# BASIC COMPOSITE CONSTRUCTION . . .

## Continued

BY RON ALEXANDER

Over the past few months we have discussed most aspects of building a composite airplane. This article will focus on a few specific items that require explanation such as proper preparation of parts prior to bonding, post-curing, blushing problems, etc.

### PREPARATION OF COMPOSITE PARTS

In the last issue, I outlined a brief procedure for preparing composite parts prior to bonding. This step is most important and needs to be amplified. The quality of a bond is directly affected by the preparation of the two parts being joined together. If contamination exists on either part, the bond may be weakened even to the point of subsequent failure. Let me emphasize that you should follow the directions found in the kit manufacturer's manual regarding proper cleaning techniques. However, the preparation procedure is important enough to warrant more detailed discussion.

First of all, when bonding to an outside mold surface (such as many of the parts you receive from the kit manufacturer) cleaning and sanding of the parts is always required. When aircraft parts are molded, a release agent is applied to the inside of the mold itself allowing the part to be removed when cured. This mold release agent must be removed prior to any bonding activity. The agent is barely visible. Water will usually remove this agent. After removal of the agent and any contaminants, sanding is then accomplished.

Any surface that is smooth because of being next to a mold must be sanded prior to bonding. Any primer that may be present must also be removed. Sanding is generally the accepted way to prepare the surface. Opinions vary on the proper grit of sandpaper to be used. Usually 80 grit to 180 grit is recommended. Our workshop experience has shown that 180 grit sandpaper is usually satisfactory to prepare the surface. Use of 180 grit will ensure the underlying fibers are not damaged or cut. The surface should be thoroughly abraded (roughed) to completely remove any glossy areas.

Abaris Training, located in Reno, Nevada, instructs the military, airlines and aerospace industry on composite construction and repair. I consult with Mike Hoke, the President of Abaris, regularly concerning composite construction. His company is considered to be one of the leading composite training companies in the United States. The following quote was taken directly from their training manual regarding surface preparation. "High surface energy is the goal, not mechanical roughness. One must shear up the top layer of molecules on the surface, creating many broken bonds, without damaging or breaking underlying fibers. A water break test can be used to determine surface energy. If surface energy is high, clean distilled water will spread out in a thin uniform film on the surface, and will not break into beads. If a water break free surface can be maintained for 30 seconds, one has achieved a clean, high energy surface suitable for bonding. If the surface is contaminated or at low energy, the water will break into rivulets and bead up.

"Note that tap water will not work. It is dirty enough to contaminate the surface itself, and one will never pass a water break test using it.

"It is important to note that the 'high energy"' condition, once achieved, is short-lived. Within about 2-4 hours the effect is lost. In composites, one should therefore wait as late as possible in the process before surface abrasion is performed, so that all else is ready and the adhesive can be quickly applied."

Dry the water off of the laminate with a hair dryer prior to applying the adhesive. If it is wiped with a cloth it will likely contaminate the area again. Do not use a heat gun for this process. The heat is too intense and may damage the cured resin.

This process also applies to peel ply surfaces. Even though a peel ply surface fractures the top layer of resin, it leaves a glossy, low energy surface in the weave pattern of woven cloth. This must be abraded for proper bonding.

So, how should you clean parts prior to bonding? The best procedure is to simply sand the surface, as discussed, and follow by a thorough cleaning with soap and water. If you are using solvents, use them initially to remove contaminants and then abrade the surface. Follow by soap and water and then immediately dry using a hair dryer. Remember to begin the bonding process within a few hours after preparing the surface.

### AMINE BLUSH

Sometimes when working with epoxy resins, you may encounter what is referred to as an amine blush. The development of an amine blush is most visible under high humidity conditions. An amine blush is a surface effect resulting from the curing agent reacting with Carbon Dioxide ($CO_2$) in the atmosphere rather than the epoxy resin. The by-product of this reaction is a compound that forms on the surface of the curing resin and readily absorbs moisture from the air. Under high humidity conditions, it will cause white streaks to appear on the surface of the resin and the uncured laminate. During cure, the white streaks usually disappear, but left behind will be a greasy or oily residue. Sometimes, this residue appears in the form of sweat-like droplets. This residue is water-soluble and will wash off with warm water. Depending on the severity of the blushing event there may even be areas of surface tackiness. This tackiness is only on the surface, and will not affect the overall properties of the cured laminate.

Amine blush must be removed before any additional laminates are initiated. Sanding will remove blush but it will also quickly gum up your sandpaper. Wiping the surface with a warm wet rag prior to sanding will reduce the gumming tendency.

The best approach is to avoid amine blush altogether. Some resin systems are inherently resistant to developing amine blush. And for others, it may seem impossible to avoid it. But there are some things you can do to minimize it greatly. Number one and foremost is, DO NOT use unventilated combustion type heating sources to warm your shop. Gas or kerosene fired salamander heaters produce copious amounts of CO2 and H2O. These are the primary ingredients needed for producing an amine blush. So, use electric heaters or ventilated exhaust type combustion heaters to keep your shop warm.

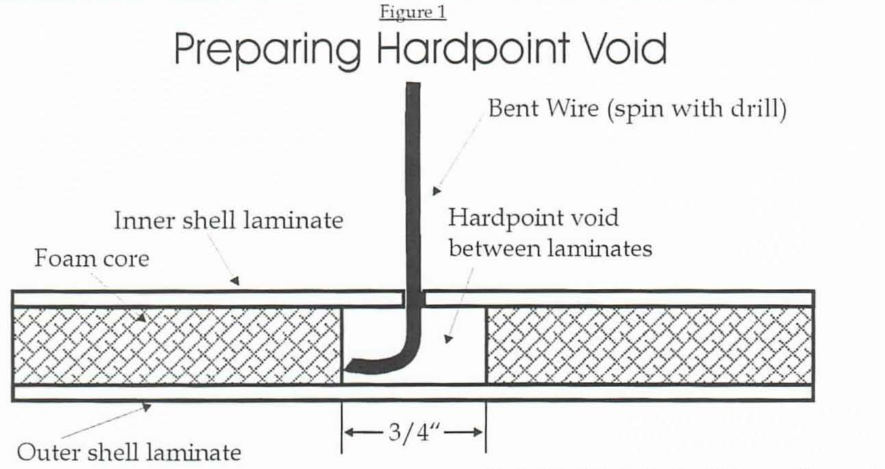
You should avoid mixing resins or doing any layups if the temperature is less than 65 degrees F. If you do a layup at this temperature you should immediately move the part into a warm room for curing. Purchase a thermometer and a humidity indicator and place them in your work area. Avoid mixing resins and working with resins if the temperature is below 65 degrees F or if the humidity rises above 80%. The best solution is to place an air conditioning unit in your workshop area.

You can reduce the susceptibility to blush in the following ways:

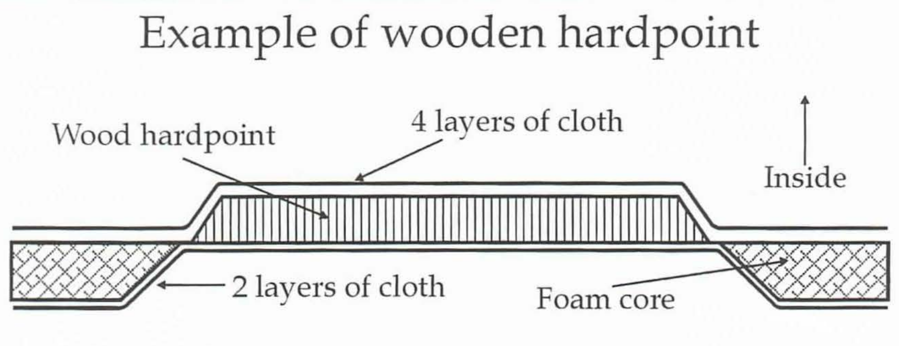
- Work in the prescribed environmental conditions.
- Use "dry" and ventilated heating sources
- Use peel ply. Amine blush usually forms on the outer-most portion of a layup. By using peel ply the amine blush is removed when the peel ply is removed.
- Cap all resins as soon as possible. This reduces their exposure to the elements.
- Use a resin with demonstrated blush resistance. Some resins are more susceptible to blushing than others.

Use of peel ply, purchasing a blush resistant resin, and working in the right temperature and humidity will all work together to minimize amine blush.

Figure 1




Hardpoint void illustration from Glastar assembly manual




Wood hardpoint illustration from Velocity assembly manual

## HARDPOINTS

Often you will be required to mechanically attach another piece to a composite structure. One method of doing this is to fabricate a "hardpoint". If you mechanically attach a piece to a fiberglass part, the fiberglass must be reinforced in the area where it will be fitted to accept the loads imposed by the attachment. An example of a hardpoint is found on the GlaStar airplane. A welded fuselage frame is placed inside a pre-molded fuselage shell. The two are attached using machine screws that are placed through hardpoints fabricated in the fiberglass shell.

The most common method of fabricating a hardpoint is to route out a small amount of foam core material between the inner and outer laminates of the shell (see Figure 1). You must be sure not to remove any of the reinforcement material on the outer and inner shells. A piece of piano wire bent 90 degrees and placed in a drill works well for this step. The core material may then be removed using a shop vacuum. After the core material has been removed, a mixture of resin and milled fiber is injected to fill the void. After the material is injected through the drilled hole, a small piece of tape may be applied to keep the resin mixture from escaping. After curing, this material provides the strength needed to serve as an attach point. You must ensure that the entire area is filled with material and no air bubbles are present. After the material completely cures, a hole is drilled through the reinforced area to receive the screw or bolt.

This is one example of a hardpoint. Various kit manufacturers use different methods. Complete instructions on fabricating a hardpoint will be included in your assembly manual.

## POST CURING

Post curing is a process used to obtain increased strength from a resin. If an epoxy resin is allowed to cure only at room temperature, its ultimate strength

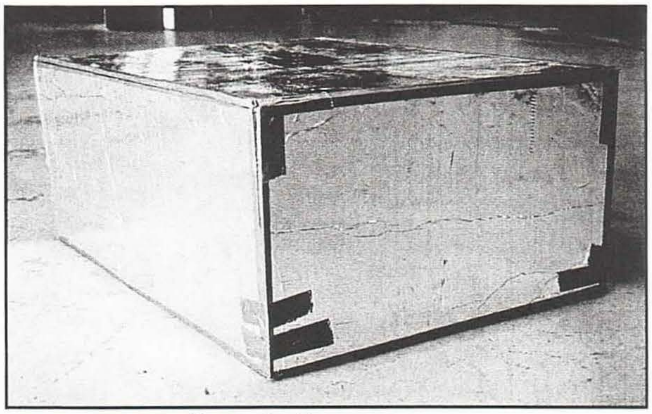
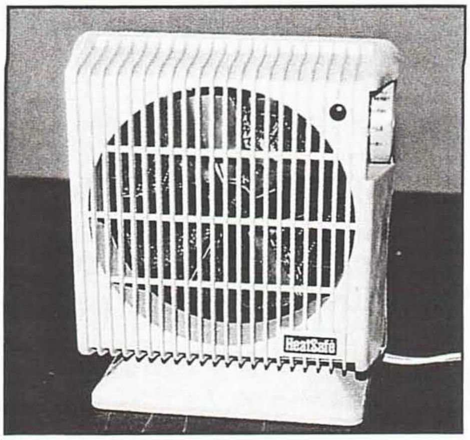
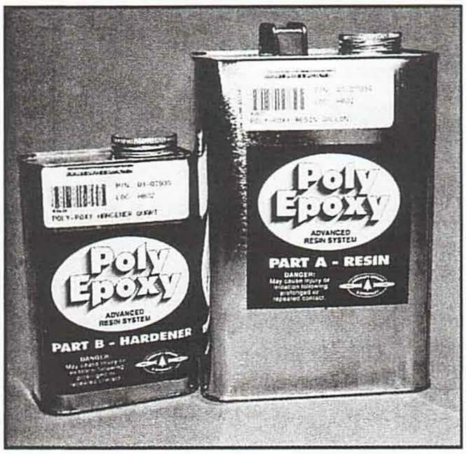


**Figure 2 - Post cure oven.**




**Post cure electric heater**




**Example of a premium epoxy**

is rarely achieved. Post curing will increase two critical performance properties of an epoxy, chemical resistance and heat resistance. Fuel tanks constructed using an epoxy will benefit considerably from post curing. Post curing the entire airplane will increase overall resistance to the heat build-up inside the airplane resulting from the high temperatures found on any ramp in the summer. This build-up of heat can reach the glass transition temperature causing a weakened state of the resin itself.

To understand post curing, it is necessary to define the term glass transition temperature or Tg. The glass transition temperature is the point where the physical properties of a resin material start to decrease as temperatures are elevated. The temperature at which the resin "transitions" (T) from a hard, glassy state (g) to a soft rubbery state is called its Tg. At the Tg the tensile strength, chemical resistance, and hardness are significantly reduced while the flexibility is increased. As you might imagine, we do not want our completed airplane to reach the Tg temperature. To prevent this from occurring, one method is to post cure the resin. Another way is to paint our airplane a light color (usually white) to preclude the temperature on the inside of the airplane from being excessive. On a 90 degree F day, it is not unusual for the temperature inside your airplane structure to reach 180 degrees F plus. This is why you see most composite airplanes painted white. The white color helps reflect the heat keeping the temperature inside the airplane component parts as low as possible.

Another term often used is referred to as the Heat Deflection Temperature (HDT). The value of this number provides us with an idea of the upper service temperature limit for a plastic. This is the temperature at which a resin will begin to soften if placed under a load. The HDT is usually about 20-30 degrees C lower than the Tg of a resin. The reason this is true is because the test to determine this value is accomplished under a load. For this reason, HDT is often a better indicator of the true upper service temperature limit for a given resin.

Regardless, it may be difficult for you to find the value of the Tg and/or the HDT of a resin. Resin manufacturers sometimes display one or both of these values within their instructions but many do not. You will have to seek out this information and determine the temperature and time required at that temperature for a post curing operation.

Should you post cure? Post curing is not absolutely necessary but it certainly is advantageous for all epoxy resins. Some resin manufactures require a post cure as standard practice. Basically, post curing your component parts and your composite airplane will ease your mind concerning the quality of your layups and bonds. If you are somewhat unsure about whether or not the resin properly cured on a particular layup or bond, post curing will likely solve that problem. If you are using epoxy to construct a fuel tank, you should definitely post cure that area. Post curing will ensure adequate fuel resistance not only for today's fuel compositions, but tomorrow's as well. Without post curing, you may encounter a gummy substance in your fuel tank that can plug gascolator screens and filters.

The bottom line in discussing this issue with Gary Hunter — an acknowledged expert on resins who works for Shell Chemical Company (a major manufacturer of epoxy resins) and EAA Technical Counselor — Gary recommends post curing a composite airplane. In his opinion, it takes all of the worries out of the construction process as it pertains to resins. It is a little more insurance that you are getting the maximum performance available from your resin system.

What about vinyl ester resins — do they require post curing? It is not necessary to post cure vinyl esters but it is helpful. Room temperature cured vinyl ester resins develop a larger portion of their ultimate properties, than most room temperature cured epoxies, and as such, they tend to be more resistant to chemicals overall. Therefore, the benefits of a post cure are not as significant. However, post curing simply improves these attributes even more.

How do we post cure? Raising the temperature of a typical laminate above standard room cure temperature performs post curing. Again, most resin systems will not reach their full strength unless they are cured at a temperature considerably above room temperature. Usually this temperature is about 40 degrees F below the Tg specified for the resin. The post cure temperature should never surpass the maximum temperature of another material in the laminate such as the foam. (As an example, polystyrene foam swells at a temperature around 165 degrees F.) Without post curing the Tg of a resin used on your airplane will only be approximately 40 degrees F above the temperature at which the resin was cured. On a hot day the temperature of a structure can exceed the Tg. That could result in the entire composite matrix softening. This softening can result in the matrix of the heated portion being weakened and pulled away. The once smooth surface now exposes the weave of the fabric. High temperatures inside structures that have not been post cured can also affect structural integrity.

With this in mind, it is important that you follow a post curing procedure. You can do this yourself by introducing the proper amount of heat into a fireproof tent-like structure containing a specific part or the entire airplane. Introduce the heat gradually to raise the temperature to that specified by the resin manufacturer. Usually this will be between 140 degrees to 180 degrees F. Let it warm up slowly and evenly. The resin manufacturer will specify the amount of time required at this temperature. An excellent method of post-curing is to rent a paint booth from a local car painter. These booths are usually heated and you can place your parts or the entire airplane in the booth. Put a couple of fans within the booth to circulate the air for even heating rates. Another built-in area to post cure is your attic. The temperature of most attics will reach 140 degrees F. Granted, you have little control over the heating but small parts can be post cured in an attic area. A regular oven can be very effectively used to post cure parts. You can purchase foil back insulation material and construct a small post cure booth. The insulation can be taped together using duct tape (see Figure 2). You can then place a thermostat controlled electric heater in the booth with a couple of thermometer probes placed through the insulation to indicate the temperature.

It is important that you properly support parts to prevent any distortion. This does not mean that you have to place a wing back in a jig. This is assuming the resin has cured for at least a week. (If you are immediately post curing then you should leave the wings in the jig.) Regardless, you must provide adequate support. This means positioning a wing on a flat surface with the leading edge down, as an example. Cowlings should be in place on the airplane or set on the floor with the forward edges down.

After the part has been heated for the required amount of time, slowly cool the temperature. Do not simply pull the part out of the heated area. Again, care must be taken to not exceed the break down temperature of other components such as the foam.

Many kit planes are manufactured from heat cured prepregs and as such, they are essentially post cured as delivered. However, the adhesive bond lines and tape layups the builder makes to assemble the prefab pieces will only have a room temperature cure. It only makes sense to post cure these bond lines and layups so the properties will better match the prefab parts from the manufacturer. This can be accomplished by introducing heat into a closed-up fuselage or wing area for a certain amount of time. After all, being made from foam or honeycomb cored composites, they are naturally insulating structures.

One way to do this is to use the exhaust from a vacuum cleaner as a mild source of heat. Many builders have used this procedure to introduce heat into a fuselage area for a period of time. All of the bulkheads that have been bonded and other resin applications will be post cured.

When to post cure is another question. It really does not matter when you post cure. It is usually best to wait at least two weeks after you have completed your layup or bonding to allow the resin to cure as much as possible at room temperature. Even if you have completed the work 6 months ago or longer you will still derive benefits from post curing.

Similarly, the fillers and faring compounds used to smooth and contour your airplanes painted surfaces will benefit from a post cure. Fillers inherently shrink as they cure, and after a few months in the hot sun a show quality finish can literally shrink away exposing the weave of the reinforcing fabric and other unsightly discontinuities. This is commonly referred to as "Print Through". Post curing your airplane after the filling work but prior to priming and painting will essentially pre-shrink these fillers and allow you to see and re-fill any resultant print through prior to final painting.

As you can see, there are many ways to post cure. There is nothing absolutely critical about the method. The slow introduction of heat up to the desired level followed by the proper time at that temperature is important. Again, slowly lower the temperature when you are through. As Gary Hunter states, "Post curing is not absolutely necessary, but the results are always comforting on that first encounter with clear air turbulence."

Next month I will conclude this series on composite construction. That article will focus on forming and proper finishing techniques. ◆

**The EAA/SportAir Workshop schedule is as follows:**

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| **August 28, 1999** | **Chino, CA (one day conference)** |
| **August 28-29, 1999** | **North Hampton, NH** |
| **October 9-10, 1999** | **Battle Creek, MI** |
| **November 6-7, 1999** | **Lakeland, FL** |

**Information on these workshops can be obtained by calling 800-967-5746 or by contacting the website at www.sportair.com. The author may be emailed at ralexander@sportair.com**

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