be tightened after the wire is hot by twisting one tube with a pair of pliers. The wire should be as tight as possible. 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. 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 and pause marks where it 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 winglets. 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

Each template has symbols for the general location of holes for the nails, #.4D (four penny) nails are good for this use. The holes in the templates should be a close fit for the nails. Be careful not to angle the nails so that the hot wire can catch on them! Some rib templates are used several times, for both inboard and outboard, this you may have to transfer the talking numbers, pause marks, trim line, and waterline to the opposite side of the template.



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. See chapter 10, 19 & 20 for clarification of the trailing edge overlap.



The hot wire should be guided around the templates with light pressures. 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 doesn't sag and doesn't 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.

Foam is manufactured in sizes that are often too small to get a solid core from a single block. It is necessary to use two foam blocks to get the size required for the wing cores. These blocks have to be joined using an epoxy/microsphere 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-min 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.

Don't 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 min-or gouge.

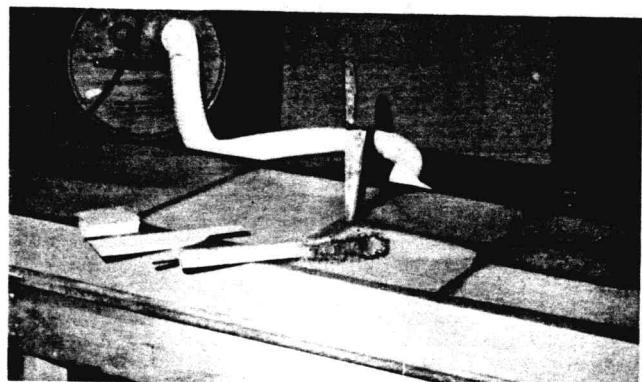
FILL SMALL GOUGES OR
NAIL HOLES WITH DRY
MICRO BEFORE GLASSING

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.

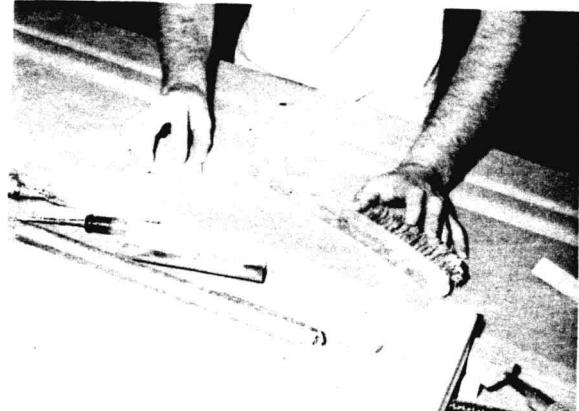
A warped core is simply weighted into the jig blocks and shimmed straight. Once the skin has been installed, the foam is held firmly in position.

URETHANE FOAM SHAPING

One of the real treats in the construction of your Long-EZ will be shaping and contouring urethane foam. Urethane is a delightful material that shapes with ease using only simple tools. A butter 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's a frequent task and a razor edge isn't necessary. Coarse 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 better half by leaving a green foam dust trail into the house.

GLASS LAYUP

The glass layup techniques used in your Long-EZ 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 VariEze, 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 Vari frustrated.

Step 1: Personal Preparation

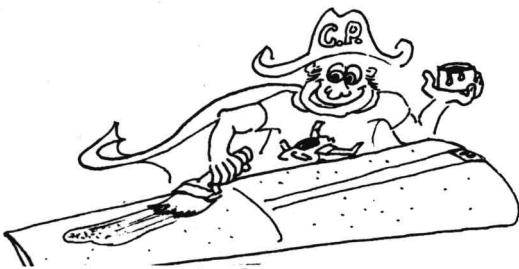
Before you get started with a layup, plan ahead. Some major layups take several hours and before getting your hands in the epoxy, it's a good idea to make a pit stop at the restroom.



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 at 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 65° F and 95°. Best results are obtained at 75 to 85°F. Below 70°F 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 on page 3-3. Remember that there isn't 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 layup.



Step 3: Prepare Surface

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 a 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 pg 3-B) 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 or PV foam, paint a liberal coat of epoxy on the surface. When laying up over Styrofoam or Urethane foam, paint a liberal coat of Micro slurry on the surface, before laying on the first ply. The slurry or epoxy can be poured on the foam and spread thin with a squeegee or it can be brushed on with a brush. Then, fill any dings or gouges in the foam core with dry micro.

Step 5: Lay on the Cloth

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. Don't 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 outeredge 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.



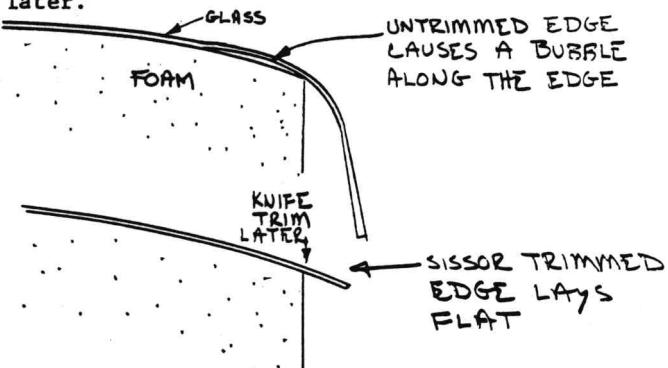
Step 6: Wet Out the Cloth

Wet out the cloth by brushing on a thin coat of epoxy. Do not use micro between plies of cloth. Extra epoxy not be necessary if there is enough epoxy under the cloth to be brought to the surface. This is done by "stripping," which involves a vertical stabbing motion of a paint brush over the cloth. This brings excess epoxy up from below to wet out the cloth, resulting in a weight savings as compared to adding more epoxy on top. REMEMBER, epoxy adds no strength beyond what is needed to wet out the white color of the cloth and fill air voids; any further addition of epoxy is only dead weight.

Where multiple plies are required, the first plies may be laid up wet and the excess resin brought up by squeegeing and stippling to help wet out the middle plies. To do this, pour epoxy onto the part and move it around the surface with a squeegee. Your work will go much faster if you make the layup too wet, then remove excess epoxy with many light passes with the squeegee. Do not squeegee too hard, as this can starve the surface of micro and introduce air. Continue to inspect for air (tiny white flecks or bubbles) and stipple or squeegee in more epoxy to remove the air. A handy squeegee can be cut from the flexible plastic found on a coffee can lid. You may also find a paint roller handy for spreading around the epoxy. Special stipple rollers are available at Long-EZ distributors. The final plies are ambitiously stippled and additional epoxy is applied sparingly. When in doubt - stipple it out, or squeegee.



As you wet out each ply, scissor trim to within $\frac{1}{2}$ " of any overhang (trailing edge, etc.). This $\frac{1}{2}$ " will be knife trimmed after the layup cures. If an overhanging 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 $\frac{1}{4}$ " to allow easy knife trimming later.



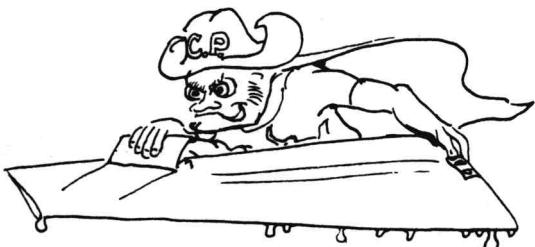
Step 7: Squeegeing

Squeegeing out excess epoxy. This involves drawing a plastic or rubber squeegee over the layup as shown. Plastic squeegees (scrapers) 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 stippling it down into the layup. The best quality layup is obtained if each layer of a multi-layer layup is squeeged. The excess epoxy which is pushed off the edge can be recovered and returned into the cup. This is easily done by catching the epoxy on the squeegee and scraping it on the side of the cup.

The finished layup should appear smooth and green 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 $\frac{1}{2}$ 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 indicates 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. Some places are not suited to the use of a squeegee and the dry brush or roller must be used to



expel the excess epoxy. On a given layup, about $\frac{1}{2}$ of your time should be spent

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 flecs 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 airflecks. If any air is visible, stipple it out. Exception: It is allowable to have many tiny bubbles of air at the foam surface of the low density PV (dark blue) foam. These are difficult to remove. More than adequate peel and shear strength exists with them present. They should be considered normal. Do not confuse this with air between plies.

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 a 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 fiber-glass 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.

Step 10: Cleanup

Brushes can be used two to four times if after each layup they are washed with soap and water. Wipe excess epoxy off with a paper towel. Wet the brush & work soap into all fibers by mashing it into a bar of soap (Lava brand is best). Rinse with hot water and repeat 3 times. Be sure they are dry before next use. We generally se a cheap brush (approximately \$2.00 to \$4.00 per dozen) and discard after two or three layups. Clean squeegees the same way.

If you use skin barrier cream (Ply No. 9) the epoxy and cream will wash off easily with soap and water. When you get epoxy on unprotected skin, Epo-cleanse is used to remove the epoxy. Both of these products are available through RAF distributors and are listed in the bill of materials. Once you are sure your skin is clean, wash again thoroughly with soap & water, even if your hands were protected with plastic gloves. If you get epoxy on tools or metal parts, clean them with acetone or MEK before the epoxy cures.

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 wipe your hands on your clothing (keep a roll of paper towels handy), 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 about $\frac{1}{8}$ 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-Aceto knife and trim the edges with a motion downward toward the edge. Experience will help you determine the correct time in the curing cycle for optimum knife trimming.

KNIFE TRIM



In the plans when "knife trim" is called for, this assumes the three to 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, dremel, bandsaw, saber saw, etc. Smooth the edge with the Dissolve Abreder. 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 six hours at 60 degrees and one hour at 90 degrees.

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 sandpaper. 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 sur-

faces should be free of oil and grease and, except for bolts, nuts, and other fasteners, metal surfaces should be dulled by sanding with 220-grit sandpaper, 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"x6" 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 good light before cure when it's easy to fix. If in doubt on overlaps be sure to stipple in enough epoxy.

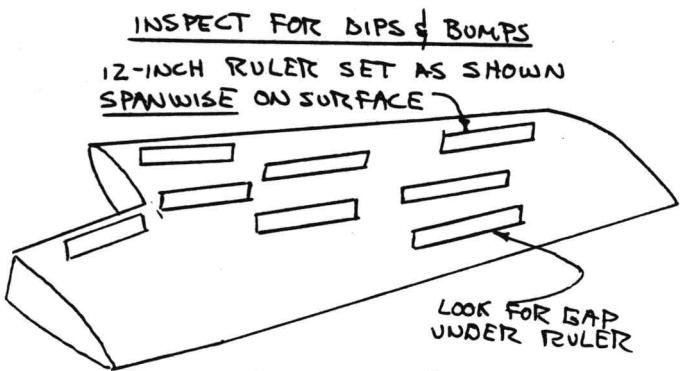
Delaminations in a new layup may be due to small air bubbles trapped between plies during the layup. The areas look like air bubbles and are distinctly visible even deep in a cured layup. Small delaminations, or bubbles up to 2-inch diameter, may be filled with epoxy by drilling a small hole into the 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 10 per square foot, change your brush and remove bristles.

Occasional sanding through the weave in the first skin ply is not grounds for scrapping the part. Care should be exercised in areas, such as the skin joints not to weaken the structure in pursuit of an optimum finish. (Refer to Chapter 25 for details). 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 straightedge 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.

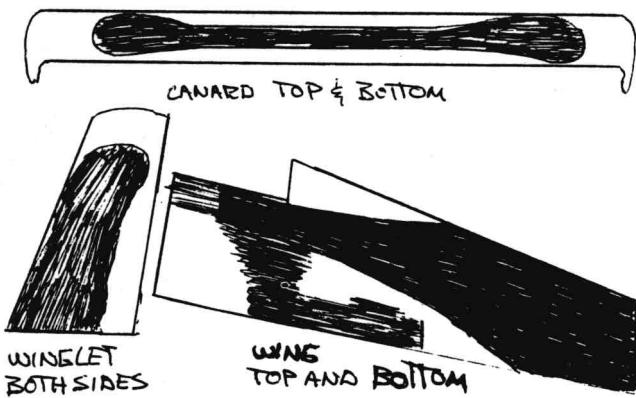
A Reprint of the inspection criteria for homebuilt composite aircraft that has been distributed to FAA inspectors is included at the end of this chapter.



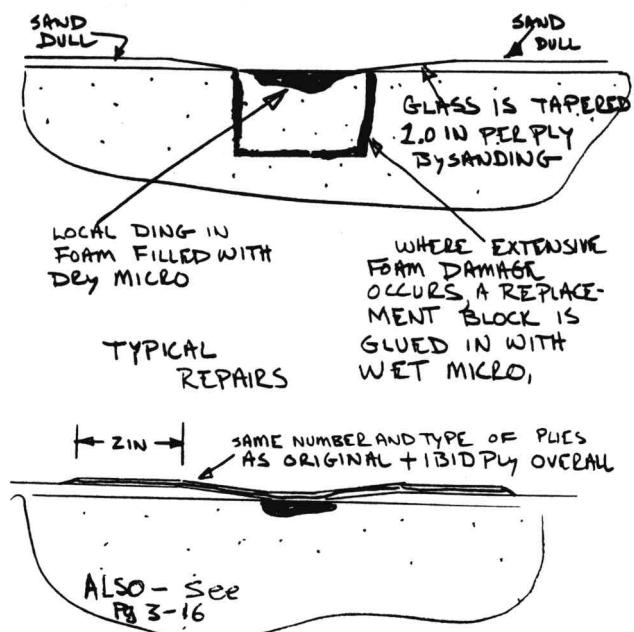
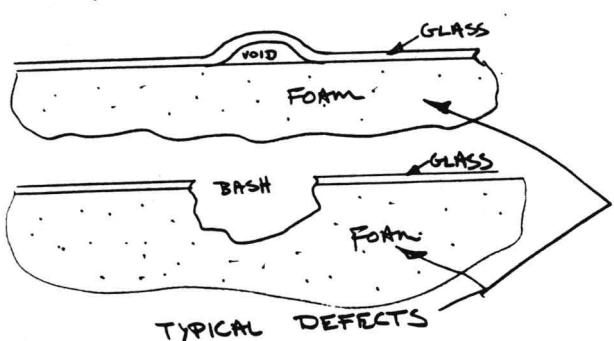
IF MORE THAN $1/16$ " GAP IS PRESENT ANY WHERE IN CRITICAL AREA, REPAIR IS MANDATORY.

The following is a listing of the "critical areas" - the portions or the Long-EZ that must meet all the inspection criteria:

1. Center section spar- entire outside skin and spar caps.
2. All portions of the fuselage within 10" of the engine mounts and canard lift tab attachments.
3. All control surfaces.
4. All flying surfaces in the shaded areas shown plus all overlaps at L.E. & T.E.



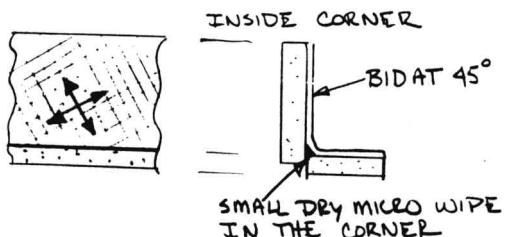
Major wrinkles or bumps along more than 2" of chord are cause for rejection in the wings, canard and winglets, particularly on the top (compression side). This does not mean you have to reject the whole wing - anything can be repaired by following the basic rule: remove the rejected or damaged area and 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, plus one more ply of BID over the entire patch. 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 hangar, etc.



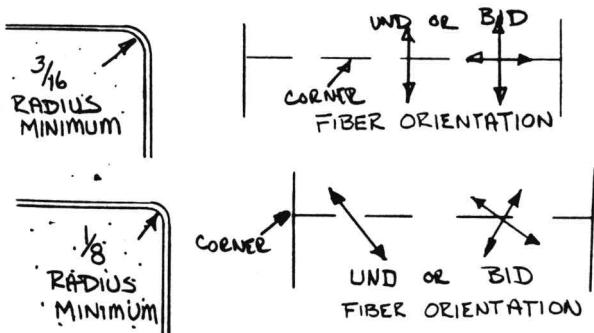
CORNER TREATMENTS

A variety of structural corners are employed in the construction of your Ez. 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.

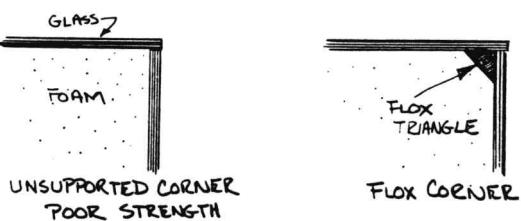
Inside corners can be laid up quite abrupt and only a very slight wipe of dry micro is needed to get the glass to lay into it. BID cut at 45° is used on this type of corner.

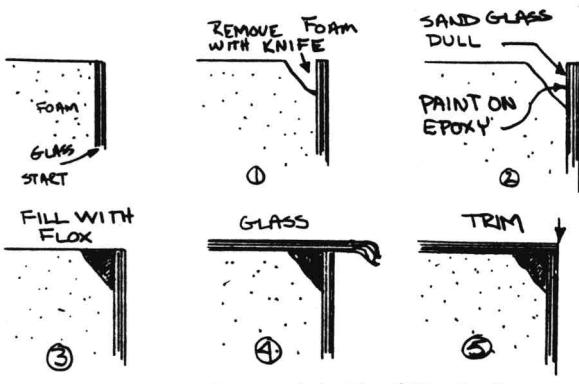


Outside corners require a radiused edge. Where the glass fibers run directly around the corner a minimum radius of $3/16$ inch is required. Where the fibers run at an angle to the radius, only a $1/8$ -inch radius is needed.



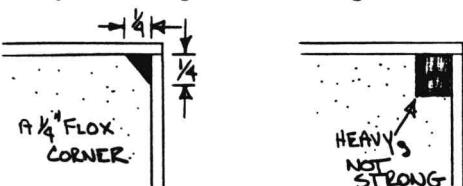
In some areas a sharp corner is desirable and maximum strength isn't required. In these areas a flox corner is used. A simple unsupported glass corner has very poor strength. To strengthen this corner a triangle of flox is used to bond the glass plies together. The flox corner is done just before one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





FLOX CORNER SEQUENCE

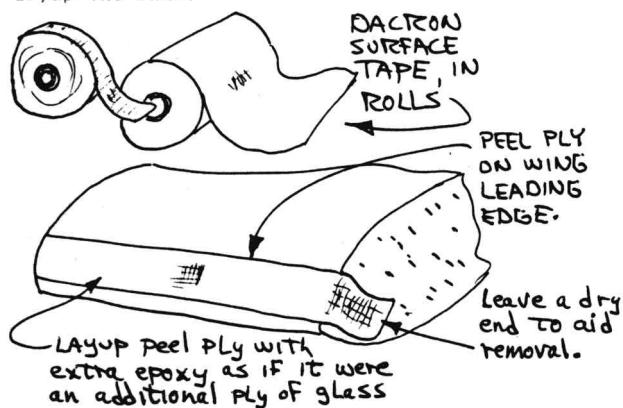
If a specific size of flox corner is desirable, an approximate dimension may be given as shown. Don't make your flox corners square. The extra flox only adds weight, not strength.



PEEL PLY

Peel ply is a layer of 2.7 oz dacron fabric which is laid 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: leading and trailing edges of all flying surfaces, outboard 15" of wings and lower 10" of winglet (for chapter 24 layups), canard & wing shear web surfaces (for sparcap layups) all joining edges of Bulkheads & Fuselage sides, fuselage skin at both ends, fuel tanks, and at Landing brake, and all other places where a Future layup will be made. Note that to peel ply the

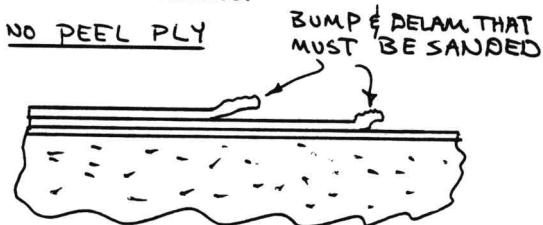
trailing edge overlap area, the peel ply is the first ply made to the foam core. Lay a strip of dacron down on the overlap notch & secure it with tacks or staples so it doesn't move when you layup the skin.



LAYUP peel ply with extra epoxy as if it were an additional ply of glass

(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/winglet junction, where the fuel tank, cowling lip, and nose joins the fuselage, 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 overlaid with a strip of dacron during the layup (lay on the dacron & 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 surface.

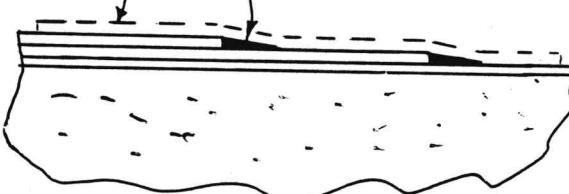
NO PEEL PLY



WITH PEEL PLY

PEEL PLY REMOVED

SMOOTH EPOXY TRANSITION.



HEALTH PRECAUTIONS

Skin Protection

If you work with epoxy on your bare skin, you can develop an allergy to it. This "sensitization" to epoxy is an unpleasant experience and is to be avoided. You generally have to get epoxy on your unprotected skin to become sensitized. If you use a protective barrier skin cream like Ply No. 9 (available from Long-EZ distributors) or disposable plastic medical examination gloves (also available from Long-EZ distributors) the allergy can be avoided. The barrier skin cream also allows you to clean up with soap and water after a layup.

The RA epoxy systems are low toxicity (SPI=2). However, many people (about 5 to 7 percent) are sensitive to epoxy to a great extent and thus will find it impossible to build their airplane without extensive skin rash, facial swelling, etc. These people can get some help by using doctor-prescribed anti-allergy medicines and/or by using elaborate masks/multi-gloves, etc., to reduce exposure, however in many cases the allergy is sufficiently strong to preclude their ability to make layups. Remember to Always use skin protection, never let epoxy come in contact with bare skin, even if you have no reaction to it. Sensitivity is accumulative, such that you may later develop an allergy unless you protect your skin.

Dust Protection

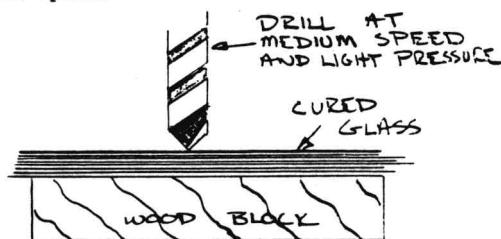
Sanding or grinding fiberglass and foams creates dust that can be harmful to your lungs. Use a dust respirator mask for these operations. Disposable dust masks are available at most paint stores.

Ventilation

Mix and work with your epoxy in a ventilated area. Some epoxy/hardener systems may irritate your eyes (like cutting onions) in a poorly ventilated work area. If your shop is not ventilated, set up a small fan to move a small flow of air in or out. DO NOT INHALE URETHANE

DRILLING, GRINDING, & SAWING

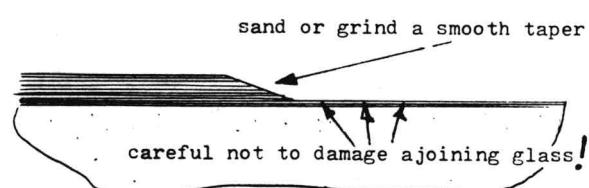
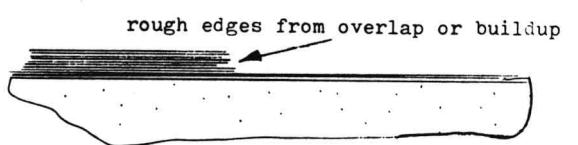
Drilling through cured glass tends to tear the surface plies on the back side. Backup a glass layup with a wood block for drilling as shown and drill at medium speed.



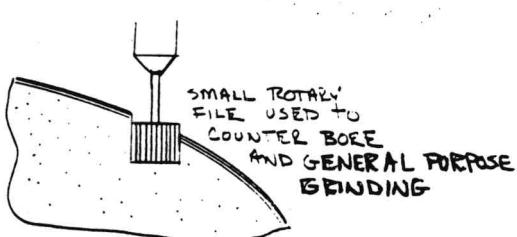
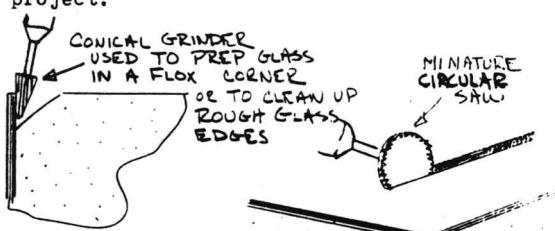
Using a small hone, grind the cutting edges of your drill bit flat as shown (not undercut). This will keep the drill from grabbing into the glass. Don't overdo it, just make a couple of light passes with the hone.



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.

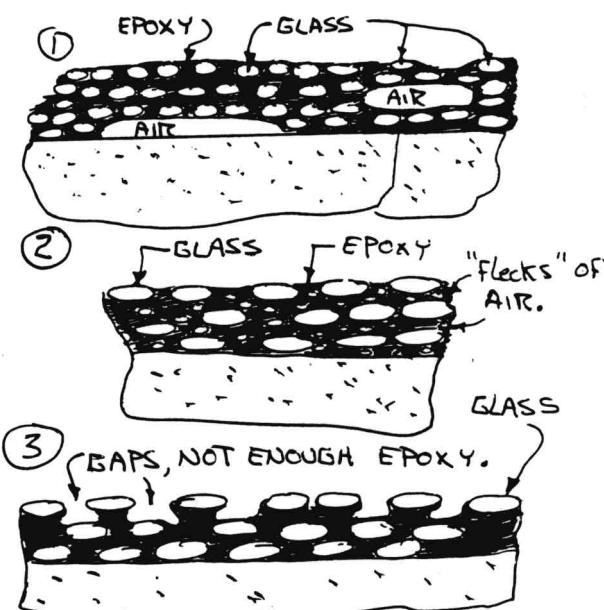


The Dremel (Moto Tool) or Home Shop (Weller) is a very versatile tool with many uses in the construction of your Ez. The kits usually have a nice selection of bits, cutters, grinders, stones, and mandrels for every conceivable use. The three types of bits shown here are the most useful for your project. 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 microballoons. 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-inch 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.



SAFE-T-POXY NEW LOW-TOXICITY EPOXY SYSTEM.

In 1979 a new epoxy system was introduced that can be used in place of the RAEF and RAES epoxy. This new system essentially eliminates the skin irritation problems experienced with normal epoxies. Safe-T-Poxy also has improved physical strengths, less water absorption and better fuel compatibility than normal epoxies. Due to its different curing characteristics, Safe-T-Poxy is less exothermic and can be used in place of both RAEF and RAES, ie, in all cases where "epoxy" is called out in the plans. Safe-T-Poxy uses a different mix ratio - see page 3-2. If you are using Safe-T-Poxy, consideration should be given to two areas: (1) When mixing micro balloons with Safe-T-Poxy, only 3M B23, 500 (available from distributors) glass balloons, should be used. If you use Quarts Q-cell balloons, due to alkaline, the cure will be delayed, depending on temperature as much as two or three days. Although it does ultimately cure, and is structurally ok, this much delay, particularly in finishing is not acceptable. (2) The Safe-T-Poxy has a higher viscosity than the previous resins, thus requiring a higher working temperature to use, especially on the larger layups. The high viscosity was selected for the Safe-T-Poxy to eliminate the tendency of the previous material to bleed-out (inducing air in the layup during cure).

If you are building in a cold garage in the winter you can still use the new Safe-T-Poxy if you take the following precautions:

- (1) Warm the resin and hardner evenly to 85-90° F prior to mixing. Do not try to hurry this. We use a light bulb under the ratio pump 3-4 hours prior to use, or keep your resin jugs in a cabinet with a light bulb inside.
- (2) It's important to have everything thoroughly warm prior to starting to work. This also cannot be rushed. It takes time to get the parts (wings, foam blocks, etc.) up to a

stable temperature through out. If you are starting from a very cold garage, the warming process could take 4 hours or more. Don't think just because the air is warm that all the material is warm.

(3) Use an electric hair dryer to warm the area as you work, being carefull not to over heat the part or epoxy. When, due to cool temperatures, a part is slow to wet out, a few quick passes with a hair dryer will greatly speed the layup time. Do not use a hair dryer to heat a cup of epoxy. This can give local hot spots and ruin pot life.

What shop temperature is satisfactory? That has a lot to do with the size of the job. Small jobs can be worked to as low as 65°F but the working time will be excessive. It will also be more difficult to remove excess epoxy, resulting in a heavier part. On large layups like the fuselage, wings etc, where there is a lot of epoxy to drag around, 77°F should be considered the minimum. Thats epoxy prewarmed to 85-90°F and all parts, glass, foam, tools, table - - everything up to 77°F for 4 hours then go to work. Those temperatures are minimums- add 5 to 10° F and your working time will be greatly reduced and parts built lighter.

SOME MORE HINTS

You can generally tell the quality of a man's workmanship just by looking at his shop. Clean up and sweep 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 flour sifter is excellent for getting any lumps out of micro. Keep micro bag closed to avoid moisture.

A key to a good glass layup is preparation. Copy the check list below and post in your shop:

BEFORE ANY GLASS LAYUP

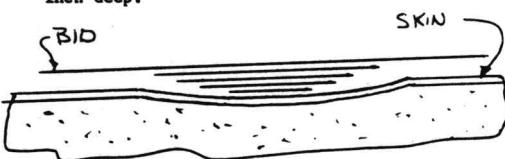
1. Tools cleaned & available
squeegee cups & sticks
brush scissors
roller ply 9 or gloves
2. Workbench clean
3. Glass cut & rolled
4. Surface to be glassed -
correct shape & smooth contour
sanded dull
dust blown or vaccuumed off
5. Temperature of room and epoxy 70 to 80°F

ERRORS - HOW TO FIX

The following are accepted practice to repair common errors. Of course, it's best to be careful and avoid the error in the first place. Remember, most errors can be avoided by reviewing your newsletters.

ERROR: Depression in skin or spar cap in spanwise direction on wing, winglet, or canard.

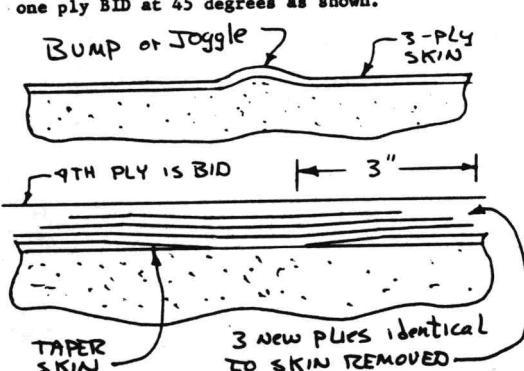
REPAIR: Sand surface dull. Layup UND plies cut as shown to fill depression, fiber orientation spanwise. Add one ply BID at 45° lapping two inches on each side of depression. This repair is allowable for depressions up to 1/10 inch deep.



ERROR: Bump in skin or spar cap in wing, winglet, or canard.

REPAIR: Using a hard block, sand bump level.

Determine number of plies in area of bump. Sand completely dull the area around bump to a radius in inches equal to number of plies at bump. Layup the same plies as effected area, being sure to observe fiber orientation. Add one ply BID at 45 degrees as shown.



ERROR: Inadvertently sanded through plies during finishing process.
REPAIR: Determine number of plies damaged. Repair as shown in "bump" repair above.

ERROR: Due to incomplete wetting of layup I have several pin holes in my wing fuel tank so it will not meet leak check.
REPAIR: Pull a mild vaccum (1500 ft) on the tank. Hold the vaccum for 1/2 hour as you brush, stipple, or rub epoxy over the area with pin holes. Then vent tank to equalize pressure. Paint a coat of epoxy over effected area. Be sure tank is vented during cure.

ERROR: Due to a poor or heavy layup, elevator or aileron will not balance to specification.
REPAIR: Start over; sloppy workmanship cannot be patched on these parts.

IMPORTANT!

Avoid adding extra systems, night lighting, or extensive avionics. Remember, the Long-EZ is smaller than the average light plane and thus is effected to a greater extent by the addition of excess weight. A light Long-EZ is a thrill to fly and has extensive utility. A Long-EZ that is loaded down with extensive systems, avionics etc, can be so heavy as to preclude two-place operation and destroy its exciting solo performance. Resist the temptation to add anything. In an airplane this small you should be carefully counting grams, not just pounds of excess weight. The best test to decide whether something should go in the airplane is as follows. Take the object in your hand. Toss it up into the air - if it comes down, its too heavy to belong in your airplane!

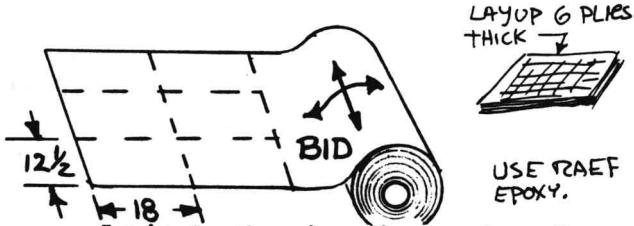
Starter - Electric start, while available for the Long-EZ, does compromise it enough so that we recommend against its installation. The engines are easily hand-propelled, particularly since you have a pusher with nose-down parking. In this configuration most aspects of manual start are considerably safer than for conventional aircraft - see Owners Manual. The plastic airplane does not conduct. Thus, your large heavy start cable must run to the battery and back. Electric start adds over 25 lb weight, most of it aft on the engine. You will initially want to fly your first flights at forward cg and at as light a weight as possible (see Owners Manual). Therefore, even if you insist on needing electric start, leave the starter and heavy cable out for your initial test flying. This will avoid possible nose balast (thus a double weight penalty).

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 intended 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.



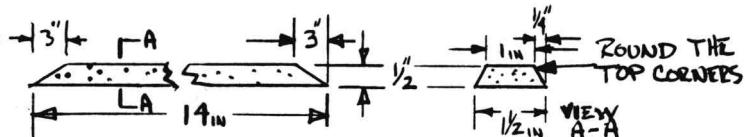
Laminate the six plies on top of the waxed paper. Try to do your best job of stippling and squeegeeing so that the plies are completely wetted but not full of excess epoxy. Let the layup cure to knife trim, about four hours. Carefully mark a 10-in by 16-in rectangle and knife trim the layup to that size 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 Long-EZ 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.

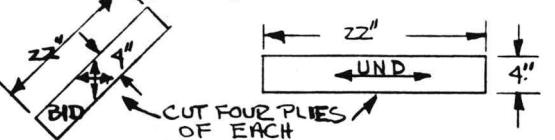
Confidence Layup

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 Long-EZ. 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.

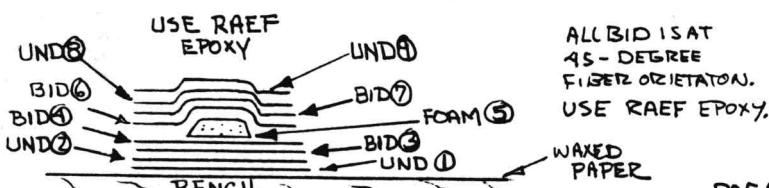
First, tape a piece of waxed paper about 30 inches long to the top of your work table. Shape a piece of green foam as shown.



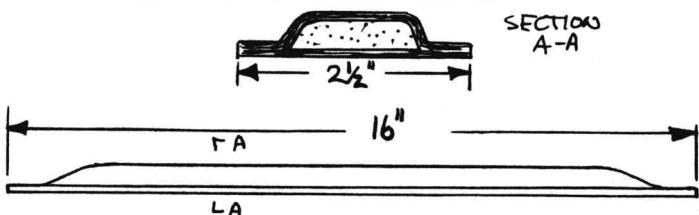
Go to your glass cutting area and cut the glass plies shown.



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.

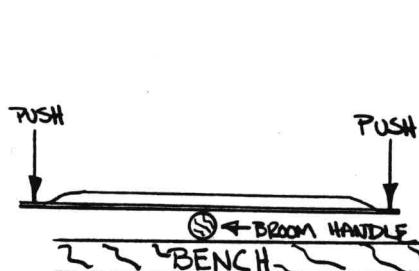


Be careful to work all air bubbles out of the corners. The best way is to stipple with the brush. The glass is oversized so that it can be trimmed to exact dimensions later. Trim to the dimensions shown after curing 24 hours. Using a coping saw or band saw.



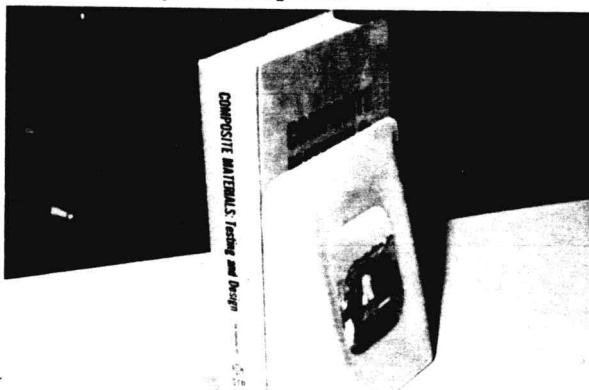
Allow the piece to cure for four days at room temperature before the load test.

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!

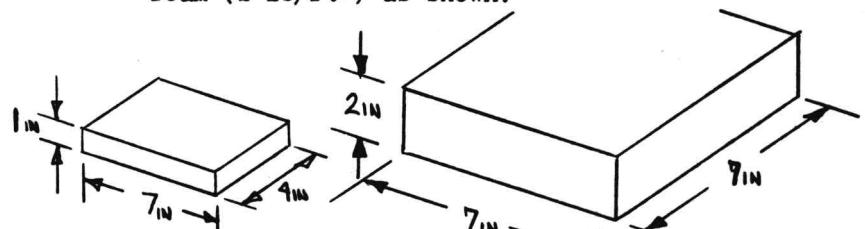


Book End

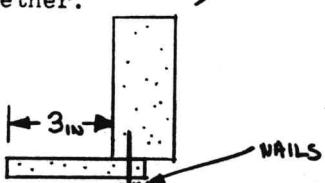
The last practice part that you will make before starting on your airplane is a book end. It takes three layups to make the book end and involves most of the operations that you will need to learn, to build your airplane.



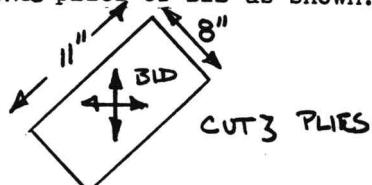
Cut the two blocks of green urethane foam ($2 \text{ lb}/\text{ft}^3$) as shown.



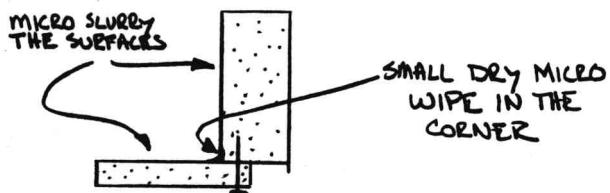
Nail them together.



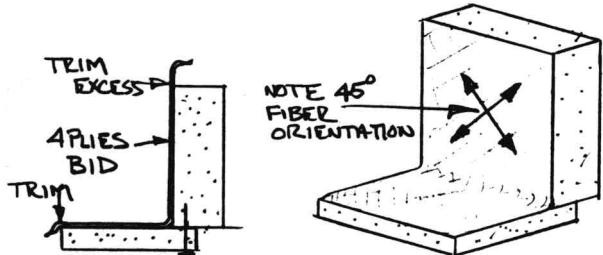
Cut Three plies of BID as shown.



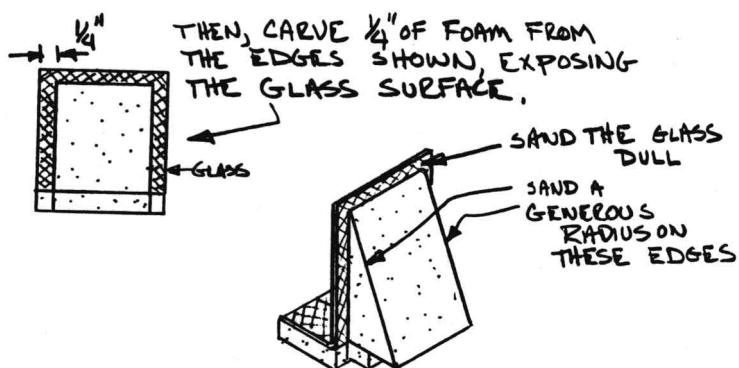
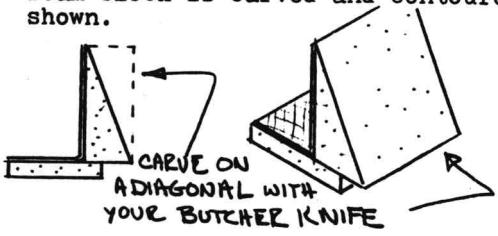
Mix 4 oz of RAEF epoxy; using about 1 oz, make a small batch of micro slurry and coat the foam as shown. Make dry micro from the leftover slurry and make a small radius with it as shown.



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.

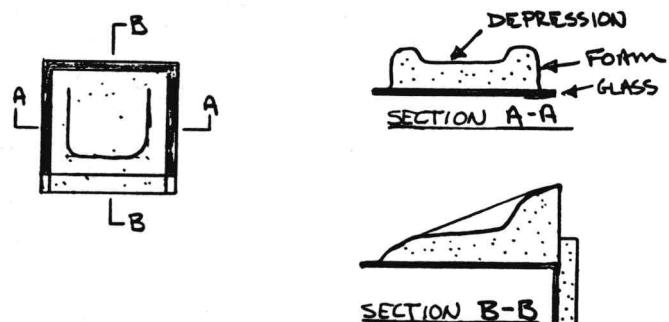


Knife trim along the foam edges. After the first layup has cured and the edges have been trimmed, the thicker foam block is carved and contoured as shown.

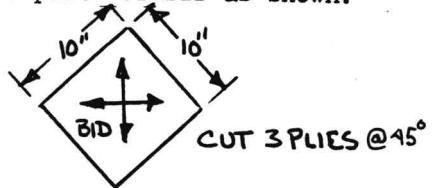


Put a generous radius on the foam edges and sand the $1/4"$ wide glass edges dull for glass to glass bond. Use your wire brush to rough out a depression in the middle of the block.

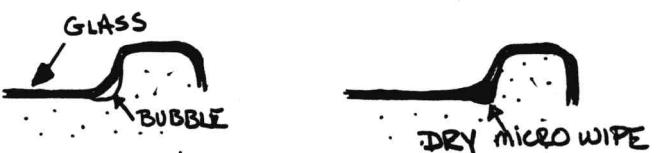
Finish smoothing the depression by rubbing it with a scrap of green foam. Radius the corners of the depression. Blow or brush all of the foam dust off the surfaces.



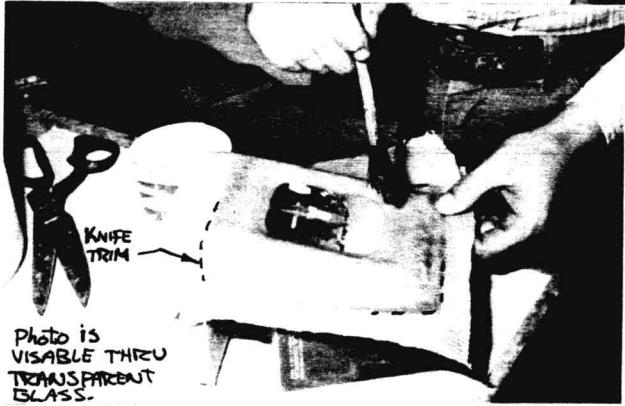
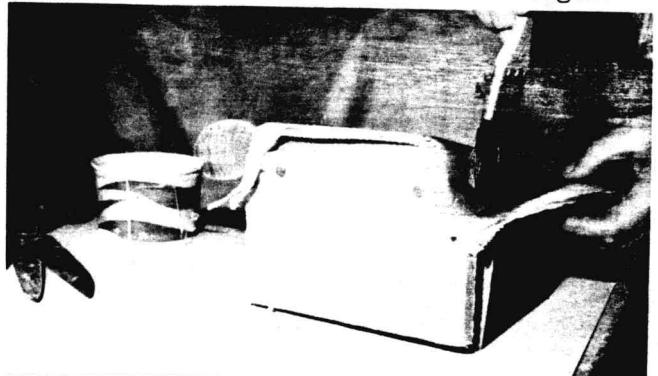
Cut three plies of BID as shown.



Mix RAEF, make a small batch of slurry and save the remaining epoxy. Slurry the foam surface 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.

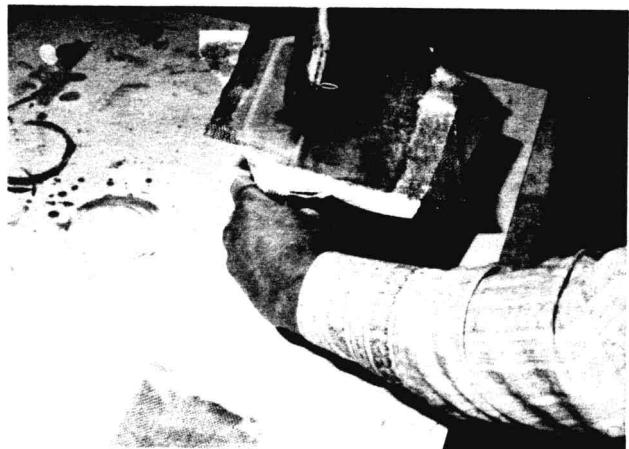


The lower edge is trimmed flush with the bottom of the foam block. Wait until the second layup is fully cured. Remove the $1/4"$ foam block with a butcher knife and sanding block. Remove FOAM for a $1/4"$ flox corner and sand the glass surface dull.





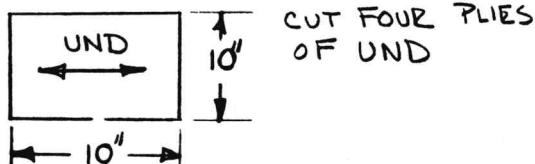
SANDING FLOX CORNER



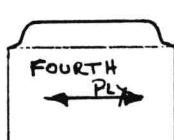
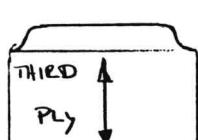
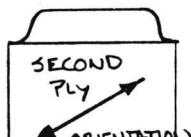
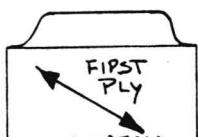
Knife trim the edges. After 12-hour cure, sand the edges with 100-grit sandpaper as required for smoothness and good appearance.



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.



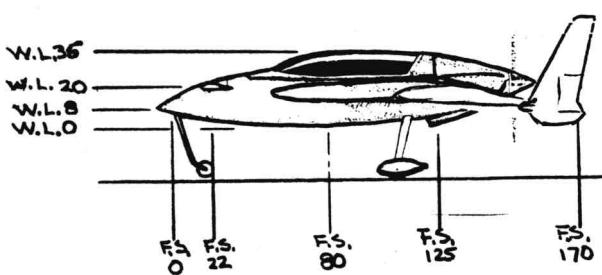
Mix RAEF, a small batch of flox, and a small batch of micro slurry. Fill the corner with flox and slurry the foam. Lay up the four UND plies with the orientation shown.



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 Long-EZ 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.

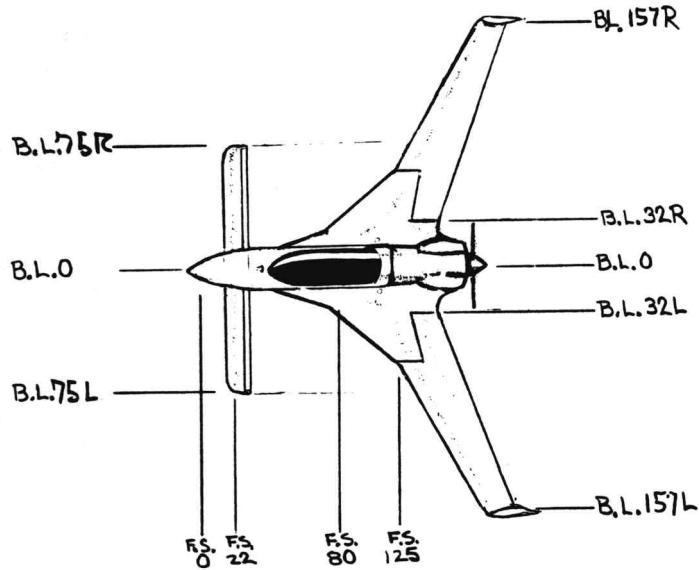
The three basic references are called butt lines, fuselage stations, and waterlines. Don't blame us for the absurd names, we didn't set the system up. All three are given in inches from some arbitrarily chosen reference, so, fuselage station 100 is found 100 inches away from fuselage station 0, and similarly 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 3S, 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. On your Long-EZ the top surface of the fuselage longerons (W.L.23) is used as the vertical reference. 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 define positions inboard and outboard. Butt line zero 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. Fortunately, your Ez is so simple that we don't need to locate very many things this way. When you start on your 4/5-scale replica of a C-5A, this reference system will be real handy.

ATMOSPHERIC CONDITIONS

Temperature has the greatest effect on the working properties of your epoxies. 75 degrees farenheit is an ideal temperature. The range from 60 to 90 is acceptable with the precautions mentioned in the section on 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.

A pneumatic riveter is not required to build your Ez. 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).

Due to limitations of the printing process used, several of the full size drawings are broken down to more than one sheet. To assemble your full size drawing, trim the edge off one sheet as shown and glue it to the adjacent sheet, lining it up carefully at the lines shown. Be careful to keep all waterlines perfectly straight.

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 it 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 Bondoed or clamped to the surface 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 Ez wing or 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 temperature 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.

- 2.2 Structural Approach
 The basic structure throughout the design is a composite sandwich of load bearing fiberglass skins separated by a light-weight 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. and 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. Interlaminar 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.

Interlaminar voids (air bubbles) up to 2 inches in diameter are acceptable when repaired as follows: A small hole is drilled into the void and epoxy is injected into the void area. Small voids such as this may occupy up to 5% of the laminate surface area.

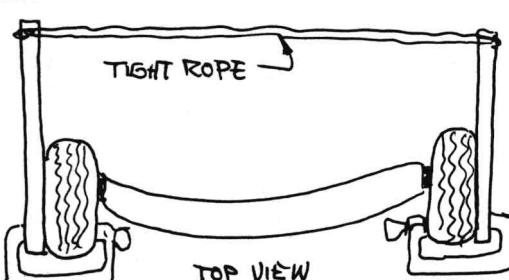
Voids greater than 2 inches in diameter should be repaired as shown in paragraph 4.

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, a 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 grounds for rejection.

3.5 Fiber disruption
 In all instances, it is good practice to have the glass fibers lying 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.



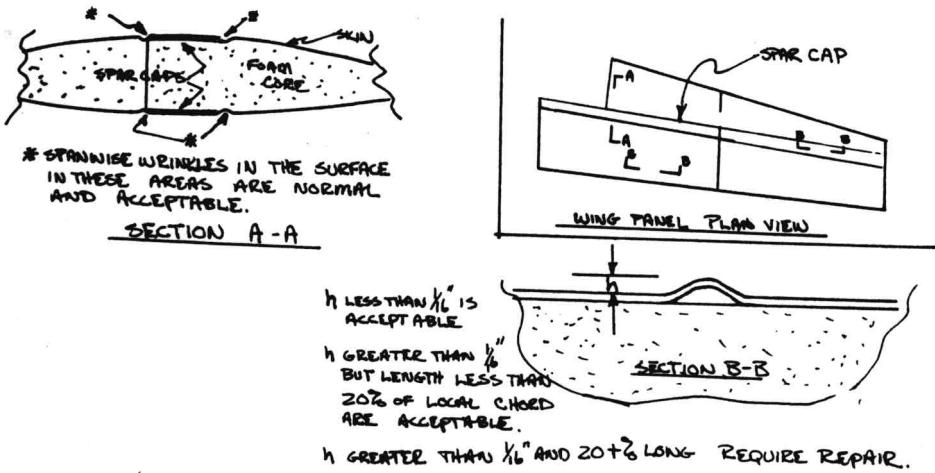
AMATEUR-BUILT LONG-EZ INSPECTION CRITERIA

1.0 Scope
 This document has been prepared to assist inspection personnel by providing recommended acceptance criteria and acceptable repair practices for the Long-EZ 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 Long-EZ 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 Long-EZ 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. The aircraft is considered to be a utility category aircraft. Long-EZ builders are being supplied with a complete owner's manual which specifies all placards, operating limitations, normal & emergency operations, flying qualities, maintenance specifications, inspection procedures, & initial flight test procedures.

CONTINUED →



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 occurred 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 Long-EZ and VariViggen SP composite sandwich structures.

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

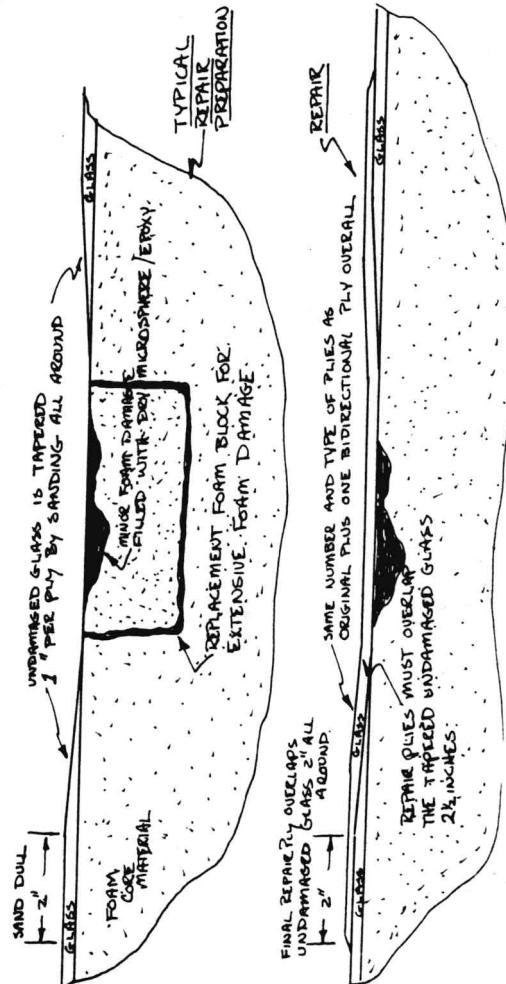
A delaminated joint should be spread, the mating surfaces sanded dull, gap filled with flox (epoxy/flocked cotton mixture), then clamped shut while it cures.

5.0 Materials

Since a wide range of similar appearing materials exists which exhibit substantial differences in physical (structural) properties, Rutan Aircraft Factory 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 Long-EZ design, and could adversely effect flight safety.

6.0 Applicability

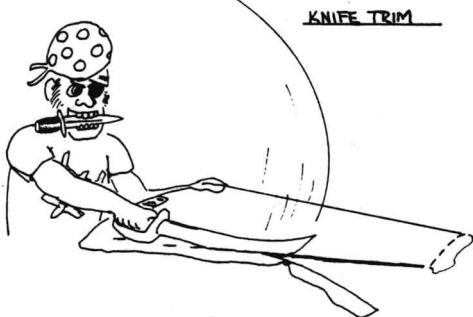
These acceptance criteria are different from and, in some cases, much looser than for similar structures found in sailplanes and other contemporary composite structures. These criteria apply only to the Long-EZ and VariViggen structures. Design safety factors in excess of three enable somewhat relaxed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



END OF INSPECTION
CRITERIA

Education Supplement

Rip this page out of your plans and staple it to the wall of your shop. While it is a handy reference, it's still a good idea to read all the words in the education chapter once in awhile. Don't skip the details - they're all important.



URETHANE FOAM SHAPING

BASIC TOOLS: Sharp butcher knife, sanding block, surfacing file, wire brush and blocks/scraps of urethane. Use a dust mask. Hack away, have fun.

HOT WIRE CUTTING STYROFOAM

Hot wire tool has two lengths: 62" for wings and 43" for winglets, canard and elevators. Wire must be tight. The adjustable voltage control is best, but the job can be done with 2 12-volt, 6-amp battery chargers or 12-volt car batteries. Foam block must be well supported and weighted. Templates must be nailed on tight. First cut the basic block to size; this determines the planform size and shape. Level the template level lines; this determines correct twist. Set hot wire temperature for about 1" travel through the foam in about 4 to 6 seconds with light pressure. Do the actual cutting at about 1" every 6-7 sec. (8-10 sec. around the leading edge). Practice on scraps first.

HARDWARE SKETCHES

AN3 3/16" dia bolt AN509
AN4 1/4" dia bolt flush head screw washer head screw
AN525

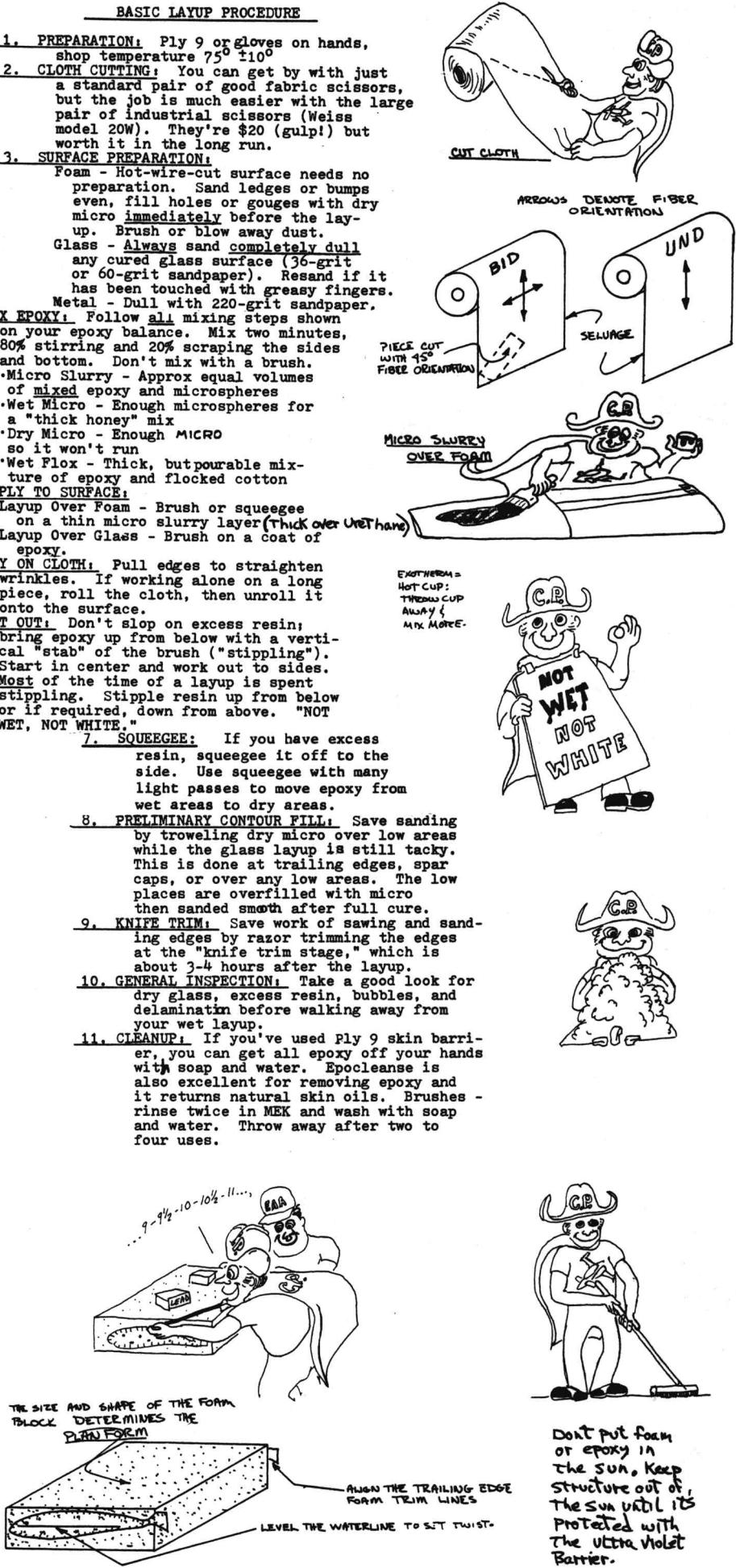


all metal lock nut plain washer wide washer
MS21042 AN960 AN970



BASIC LAYUP PROCEDURE

- PREPARATION:** Ply 9 orgloves on hands, shop temperature 75°-110°
- CLOTH CUTTING:** You can get by with just a standard pair of good fabric scissors, but the job is much easier with the large pair of industrial scissors (Weiss model 20W). They're \$20 (gulp!) but worth it in the long run.
- SURFACE PREPARATION:**
 - Foam - Hot-wire-cut surface needs no preparation. Sand ledges or bumps even, fill holes or gouges with dry micro immediately before the lay-up. Brush or blow away dust.
 - Glass - Always sand completely dull any cured glass surface (36-grit or 60-grit sandpaper). Resand if it has been touched with greasy fingers.
 - Metal - Dull with 220-grit sandpaper.
- MIX EPOXY:** Follow all mixing steps shown on your epoxy balance. Mix two minutes, 80% stirring and 20% scraping the sides and bottom. Don't mix with a brush.
- APPLY TO SURFACE:**
 - Layup Over Foam - Brush or squeegee on a thin micro slurry layer (thick over urethane)
 - Layup Over Glass - Brush on a coat of epoxy.
- LAY ON CLOTH:** Pull edges to straighten wrinkles. If working alone on a long piece, roll the cloth, then unroll it onto the surface.
- WET OUT:** Don't slop on excess resin; bring epoxy up from below with a vertical "stab" of the brush ("stippling"). Start in center and work out to sides. Most of the time of a layup is spent stippling. Stipple resin up from below or if required, down from above. "NOT WET, NOT WHITE."
- SQUEEGEE:** If you have excess resin, squeegee it off to the side. Use squeegee with many light passes to move epoxy from wet areas to dry areas.
- PRELIMINARY CONTOUR FILL:** Save sanding by troweling dry micro over low areas while the glass layup is still tacky. This is done at trailing edges, spar caps, or over any low areas. The low places are overfilled with micro then sanded smooth after full cure.
- KNIFE TRIM:** Save work of sawing and sanding edges by razor trimming the edges at the "knife trim stage," which is about 3-4 hours after the layup.
- GENERAL INSPECTION:** Take a good look for dry glass, excess resin, bubbles, and delamination before walking away from your wet layup.
- CLEANUP:** If you've used Ply 9 skin barrier, you can get all epoxy off your hands with soap and water. Epocleanse is also excellent for removing epoxy and it returns natural skin oils. Brushes - rinse twice in MEK and wash with soap and water. Throw away after two to four uses.



MINIMUM RADIUS FOR GLASSING OUTSIDE CORNERS



Fibers at 90° - 3/16" radius



Fibers at 45° - 1/8" radius

QUALITY CONTROL CRITERIA/REPAIRS

See the Education section