SECTION 2:

Laminating Procedures

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2.010 INTRODUCTION

WHAT IS FIBERGLASS

Fiberglass is produced by drawing single fibers of molten glass into very small diameter strands or filaments.
These are then wound together to form larger strands. The larger strands are then woven or combined to form various types of cloth.

WHAT IS RESIN

Resin is a type of structural adhesive. The resin used on the ***EXPRESS*** is a type called Vinyl Ester, which is manufactured by Dow Chemical Company. When cured it has very high strength, and is safe and easy to use.
Vinyl Ester is a multipart resin system because chemicals are added to it to cause it to cure.

THE FIBERGLASS/RESIN LAMINATE

The interface of the fiberglass to resin creates the stronger, lightweight material required in aircraft structure.
The fiberglass cloth layers are built up and saturated by resin, which is then allowed to cure. This is a fiberglass laminate. The resin carries the load from the fibers into any adjacent structure, thus distributing the load evenly within the structure.

THE FIBERGLASS/FOAM SANDWICH

When a piece of thick, low-density core material is faced on both sides with a high strength skin, a structural sandwich is created. A sandwich is simply the ultimate that can be obtained in efficiency for structural members that must carry loads. The EXPRESS has many parts made from a sandwich of polyurethane foam core of varying thickness and densities, and a fiberglass laminated skin.

2.020 ALL ABOUT FIBERGLASS

The following list describes the materials and their uses for building the ***EXPRESS***.

1. **Bi-directional cloth (Bid)** - fiberglass cloth woven with an equal number of strands at 90' to one another. The most frequently used cloth for laminating parts.

2. **Unidirectional cloth (Uni)** - fiberglass cloth with the strands going in one direction, and a few strands at 90' to hold it together. Occasionally used, when high strength in one direction is required.

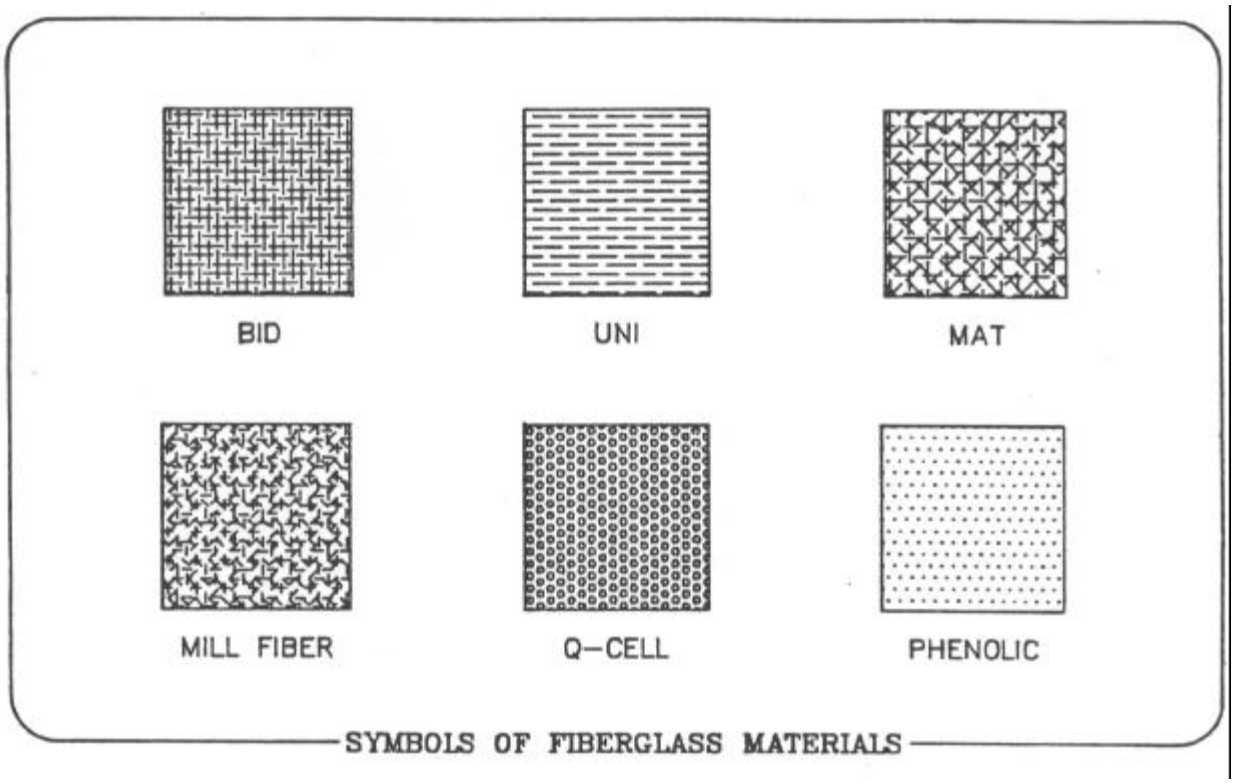
3. **Chopped strand mat (Mat)** - fiberglass cloth made from many short strands of glass laid in all directions.

4. **Milled fiber (mill fiber)** - fiberglass strands processed into very short glass fibers. When mixed with resin, it forms a paste-like substance which is used as a filler when structural strength is required.

5. **Q-cell** - special type of microspheres, or very small hollow quartz bubbles. When mixed with resin, they form a lightweight substance, which is used frequently as filler, but has no strength.

6. **Phenolic** - Many sheets of linen or other material, laminated together under high-pressure and heat. This creates a part with the hardness and strength of metal, but with the ability to bond well to other fiberglass materials.

The following symbols are used to represent these materials throughout the assembly manual.

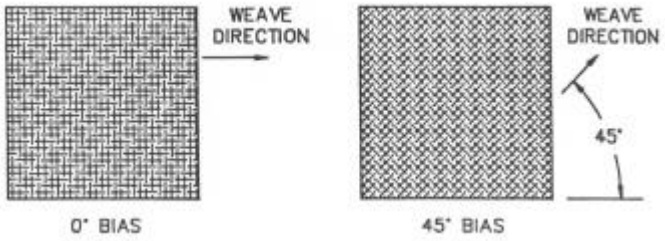


SYMBOLS OF FIBERGLASS MATERIALS

FIBERGLASS CLOTH

The strength in fiberglass cloth is in the direction of the weave. The term used to refer to the orientation of cloth in relation to its weave is bias, which is measured in degrees from the direction of the weave.

Bid has half of the weave in one direction, and the other half at 90', giving the cloth the same strength in both directions. It is usually layed up on a 45' bias for strength considerations. This also allows easier lay-up onto contours and angles, and prevents cloth separation on edges. Occasionally bid is laid on a 0' bias.

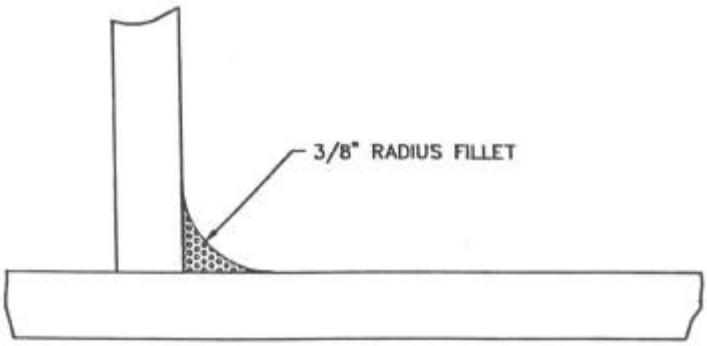


Uni has 95% of the weave in one direction, giving it exceptional strength in that direction and very little at 90' to it. The few strands in the other direction are just to hold the cloth together. Because of this, Uni is almost always layed up on a 0' bias. It is used when strength is required in one direction only, such as in a spar cap or gear leg.

Mat has strands going in all directions, giving it equal but minimal strength in all directions, so it has no bias. Mat is normally used to absorb resin when 2 large areas are being joined and no other method of lamination is possible, such as the wing skin closeout.

Q-CELL AND MILL FIBER RADII

When bending fiberglass cloth onto 2 parts that intersect, the cloth will not bend sharply where the surfaces meet. A radius-filler is used to form a concave junction along this intersection. You will form a 3/8" radius of filler. 0-cell is used most frequently as a radius-filler, and does not have structural strength. Mil fiber is used occasionally, when strength is required from a fillet.



FIBERGLASS STORAGE

Fiberglass products should be stored so they will be kept clean and free from water and humidity. Fiberglass that is dirty, or has been wet, must not be used. The best storage for fiberglass is a closet with a door.

2.030 ALL ABOUT RESIN

THE RESIN SYSTEM

The Vinyl Ester resin system used in the EXPRESS was chosen for various reasons. Some of these reasons apply to its use in other industries. For example, storage tanks for fuel and other chemicals are made with Vinyl Ester, because it has excellent chemical and corrosion resistance properties. Fiberglass reinforced pipe is made with it due to its strength and ability to adhere to glass. We also prefer Vinyl Ester because it is less toxic, easier to mix, and to apply than some other resins.

Vinyl Ester is quite different from the epoxies or glues found in hardware stores. Its formulation is for special applications like the aerospace industry, where there is more quality control.

Vinyl Ester consists mainly of a base resin. A catalyst is added which causes a chemical reaction in the resin, causing it to eventually cure.

RESIN CATALYST

Resin is catalyzed with methyl ethyl ketone peroxide (MEKP) to cause gelation and then final curing. Because gelation and cure occurs so quickly, only small batches of resin are catalyzed, just prior to lay-up time.

The following list describes the various stages that resin goes through after being catalyzed.

1. **Working Time** - the amount of time after the catalyst is added before the start of gelation. The only time the resin can be applied. Usually anywhere from 10 to 90 minutes.

2. **Gel** - the resin begins to change from a liquid to a solid.

3. **Exotherm** - energy in the form of heat is released as a result of the chemical reaction. The hardening process increases rapidly because of the heat.

4. **Cool** - after the exothermic reaction ends, the resin cools.

5. **Green Cure** - when the resin is hard or stiff enough to allow trimming of excess cloth with a knife. Usually obtained from 15 to 45 minutes after gelation, depending upon temperature.

6. **Initial cure** - the laminate gains approximately 75% strength, usually reached from 16 to 24 hours.

7. **Final cure** - the laminate gains full strength, reached in 3 to 4 days at 740 F.

WORKING TIME OF RESIN

Working time is the time after the catalyst is added, and before the start of gelation. This is the only time the resin can be applied successfully.

The ratio of catalyst is the primary factor in determining the working time of resin. Listed below are other factors that can affect the working time.

The following factors can increase working time:

1. Cooler room temperature.
2. Cooler resin temperature.
3. Wind or breeze.

The following factors can decrease working time:

1. Warmer room temperature.
2. Warmer resin temperature.
3. Large batch size.
4. Thick laminates.
5. Direct sunlight.

The Resin/Catalyst Ratio chart gives the approximate working times at different ratios. It does not take into account other factors that may affect the working time. The Medium catalyst ratio is recommended for most lay-ups. The Slow ratio may be used when first learning the lamination process, when the lay-up is large, or when the conditions are Indeterminate. The Fast ratio should only be used when the builder is proficient at laminating, and when the lay-up is small.

When working with resin, always be aware of the time elapsed, and the estimated working time. A cooking timer is a good method to track time.

GELATION OF RESIN

When a batch of resin begins to gel, it will develop a paste-like consistency for approximately 2 to 3 minutes, and then suddenly solidify.

When the resin begins to gel, it will become unworkable on cloth, but there will still be enough time to save the brush with acetone solvent. When the resin starts to gel, acetone loses its effectiveness to dissolve it, so be sure clean-up is accomplished before the resin gels.

BATCH SIZES OF RESIN

The manual will give the recommended total batch size for each procedure, as determined by the sizes of the lay-ups. When you become more proficient with resin use, you will be better able to estimate the amount of resin required.

There are several reasons for using small quantities of resin. Small batches limit the area that can be saturated with resin, so more time is allowed to do a good job before the resin gels. If a large area must be layed up, divide it into sections of small batch sizes. This way the resin will gel in sections. The next area can be worked even if the previous area starts to gel. This way the builder never gets ahead of himself.

RESIN STORAGE

Resin should be kept at room temperature when used. It can take several hours to heat resin to the proper temperature, so if your shop is not kept heated, provide a separate heat source for the resin. A good method is to store it inside a locker or closet with a light bulb.

CAUTION

The materials used in fiberglass construction are highly flammable, especially the acetone and catalyst. Keep them away from direct sunlight, heat, sparks, and open flame. Keep track of all materials and store in a cool, clean, well ventilated area. Make sure all containers are sealed when not in use.

CATALYZING RESIN

Use discretion when determining the mixing ratio of resin to catalyst. First determine the batch size required. Then estimate the amount of time required to complete the lay-up. Use the Resin/Catalyst Ratio chart to determine the amount of catalyst required. Also take into account the temperature of the shop, and the other factors that affect working time.

CAUTION

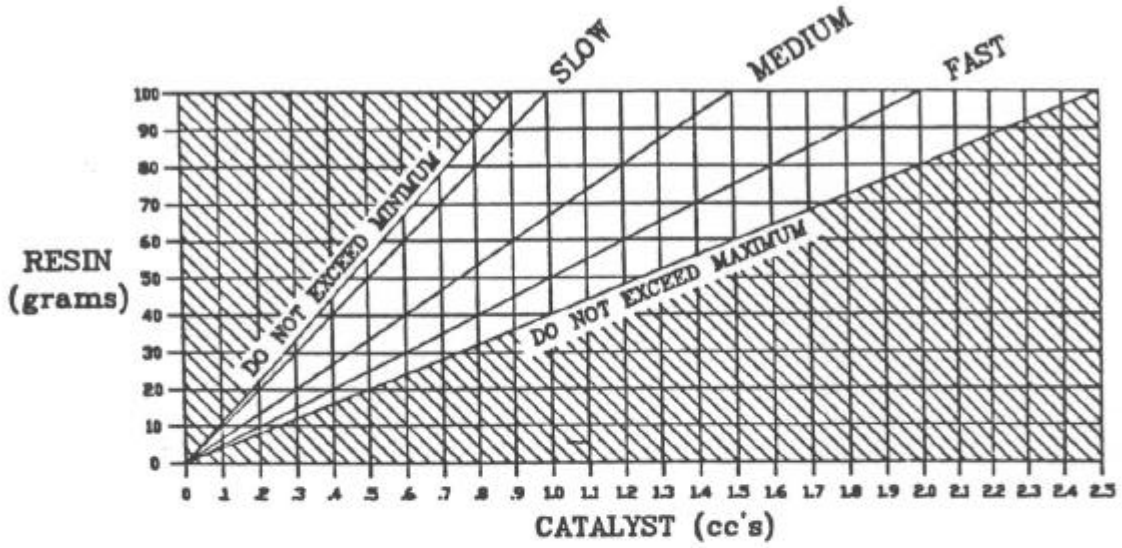
Under no circumstances should you go under the minimum or exceed the maximum amount of catalyst. If so, the lay-up could suffer a reduction in strength.

When mixing the catalyst with the resin, be accurate. Also, wear eye protection and be extremely careful when mixing it with the resin.

CAUTION

MEKP CATALYST - Keep away from fire. Harmful or fatal if swallowed. Harmful if inhaled. Severe eye irritant.
One drop in the eye will cause blindness, unless eye is washed within a few seconds after contamination. Safety glasses are required when mixing resin. Keep any eyewash bottle filled with clean water at the resin mixing station. In case of eye contact, immediately flush with plenty of clear water, and see a physician. Store in original closed container in a cool location. Protect from direct sunlight, heat, sparks, and open flame. Do not add to hot materials. Prevent contamination with foreign materials. When the container is emptied, it must be destroyed, and must not be reused for any purpose. Failure to observe these precautions may result in explosive decomposition.

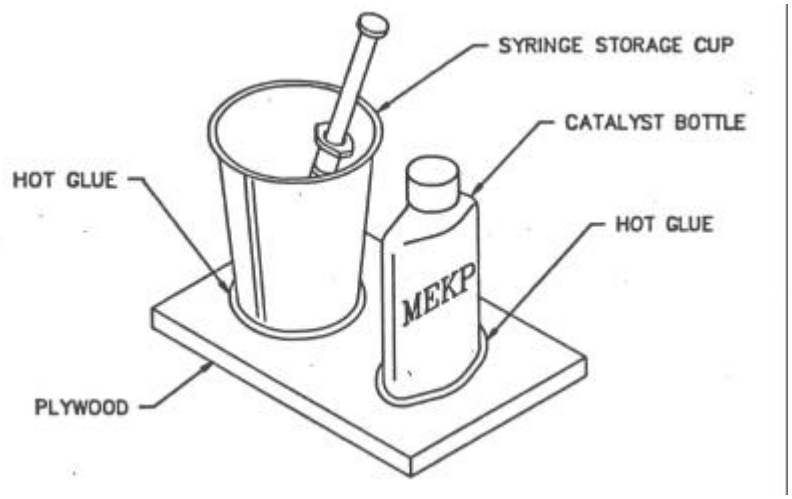
RESIN/CATALYST RATIO CHART



	SHOP TEMPERATURE (F)			
	50°	60°	70°	80°
CATALYST %				
SLOW	65	55	30	15
MEDIUM	45	30	20	10
FAST	35	20	15	10 or less
	APPROX WORKING TIME (minutes)			

Before using the catalyst, hot glue the catalyst bottle and an unwaxed cup to a 4" x 6" piece of plywood. This will stabilize the bottle when using the syringe, and give you a cup to store the empty syringe.

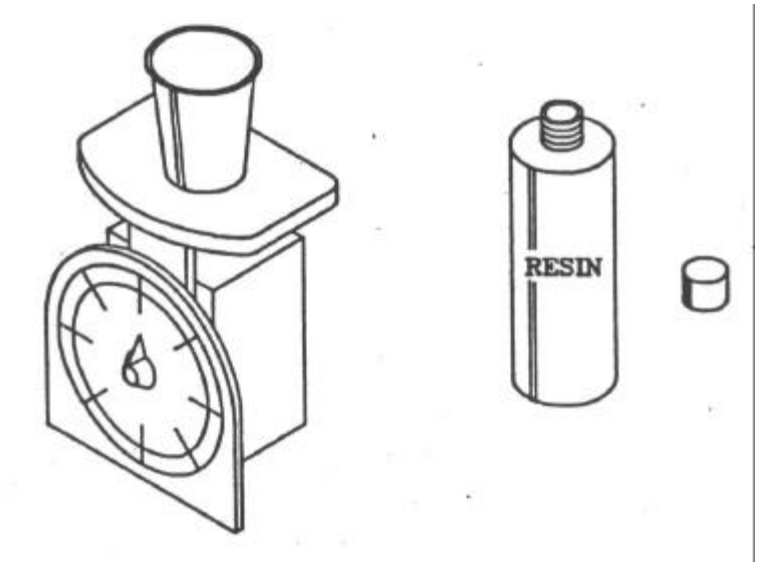
When storing the syringe, always leave it partially open, so the plunger tip does not stick. The syringe should also have scotch tape over the ink, to prevent contaminating the catalyst. Keep the catalyst bottle capped at all times, when not in use.



Start by placing an unwaxed paper cup on a gram scale. Set the scale to 0, and pour the required amount of resin into the cup.

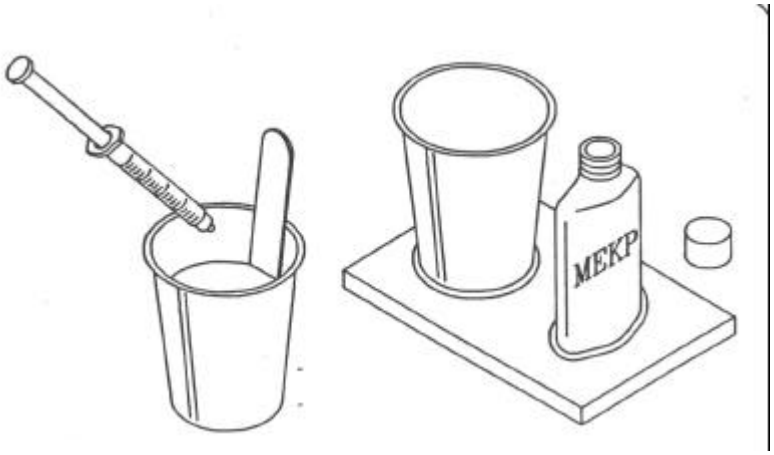
CAUTION

Do not use a waxed container as a resin-mixing vessel.
The wax will contaminate the resin and parts.



Using a syringe marked in .10 cc increments, carefully measure the amount of catalyst, and gently squirt it into the mixing cup. Immerse only the tip of the syringe, not the barrel. Use a wooden tongue depressor with one end cut square to stir the resin. This allows you to scrape the corners of the cup.

Stir gently but thoroughly, scraping the sides and bottom of the clip. The mixing should take approximately 30 to 60 seconds. Mixing should be done to entrap the least possible amount of air. After mixing let the resin sit 15 to 30 seconds to allow air bubbles to escape.



Set a timer to track the elapsed time, keeping in mind the estimated working time. After the lay-up is complete, there may be some residual resin in the cup. Do not set the cup on a fiberglass part, because the heat caused by the exothermic reaction in the cup could damage the part. The cup can be reused for future resin batches, only after the residual resin has cured.

CAUTION

Do not reuse the container until the resin in it has cured, because the leftover uncured resin will upset the gel time of the next batch.

PREPARATION FOR WORK

Before you start working with fiberglass, always plan ahead. some lay-ups may take several hours, so before getting your hands in the resin, a visit to the restroom is in order. Make sure your shop is clean, and all your tools are clean and easily accessible.

Your shop should be heated to the proper temperature, and well ventilated. The temperature can range from 50 to 80, but a good rule of thumb is a room temperature that you are comfortable working in. Wear latex gloves for skin protection when working with resin, and wear old clothes, coveralls, or a shop apron.

All surfaces, which are to be bonded, except those that have peel plied finishes, must be prepared prior to bonding. First, wipe the surfaces with acetone, using a 100% cotton, clean, un-dyed rag. Then, lightly sand with #80 grit sandpaper.

An example of a surface, which has a peel plied finish, is any rib face. The web of the main spar is an example of a surface, which is not peel plied.

CAUTION

Contact of resin with fingers and hands poses no serious problem, but prolonged contact should be avoided. Wear tight fitting latex medical gloves to avoid any contact with skin.

CAUTION

The strong vapor smell of the resin before it cures is from the styrene in the resin as it evaporates away. Always laminate in a well-ventilated area. High concentrations of styrene in small, enclosed areas may cause nausea. Avoid breathing these vapors when high concentrations exist. We recommend the use of a vapor spray mask. We also recommend that construction be done in a garage or area separate from living quarters because of the vapors present.

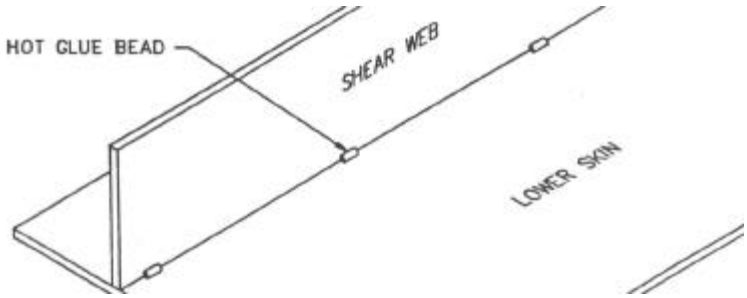
FITTING AND ATTACHING PARTS

The composite parts in the kit are precision cut by computer controlled equipment for a very accurate fit. However, due to the nature of the materials and processes, there may be times when a part does not fit as well as required. Before attaching a part, place it in its location and check for gaps or interference. Most parts will have a location line inscribed into the mating part, or directions on locating the part. If the edge of a part needs trimming, use a sanding block or sandpaper, and carefully remove only what is necessary.

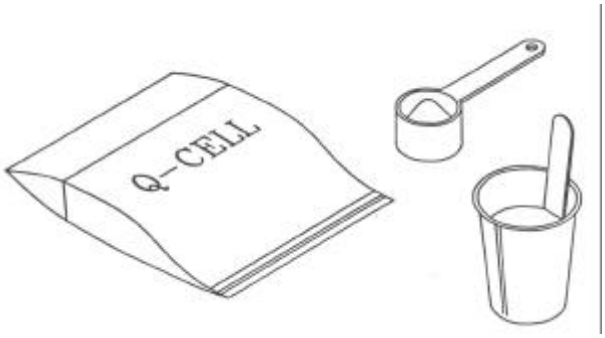
CAUTION

Avoid breathing the fiberglass particles while sanding fiberglass. We recommend the use of a non-toxic particle mask.

After the part fits correctly, it can be attached. To do this use hot glue. Place the part in the correct location, and level it vertically with a bubble level if required. While holding the part, use a skip 'welding' technique to glue it in place along the intersection of the parts. This consists of short beads of glue, no greater than 1/8" in diameter, and 3/8" long, spaced 6" apart.



MIXING AND APPLYING Q-CELL

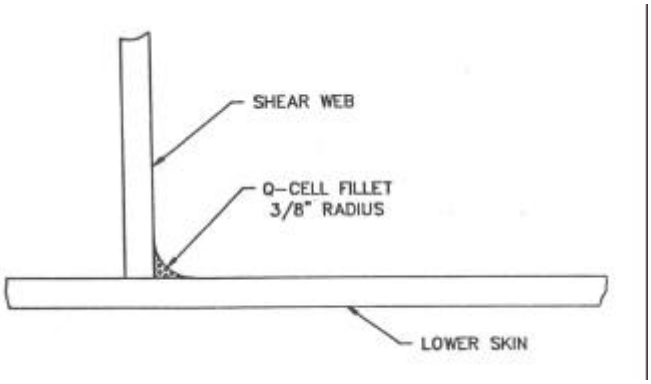


To mix Q-cell, measure the amount of resin required in a mixing cup, and add the proper amount of catalyst. Carefully add small amounts of Q-cell powder to the batch of resin and stir. Keep adding small amounts until a thick consistency is achieved, **that will not sag or run.** The best way to test this is to scoop some onto the end of the stir stick and hold it at a steep angle. The mixture should not run down the stick at all.

CAUTION

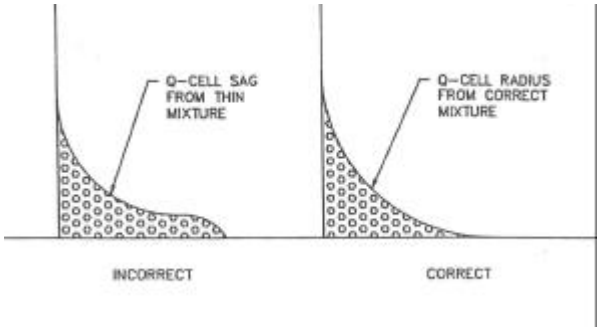
When mixing Q-cell, wear a particle mask and keep your face away from the balloons that may float up into the air. They can irritate your eyes or lungs.

Use a stir stick to apply Q-cell to the inside corner intersections. The stick should have a 3/8" radius at the end. Scoop the Q-cell mixture into the intersection, and hold the stick at a slight angle while running it along the intersection to produce a 3/8" fillet of Q-cell. If any voids develop, add more Q-cell mixture. Smooth the fillet as much as possible, and scrape any excess off to avoid excessive sanding later.

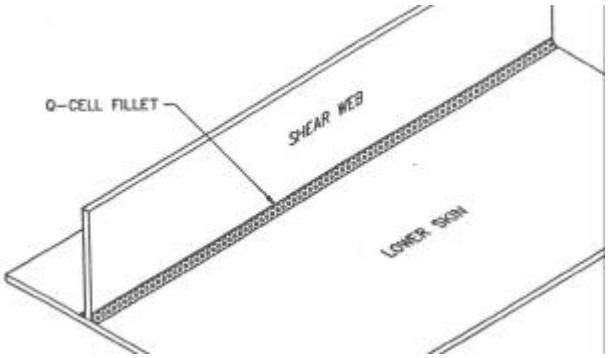


MIXING AND APPLYING MILL FIBER

To mix mill fiber, measure the amount of resin required in a mixing cup, and add the proper amount of catalyst. Add small amounts of mill fiber material to the batch of resin and stir. Keep adding small amounts until a thick consistency is achieved, **that will not sag or run.** The consistency should be thick enough to stay on a wooden tongue depressor without running off, although still be fully saturated with resin.



Use a stir stick to apply mill fiber to the inside corner intersections. The stick should have a 318" radius at the end. Scoop the mill fiber mixture into the intersection, and hold the stick at a slight angle while running it along the intersection to produce a 318" fillet of 0-cell. If any voids develop, add more mill fiber mixture. Smooth the radius as much as possible, and scrape any excess off to avoid excessive sanding later.



CUTTING FIBERGLASS CLOTH

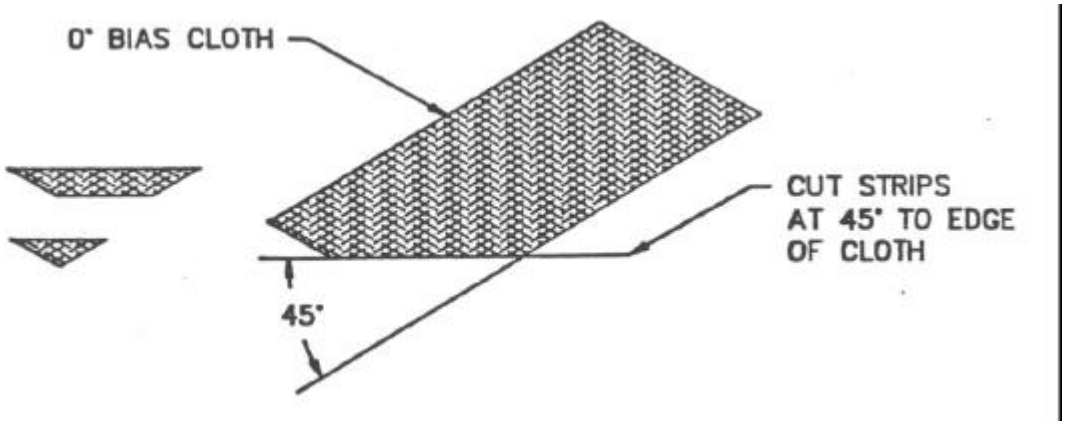
Each layer of cloth, or ply, has to be marked and cut to the dimension required. This should be done on a clean, smooth surface, with clean hands and clean tools. You will need a sharp pair of scissors, a felt tipped marker, a straight edge, and a tape measure the small amount of ink from marking on the cloth has no detrimental effect.

Each procedure in the manual lists the type of cloth, the quantity and width of each ply, and which bias to use. The most common type of lay-up you will do use narrow strips of bid cut on a 450 bias. You will stretch the ply out slightly before laying it up, so it does not stretch during the lay-up. When bid is stretched in one direction, it shrinks in the other direction. In this case, cut full-length strips, slightly wider than required (i.e. cut 3" wide for a 2" finished width). Hold the ply up to the seam to be laminated, and stretch it gently to the finished width. Now mark the desired length and cut it.

When a 45' bias is called for, it is not critical to measure the 45' angle exactly. Your estimation of an approximate diagonal is adequate when cutting and laying up he cloth.

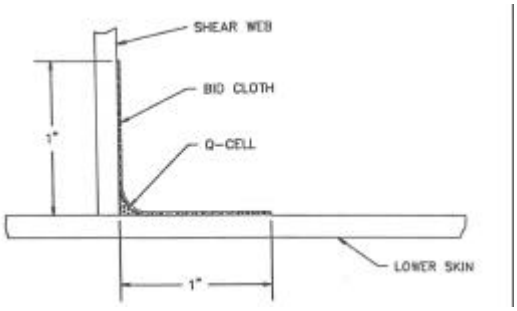
When cutting wide pieces of bid, or cutting Uni or mat, the cloth are not stretched. The bid pieces that fall into this category will be noted during the procedures. In these cases, lay the cloth out flat, mark and cut it to shape without distorting it.

If several plies are cut at once, it may help to number them with a marker before cutting. Save any clean scraps - they will come in handy for small lay-ups.

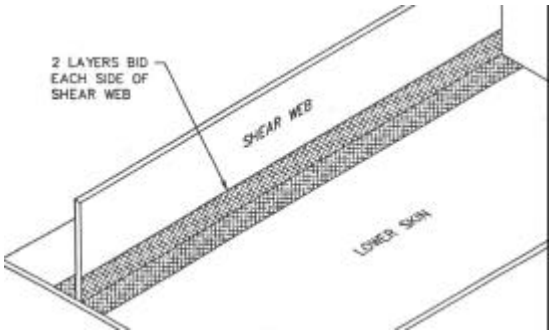


LAYING FIBERGLASS CLOTH

Prior to laying down the first ply, apply a coat of resin with a brush, onto the area to be laminated. This helps prevent air bubbles from forming under the cloth. Laying the cloth down on a dry surface will create air bubbles and make saturation time longer.



Lay the cloth down as neatly as possible, making sure it is centered on the seam or part and in the specified orientation. When laying up a long piece, it is best to roll it up, apply it to one end of the part, and unroll it onto the part. Pull the edges to straighten the cloth and to remove wrinkles. Maximum strength and stiffness is obtained if the cloth is not wavy or wrinkled. To remove wrinkles, study the direction of the fibers, follow the fibers to the outer edge of the cloth, and pull on the cloth. Do not push a wrinkle off the part, or the cloth will bunch up. When the ply is free of wrinkles, lightly squeegee or brush from the center outward to smooth the part.



If the area to be layed up is small, the ply can be cut oversize for ease in handling. As you wet out each ply, scissor trim it to about 1/2" of any overhang. This should be trimmed off with a knife when the part reaches green cure.

Once the cloth has been layed down, resin is added to saturate it. The proper amount of resin to be applied when saturating the fiberglass cloth is described as when the cloth looks wet, rich in color, but is without puddles or dry spots. The cloth pattern should still be visible on the surface and not glazed over with excess paddled resin. White, or pale dry areas need more resin. Once the laminate begins to cure it is too late to add more resin to touch it up.

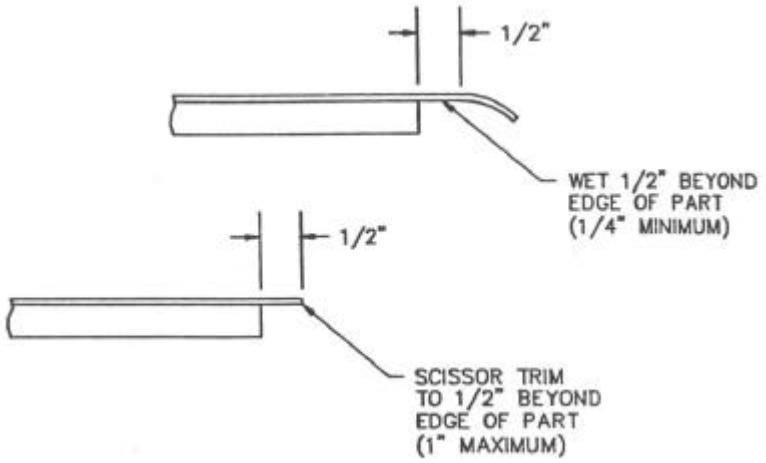
CAUTION

If a part gels before it is adequately saturated it must be reworked. You may be able to peel the layer off if you do so immediately. Otherwise, remove the unsaturated layer by sanding with rough sandpaper after it has cured. <u>Do not sand into the previous layer.</u> Once the layer(s) has been removed, vacuum the area and continue.

Apply the resin with the brush being careful not to put too much resin on, because excess resin is difficult to remove.

Now spread the resin out so the entire piece of cloth is wet. This can be done with a brush or a squeegee. Normally a brush is used in small areas or corners. The majority of the lay-ups on the EXPRESS fall into this category. In larger flat areas, a rubber squeegee can be used. Spread the resin out using medium pressure, raking across the surface of the cloth. If too much resin exists, the laminate will float. Be careful not to shift the cloth on the part when raking.

If the ply was cut oversize, and extends beyond the edge of the part, wet it 1/2" beyond the edge of the part (a minimum of 1/4"). Scissor trim it to 1/2" (a maximum of 1") so the cloth can be trimmed with a knife after green cure.



Once the cloth is wet, excess resin must be worked out of the lay-up. When using a brush, wipe the brush over the edge of a cup several times to dry it, then soak the excess resin up with the tip of the brush. In larger flat areas, a rubber squeegee can be used to remove excess resin, and is usually more effective than a brush. Apply just enough pressure to move any excess resin to the edge of the ply, without moving the cloth. When a puddle of resin develops, scoop it up with the squeegee and return it to the cup. When the resin can no longer be scooped, use a brush to remove it.

During the saturation process, air bubbles or air pockets may develop underneath the cloth. Air bubbles in a laminate detract from its strength and corrosion resistant properties. If the air bubble is excessively large, and trapped between plies, delamination can occur. The area looks like an air bubble, is slightly lighter in color than the surrounding area, and is distinctly visible even deep in a cured lay-up.

To remove air bubbles with a brush, use a dabbing or stippling technique. This is a vertical light stabbing motion with the brush. This will cause the air to bleed through the cloth, or when the bubble is larger, it can be worked to the edge of the cloth. When using a squeegee, start in the middle and work the bubbles to the outer edge of the ply. Use firm but not excessive pressure when brushing or squeegee the resin into the cloth. Excessive pressures may fracture existing air bubbles and make them more difficult to remove. Always eliminate all air bubbles from one ply before proceeding to the next ply.
Some procedures will call for the use of a brush extension to reach certain areas, such as in parts of the empennage assembly. The procedure is the same as with a regular brush.

On lay-ups consisting of long narrow strips or large areas, do not wet the entire surface at once. Saturate one section at a time, removing any excess resin, before moving on to the next section. This way the cloth is sure to be saturated before gelation. If a section starts to gel behind the one in work, it is not ruined because it is already completely saturated.

Let each layer become tacky to the touch before applying the next ply. When laying up multiple plies of cloth, there is no need to wet the area again, because the surface will still be wet from the previous layer of cloth. If the previous layer has dried and cured, then the area to be laminated will have to be wetted again to aid in cloth saturation.

APPLYING PEEL PLY

After the final ply has been layed up, you must be sure that all edges are smooth, with no threads of fiberglass sticking up. These will become as hard as pins when the resin has cured. They are referred to as "meathooks" and can really hurt if you get poked by one.

To prevent this, and to give your lay-up that professional look, you can apply a material called peel ply to the edge of the lay-up. We leave this step as an option to the builder, since it is not necessary. The peel ply you will use is a nylon material, and comes on a roll I" wide.

Before applying the peel ply, the last ply must be layed, saturated, and excess resin removed. Unroll the peel ply and hold it up to the edge to be treated, and cut it to length. Then smooth the strip of peel ply onto the edge with your fingers, so it is centered. After the resin from the lay-up has reached green cure, the peel ply can be removed. Pick up one end of the ply, and peel it off the part.

CAUTION

Do not apply peel ply to intermediate layers of fiberglass. If unintentionally left on between plies, it will cause delarnination of the part.

INSPECTING THE LAYUP

After you have finished the lay-up, but before it cures, take a few minutes to give it a good inspection for trapped air, dry spots, excess resin, and delamination. It is much easier to correct these problems while the lay-up is wet than to repair the cured lay-up. Use a good light for the inspection, and view the lay-up from different angles.

Some lay-ups will be more critical than others. If a lay-up is critical, the criteria for quality will be listed in the procedure. Otherwise, use the general rules you have learned for lay-up quality.

The best solvent to use with resin is acetone, which is available at most hardware stores. Acetone loses its effectiveness, as a solvent when the resin begins to gel, so be sure to start cleanup before the resin starts to gel.

Use acetone for cleaning resin from brushes, squeegees, hands, etc. If the resin begins to gel while still on the brush, the brush may be ruined if not immersed in acetone immediately.

CAUTION

Acetone is highly flammable. It is harmful to the eyes and skin and should not be inhaled. It is also poisonous if swallowed. Read all safety precautions on the container.

Care should be taken when disposing of the catalyzed resin. An exothermic reaction is set in motion when catalyst is mixed with resin. Enough heat can be generated in this reaction to cause a fire under the right conditions, depending upon the depth of the resin in the mixing vessel and the amount of catalyst used.

CAUTION

Do not put catalyzed resin near flammable objects or in the trash until it has gelled, exothermed, and cooled. Fire or explosion may result.