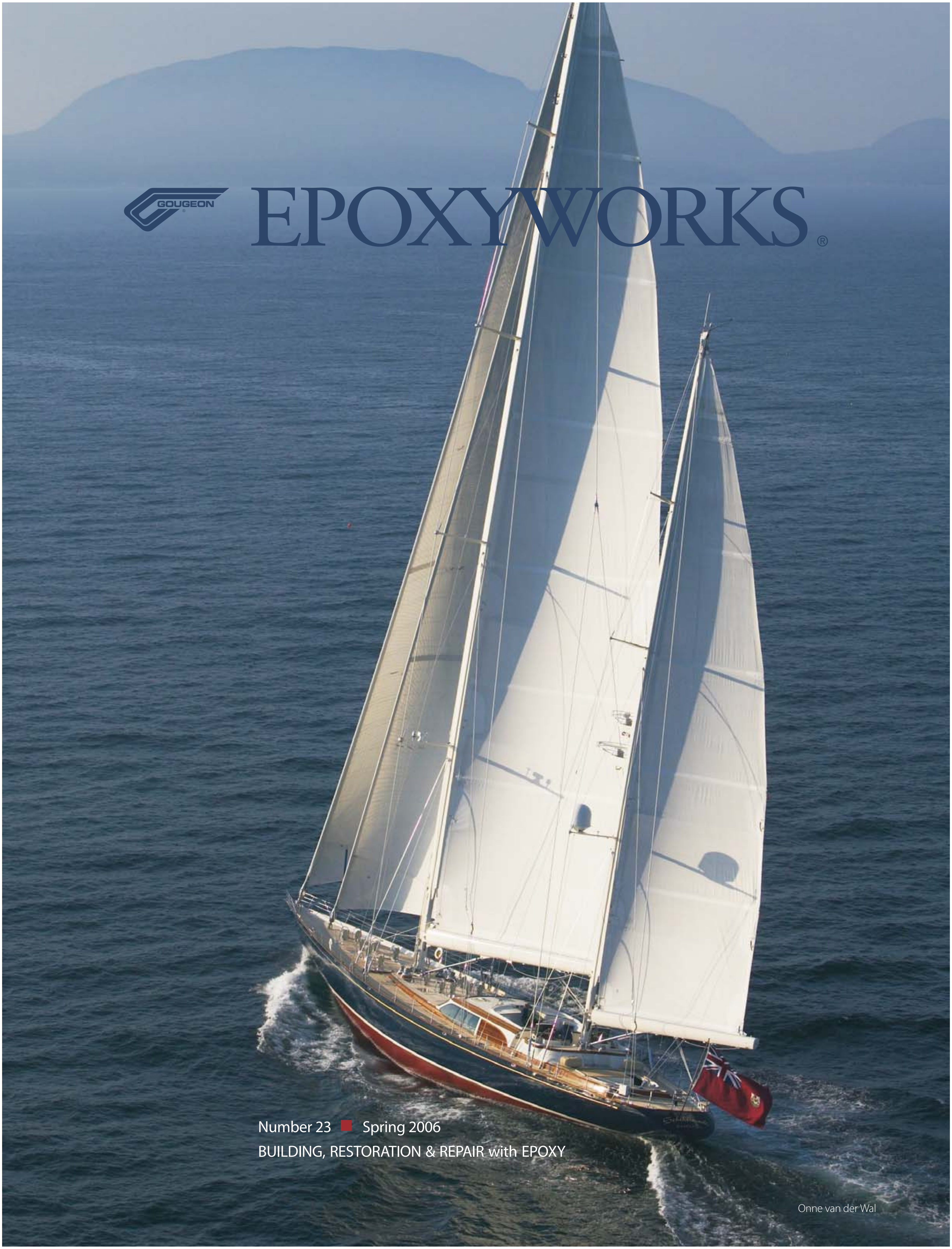

EPOXYWORKS®

Number 23 ■ Spring 2006

BUILDING, RESTORATION & REPAIR with EPOXY

Onne van der Wal

In this issue

EPOXYWORKS®

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Onne van der Wal

Cover story

Billy Black

Scheherazade update

Onne van der Wal

While *Epoxyworks* was out of circulation, we missed reporting on an important epoxy event, the launching of the 155' ketch, *Scheherazade*, at Hodgdon Yachts in East Boothbay, Maine. We are a little late in the reporting, but cannot let the event pass without acknowledging this beautiful union of wood/epoxy technology, elegant design, and superior craftsmanship.

You may recall from *Epoxyworks* 17 and 19 that *Scheherazade* was to be one of the largest cold molded wood/epoxy vessels ever built in the United States. Her 3½" thick hull is made of inner and outer layers of ⅞" Douglas fir planking running fore and aft and separated by four diagonal layers of 7⁄16" western red cedar bonded with WEST SYSTEM® epoxy. Douglas fir replaces the cedar in highly loaded sections of the hull. All fasteners used to install deck hardware (including the massive winches) are glued in place with epoxy thickened with high-density fillers.

Billy Black

Interior cabinetry is black walnut and fiddleback sycamore. Interior details include hundreds of shells, starfish, and other marine life that were hand-carved from single blocks of wood.

With a staff of up to one-hundred people working on *Scheherazade* at one point during the build, the project took approximately four years to complete. She was launched on September 27, 2003.

Visit hodgdonyachts.com for a look at past projects and progress on the Ted Fontaine-designed 98' ketch currently under construction. ■

Scheherazade

Designer	Bruce King
Interior designer	Andrew Wench
LOA	154'-7"
Beam	28'-6"
Draft	13'-0"
Main mast height	174' above the deck
Mizzen height	110' above the deck
Sail area	9,940 sq ft
Hull thickness	3½"
Bare hull weight	110,000 lb
Ballast keel weight	150,000 lb

Dana Jinkins

Billy Black

The limitations of statues

By W.D. Bertelsen

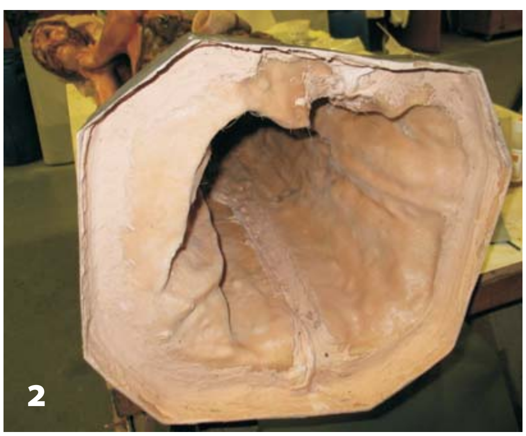
Creating lasting outdoor art has challenged humans since the dawn of time. One has only to think of the pyramids (still there), Stonehenge (mostly there), the Colossus of Rhodes (long gone), or the Easter Island monoliths (surviving, but then two heads are better than one). In more recent times, there's Mt. Rushmore, Stone Mountain Georgia, and the Statue of Liberty. The goal is nothing less than perpetuity. But of course, outdoor sculpture needs to be done right or it won't last. Making statues, i.e., permanent structures that look like people, is particularly difficult.

One recent December, I received a call from a fellow member of St. Luke's United Methodist Church in Essexville, Michigan. St. Luke's was attempting to deploy an outdoor nativity scene composed of a number of life-like, molded-fiberglass figurines. The problem was that the shepherd figure was damaged and could not take his watch.

The figurines were high-quality pieces with intricate detailing, made by a local Christmas ornament firm. However, while they had been manufactured to very high artistic standards, the figurines were structurally unsound for outdoor use. The manufacturer provided no means for anchoring them down. In previous years, volunteers had simply attached each to a plywood slab with big toggle bolts through a thin bottom panel. They then spiked the slab corners into the ground.

In due time, a typical Michigan winter froze Shep to the earth as if cast in concrete. A hasty post-season shove, intended to release him, instead fractured the tenuous joint between the sides of the pedestal and the bottom panel engaged by the toggle bolts. Shep had broken off all the way around the edges of his pedestal *(Photos 1 & 2)*. It was not a premeditated crime. The charges were "baseless."

I got the call because it was known at St. Luke's that I work for an epoxy company. (Few are aware that my specialty is testing composite materials to destruction. I am much more experienced at breaking structures, to measure their strength, than at repairing them.) However, I knew our knowledgeable GBI technical staff might be able to devise a repair strategy that I could handle.



1 & 2— Shep after being knocked off his base.

3—The gluing area of the pedestal was prepared for bonding by thoroughly abrading the surface with a wire wheel tool on a cordless drill.

4—A bead of thickened epoxy in the outline of the pedestal was applied to the new base.

5—After the pedestal was lowered onto the bead of epoxy, a large fillet was created around the exterior of the joint

It was clear that the base/pedestal joint needed to be redone with WEST SYSTEM® epoxy. The old polyester-encrusted base was discarded and replaced with a sandwich composite panel left over from past GBI test programs. I found an undamaged two-foot-square panel with a foam core and thick fiberglass face sheets.

In order to effect a rugged, epoxy bond to the sandwich panel, it was imperative to take full advantage of the generous surface area afforded by the pedestal sides. GBI's Tom Pawlak emphasized the need for good, pre-bond surface preparation. He produced a wire wheel tool with which to scuff the perimeter to create fresh bonding surface *(Photo 3)*.

Thus began a series of lunch-hour work sessions. I kept at it until I got below the paint and into the glass fibers. I cleared enough width to accommodate a generous fillet of filled epoxy. The plan was to go with WEST SYSTEM 105/206 containing enough 407 Low-Density Filler to create a mayonnaise consistency, ideal for filleting.

Before mixing the epoxy, I placed Shep on his new base with the textured side up and traced around the sides of the pedestal with a permanent marker. Removing Shep, I had a guide line that would permit me to trowel on filled epoxy with enough precision so that the glue could grip the inside of the pedestal as well as the outside. The inside blind fillet would effectively double the joint strength.

While I was tracing the perimeter, Tom had a quietly brilliant suggestion: install a series of stainless deck screws just inside the perimeter line to be engulfed by the epoxy, further enhancing the grip. It was done in minutes.

It was my idea to through-bolt the sandwich faces in several areas to discourage the start of a peel that might separate the upper joint face from the foam core. For drainage of internal moisture and condensation that might accumulate in the field, I drilled a ¼" hole in the middle of the base. I also drilled an ⅛" hole under each of Shep's elbows to allow air pressure to release during bonding. These holes would also allow equalization whether Shep was on winter display or in summer stand-down in a hot storage shed.

6 —Shep (far right) was back on duty with twelve days to spare.

To complete the surface preparation for bonding, I used the wire wheel to abrade the textured glass surface of the new base on either side of the pedestal outline. We applied epoxy to the base and to both the inside and outside of Shep's pedestal rim *(Photo 4)*. With the new base face up on the workbench, we lowered Shep into position and crafted the exterior fillet *(Photo 5)*.

The finishing touch was to coat the foam edges of the new base with neat WEST SYSTEM105/206. After an overnight cure, Shep was ready to return to the St. Luke's. Thanks to WEST SYSTEM epoxy, the complete display was back on line, with still twelve days to go before Christmas Eve *(Photo 6)*. ■

W. D. Bertelsen is the Chief Testing Engineer at Gougeon Brothers. This the first recorded incidence of Bill not destroying an object after gluing it together.

The "lost foam" method of composite fabrication

"Lost foam" composite fabrication uses Styrofoam™ as a male mold, over which composite materials are applied. The Styrofoam is then dissolved out of the cured part with acetone or lacquer thinner, leaving a hollowed out shell. (Other types of foam may not dissolve, so use styrenated foam exclusively for this process.) It is used to produce custom (one-off) parts with a molded interior cavity. Since the mold is destroyed after the part is built, this version of the lost foam method is not a production process. With this method, any shape that can be carved or molded out of Styrofoam can be turned into a fiberglass/epoxy composite. For example, this method can be used to fabricate air scoops and intake plenums for combustion engines, masthead fittings, and various types of nozzles or plumbing applications.

Brian Knight and J.R. Watson recently built small composite parts that required a specific hollow space. Both used the lost foam method to build the parts. These articles demonstrate two different approaches to a problem and how the method can be modified to suit individual needs.

1 Fabricating an air scoop

By Brian L. Knight

I used lost foam construction to fabricate a fiberglass air scoop for my son's Formula Continental C race car. Our project started because a modification to the shape of the race car body necessitated the construction of a new air scoop. The air scoop is bolted to the car body so if either the air scoop or the body is damaged (a very likely scenario), the repair will be simpler. To fabricate the scoop, I made a Styrofoam male mold, surrounded the mold with fiberglass, and then dissolved the Styrofoam to leave a hollow part. I used Styrofoam to build the male mold for several reasons. It is readily available at most lumberyards, it is easy to shape with files and sandpaper, and it is easy to dissolve with lacquer thinner.

1—Viewed from behind, the finished Styrofoam mold carved to fit in place on the body where it will be installed.

2—The air scoop mold viewed from the front. The mold is in the process of being covered with clear packaging tape to prevent epoxy from bonding and to provide a smooth interior surface in the finished part.

Carve/shape a Styrofoam blank

The blank was built up of several layers of foam and then carved to shape. To build the blank, I used WEST SYSTEM® epoxy because it does not chemically attack the foam. However, the hard glue lines at each layer of foam can cause difficulties when shaping the part. Styrofoam has a density of about 2 pounds per cubic foot—very low. Unless the density of the glue line approximates the foam, the shaping process will remove foam much more quickly than the glue lines. This leaves unacceptable ridges at each joint in the foam. So to make shaping easier, I used epoxy thickened with 410 Microlight™ to glue the layers of Styrofoam together. Microlight has a very low density and does not make hard glue lines that other fillers might.

I used Surform™ tools, coarse files, and sandpaper to shape the mold. I made no attempt to get a good surface finish on the mold—I just concerned myself with the overall fairness. Since fiberglass will not conform to sharp corners, I used fillets of 410 Microlight on all inside corners.

I used clear packaging tape as a mold release *(Photos 1 and 2)*. One thing to pay attention to—epoxy does not adhere to the shiny side of the tape, but it will lock itself into wrinkles and gaps in the tape. So, do a neat job of applying the tape to avoid difficulty removing the tape from the cured part.

Apply the fabric

I applied a couple of layers of wet-out fiberglass cloth to the bottom of the foam and wrapped it up the sides a few inches. Then I allowed this to cure.

The next step involved sanding the cured edge of the fiberglass where the first application ended. There were lots of sharp "hairs" sticking up as well as several wrinkles in the glass. I carefully sanded this area smooth, taking care not to gouge into the Styrofoam immediately adjacent to the cured glass.

Then I applied several layers of fiberglass to the remainder of the part. These overlapped the previously applied cloth *(Photos 3 and 4)*.

When all the epoxy had cured, I sanded enough so that I could handle the part safely without getting cut on sharp edges and then cut a hole through the bottom fiberglass skin. This hole was sized to allow the carburetor and air cleaner to fit inside the air scoop. The hole also provided access to the inside of the scoop to make the job of removing the foam easier.

Dissolve the foam and clean up the inside

Lacquer thinner will effectively dissolve Styrofoam. Poured slowly over the foam, the lacquer thinner reduces the foam to a viscous blue liquid. When the lacquer thinner evaporates from the liquid, it leaves a small, hard plastic residue. For the air scoop, I used about a cup of lacquer thinner.

After dissolving the foam, reach in and remove the epoxy "ribs" that are left. The ribs are the epoxy layers (which are not attacked by the solvent) used to laminate the layers of foam. They need to be removed by hand.

The tape will generally remain with the part and will peel off after the foam is destroyed. This will also allow the removal of the fillets that are left after the foam is dissolved.

Finish the scoop

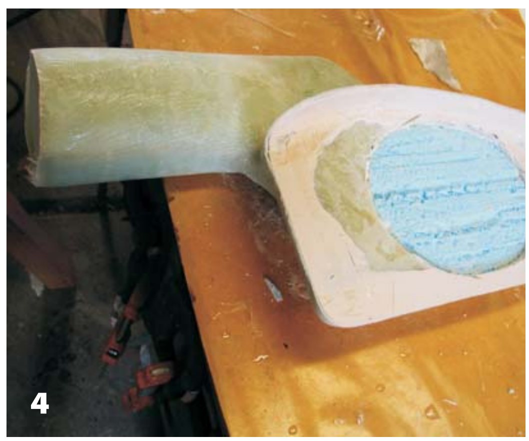
I wanted the air cleaner to fit precisely to the top of the car body. To accomplish this, I applied clear packaging tape to the body, applied a layer of 410 Microlight to the tape, and placed the air scoop in the putty. The 410 did not stick to the tape; it stuck to the bottom of the air scoop. This made a perfect fit between the two parts. Then I removed the tape from the body.

Because this part was built on a male mold, it required considerable fairing. I used epoxy thickened with 410 Microlight to make an easily sanded fairing compound. This was applied with a plastic spreader and allowed to cure. Lots of hand and block sanding later, the part was almost ready for paint *(Photos 5 and 6)*. To seal the sanded 410, I applied one last seal coat of neat epoxy.

The term lost foam is also used in metal casting. Similar to the lost wax method, the foam or wax is an exact pattern of the finished part within a sand or plaster mold, which is displaced by molten metal.

In lost foam composite fabrication, the foam is a core or male mold over which the finished part is built.

3—The fiberglass has cured over the Styrofoam mold before it is trimmed and sanded.



4—The cured part and mold from below before the foam was dissolved with lacquer thinner.

5—The cleaned up part after cleaning out the interior and fairing the exterior with epoxy/410 Microlight Filler.

410 fairing compound was also used to make a body-conforming base for the air scoop.

6—The finished air scoop viewed from the front. The lost foam method of composite fabrication was ideally suited for the scoop's aerodynamic shape.

7—Viewed from the top, the finished air scoop with two coats of white automotive paint and one clear coat.

After a final wet sanding of the seal coat, I sprayed several heavy applications of lacquer primer on the part. This was wet sanded and two coats of Omni™ automotive paint were applied. One more wet sanding followed by a coat of Omni Clear finished the job *(Photos 6 and 7)*. ■

2 Building a masthead fitting

By J.R.Watson

The masthead fitting had several design requirements:

- It must fit within an existing spar size and shape.
- It must have sufficient wall thickness to bear expected forces.
- It must house the sheave and provide adequate room to internally route the halyard.
- It must offer an attachment point for the topping lift.

Here's another use of the lost foam method to produce a custom part with a molded interior cavity. In this case, the part was a mast head fitting to hold an internal sheave and provide a route for the halyard to pass. This method can be adapted to a variety of other applications, as demonstrated in the previous article.

Making the foam mold

The first step was to make a full-size drawing of the fitting to use as a reference for manufacturing *(Photo 1)*. Using the drawing, I fashioned Styrofoam to represent the fitting's internal void. I bonded pieces of foam together to produce a billet of sufficient size, using the bond lines for a centerline to aid in measurements. (By using more layers of foam, you could use the additional glue lines each side of the centerline to produce contour lines for additional shaping guides.)

From the drawing, I made templates of the two side views. I taped them to the foam billet so I could rough-out the mold on a band saw *(Photo 2)*. Then I rounded over and smoothed the corners with sandpaper *(Photo 3)*. I bonded the sculpted foam blank to a temporary base to facilitate handling and applied paste wax to the mold to fill the porosity of the foam. This was done to produce a smoother surface and promote release of laminate later on.

Applying the fabric

Next, I applied a ⅛" thick layer of WEST SYSTEM® 105/205 epoxy (thickened to a grease-like consistency with 406 Colloidal Silica and 423 Graphite Power) over the entire part.

I wet out strips of woven graphite fiber reinforcement and pressed them into the thickened mixture until I achieved an estimated thickness of ¼". (Any more than this could have resulted in excessive exothermic temperatures.) While the laminate was still wet, I covered it with plastic (a freezer bag) and wrapped it with self amalgamated tape. This consolidated the laminate, extruding excess resin out the bottom. Reducing resin content to around 45% resin/55% fiber improves mechanical properties. Then I allowed it to cure.

I removed the cured part from the temporary base and dug out the foam with a carving chisel, hand-held rotary tool (Dremel™), file, and knife. As I approached the wax-covered exterior surface of the mold (now the interior surface of the masthead fitting), the foam fell off, revealing and replicating the sculpted surface.

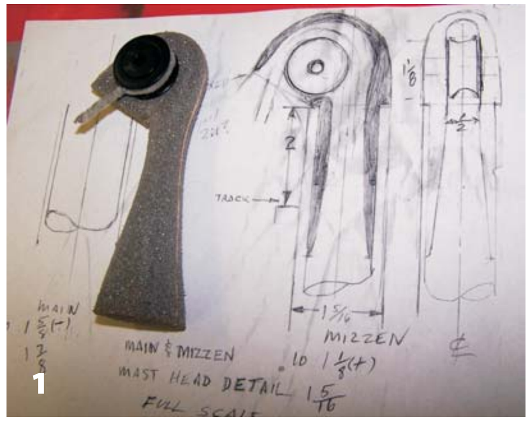
Then, I applied additional layers of fabric. I first applied another thickened epoxy/406/423 layer, which helped span minute surface irregularities. I used braided reinforcing material for these layers, taking care to overlap and align successive layers. Tape was produced by cutting braided sleeve material. With braid, fiber orientation can be adjusted simply by compressing or tensioning the material. I used templates made from the drawing to aid in establishing the finished shape/size. Round templates produced from paper towel core made for accurate sizing of round sections. After achieving the shape I wanted, I allowed the final layers of fabric to cure.

I located the sheave axle hole by measuring off the drawing with calipers. I first drilled undersize to check for accuracy with the real part and then drilled to axle size. You can make the topping lift of various materials; in this instance, I stitched nylon line together and wrapped it with thread for flexibility and light weight. I bonded the fiber part of the line to the crown of the fitting and covered it with fairing compound and a layer of braided tape *(Photo 4)*.

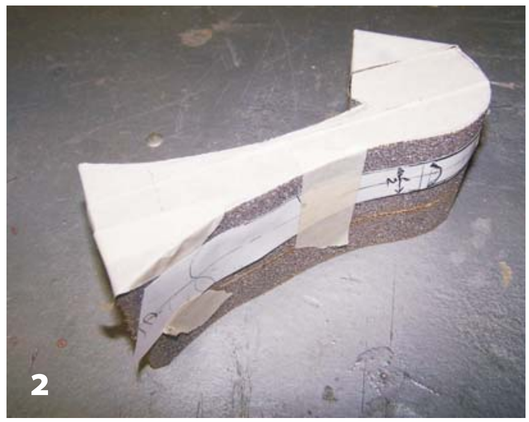
A tip for mounting the fitting to the mast

To prevent obstructing the passage with adhesive when the fitting is installed into the top of the mast, I inserted a common balloon covered with a thin layer of Vaseline™ down into the cavity. I inflated it after the fitting was inserted into the masthead, thereby pressing any invading excess adhesive against the spar and out of the way of the halyard. The balloon also exerted sufficient force to prevent any minute movement from the fitting's intended location until cure-up was achieved. The Vaseline made it easy to remove the deflated balloon after everything had cured.

Final blending and touch-up was done after cure-up, and a cover of carbon fiber braided sock was applied as further reinforcement. After a final coating and sanding, the fitting was primed and painted. ■

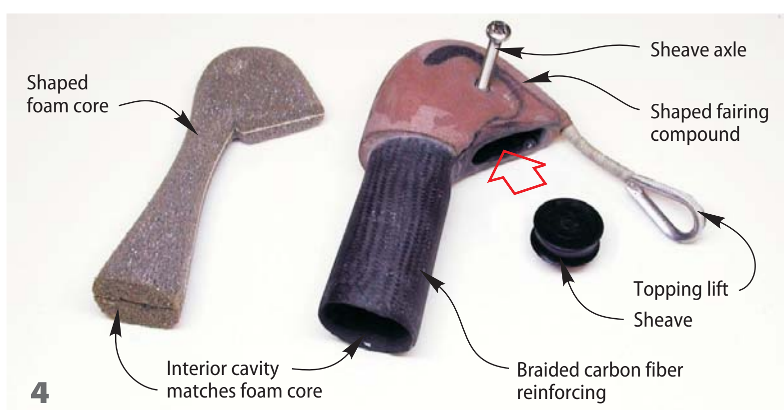


1—Make a full-size drawing of the part to make templates and use as a reference for manufacturing.



2—Make templates of the two side views and tape them to the foam billet. Use a band saw to cut out the rough shape of the mold.

3—Then round over and smooth the corners with sandpaper.



4—The nearly finished fitting with a duplicate of the foam mold. After the inside was cleaned out, additional fabric was applied to achieve the final exterior shape. The outside was faired and shaped before the topping lift and sheave were installed.

If you can't take the heat . . .

Understanding the effects of high temperatures on cured epoxy

By Bruce Niederer

Among both professionals and amateurs in the world of composites, there are certain enduring misconceptions and rumors regarding the effects of elevated temperature on an epoxy bond. Armed with just enough misinformation to be dangerous, folks will make important decisions that can lead to costly or time-consuming mistakes that might have been avoided if they had an adequate understanding of the principles that encompass epoxy structures and temperature. By defining some commonly used terms and briefly discussing issues surrounding application, we hope to dispel some of these misconceptions.

1—The test apparatus holds five of the test samples shown below in a bath of heated oil while a three-point load is applied to the sample.

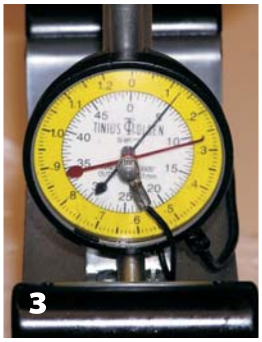
2—This shows how the load is applied to the coupon of epoxy. The coupon is still solid, but has bent, illustrating the concerns regarding creep.

The most commonly used and misunderstood term is *heat deflection under load* (HDUL), often shortened to simply the *heat deflection temperature* (HDT). This shortened name helps to breed some of the confusion. HDUL is a standard test (ASTM D-648) used industry-wide to characterize the thermal behavior of a resin system. The test determines the temperature at which a bar or coupon of cured epoxy (without reinforcing fibers) ⅛" thick × ½" wide × 5" long and under a point load of 264 psi will deflect 0.1" (~ 7⁄64"). The test sample is loaded in the test apparatus and simply supported at both ends, on edge, and the load is applied in the center—a typical three-point bend test *(Photos 1 & 2)*. Then the sample is lowered into an oil bath that heats slowly up from room temperature and stops when the sample deflects the 0.1" *(Photo 3)*.

The misconceptions are that above this temperature the epoxy no longer has any structural integrity, adhesive strength, and/or that it even begins to return to a liquid state! None of these correctly characterizes what is happening. With an understanding of how HDUL is measured, it should seem obvious that the epoxy becomes more flexible as the temperature rises above room temperature (typically 72°F), but the epoxy is still quite strong. Although it is true that there are epoxy systems on the market formulated to have an HDUL lower than room temperature, these epoxies are for specific, non-structural applications.

Here's an example which demonstrates that epoxy retains its structural integrity and adhesive strength after exposure to high temperatures.

We have glued two blocks of mahogany together with WEST SYSTEM® epoxy, allowed it to cure for one week at room temperature, and then exposed the whole assembly to 200°F for 3 hours before forcing a chisel into the glue line to fail the joint. When the joint was examined closely, we found that the primary failure was in the wood and not the epoxy. Experience has also shown that while heat tends to soften epoxy while it remains warm, if WEST SYSTEM epoxy is not exposed



3—A gauge measures the deflection of the epoxy sample as the temperature of the oil bath increases.

to damaging heat (exceeding 230°F for extended periods), it will return to full strength when cooled to room temperature.

What this test does not reveal is the behavior of a loaded or pre-stressed bond line. Joints of this nature are subject to static or constant loads, often referred to as *creep loads*. When epoxy is used for building projects, this aspect of the design and engineering must be considered.[1] The anticipated load and working temperature of the joint may indicate that additional techniques be applied to insure the long-term viability of the joint. Such techniques can include using mechanical fasteners, increasing the surface area of the bond, increasing the thickness of a composite laminate, or incorporating more thin laminations in a curved wood laminate so each lamination has less stored energy. All of these reduce the effect of creep loading in a joint or lamination.

A more ambiguous term that is often misunderstood by the end user is the *glass transition temperature* (Tg). This term is also reported differently by various resin manufacturers, which adds to the confusion. The glass transition temperature can be measured by various methods, such as a Differential Scanning Calorimeter (DSC), Dynamic Mechanical Analysis (DMA), a torsion pendulum, the dielectric constant, volumetric methods, and even "bouncy balls". Since the value of Tg depends on the strain rate and the heating/cooling rate, there cannot be a single, exact value for Tg. Resin manufacturers use different methods and different reporting criteria for Tg, which leads to inconsistencies when comparing data from multiple sources. Each of these methods serves to define a point at which cured epoxy, which is an infusible solid, becomes a rubbery solid. A good way to visualize this is to think of a rubber garden hose left out in the winter versus the same hose in the summer. In the winter it's hard and stiff, in the summer it's soft and flexible—but either way, it's still a garden hose.

We believe the temperature that a manufacturer reports in the product literature for glass transition should be within a few degrees of the HDUL temperature for the design and engineering reasons outlined above. However, often times the Tg is significantly higher. The reason for the discrepancy lies in how the test is performed and subsequently reported. We measure Tg by DSC, which conforms to ASTM standard D-3418, and choose to report the onset of the transition. This results in a value close to the HDUL. It is also legitimate to report the midpoint or endpoint—as long as you disclose how Tg was determined.

Here's how it works. A small sample of cured epoxy is placed in a small aluminum crucible about ¼" in diameter and placed in the DSC machine next to an identical, but empty, crucible. This is the 'differential' aspect of the test. The test chamber is a small oven that can measure and record the differences in heat output and/or uptake between the two crucibles. The oven then runs through a heating cycle from 30°C (86°F) to 200°C (392°F) at 10°C/min and the minute differences in the heat output/input are recorded by the machine's sensors. After this heating is finished, the oven cools and the heating cycle is repeated; however, for this run, the epoxy sample has been effectively post cured by the initial heat cycle. As a result, the glass transition temperature will nearly always be significantly higher. In fact, ASTM D-3418 can be interpreted to require the measurement of Tg from this second heat cycle to "erase thermal history." From a formulator's point of view, this data is useful; from a builder's point of view, it is not practical.

A close look at a WEST SYSTEM Technical Data Sheet shows that we report the "onset of Tg" measured from the first heat cycle, as well as the "ultimate Tg", which is from the second heat cycle. We believe onset of Tg is the most useful value to report because it's not practical for anyone to post cure their project to 392°F and, in fact, epoxy can be damaged by exposure to this high a temperature. Now this may be hard to accept, (especially during this political season where honesty is valued at such a premium), but some manufacturers report the ultimate value and don't bother to tell their customers! I know, I know, it's shocking—but business can be brutal. Regardless, the practical implications from the Tg information are the same as discussed for the HDUL.

To summarize, keep in mind the meaning of the terms and test methods discussed in this article. HDUL means heat deflection under load and it's of key importance to remember this element of the test when someone refers to it as heat deflection temperature and wants to argue that the epoxy will fail at this temperature. A 264 psi load is quite a significant load. So if a joint or bond line is not loaded to a similar level, or is in fact not loaded at all, the likelihood is that neither the epoxy nor the joint will fail. Similarly, the glass transition temperature, or Tg, if reported honestly, defines the point where the epoxy begins a transformation to a rubbery solid. Most importantly, neither term defines a temperature above which epoxy cannot be used. Still, if your joint will live in a working environment at or near the HDUL or Tg temperature, then you should consider the nature of the joint within the structure to decide if epoxy alone is sufficient or if other techniques are called for. If you have questions, our technical staff is available Monday through Friday 8:00 a.m. to 5:00 p.m. EST by calling 866-937-8797 toll free. ■

[1] See "Designing for Rigidity and Strength under Static Load" in *Modern Plastics Encyclopedia* 1986-87, p. 403 for a detailed discussion.

Rebuilding an International 110

By Tim Botimer

1—My International 110 (Number 300)with the glass and paint removed.

I first got into International 110 sailing 15 years ago and soon bought an old fixer-upper boat. After sailing it for a couple of years in a decrepit state, I made the decision to fix it right. I had worked with WEST SYSTEM® products before, and I was pretty familiar with the product line. I had done significant repairs on a 1965 plywood Thunderbird and a 1950s vintage Flying Dutchman, which incidentally was one of the original test boats when Jan and Meade Gougeon first came out with the product. I had never tackled anything on the scale of the 110 project, and at the time it was the only boat I had.

The International 110 was designed by C. Raymond Hunt, and many are home built. Mine was Number 300, the first one produced by Jesek Brothers boatbuilders of Holland, Michigan. The boat is constructed of ⅜" Douglas fir marine plywood over Douglas fir frames. The four keel frames are white oak. It sailed in the very first 110 Nationals in 1941.

The boat was showing its age, so the first thing I did was strip off the heavy fiberglass cloth on the hull to see what I really had *(Photo 1)*. I knew I would be putting a new bottom on at the very least, and I wanted to know what I was getting into from the start.

With the glass and paint (at least 10 coats, all of different colors) removed, I found that the sides and the bottom were both dry-rotted along the seams. The bottom frames were still in pretty good shape except that they were the wrong shape. The first eight feet of the bottom was too flat and then there was a two inch hump where the keel frames were.

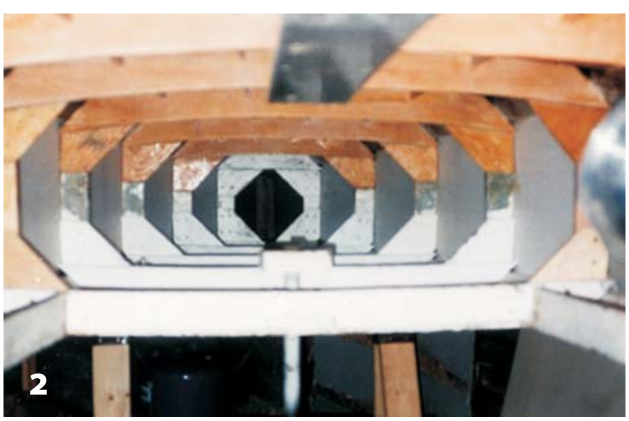
I replaced one of the oak keel frames and repaired the others. I found that the ends were rotted where the screws that hold the chine on to the frames went in. I scarfed a new end onto one frame, and I used a Dutchmen scarf to repair some rot on another. The frames were just like new.

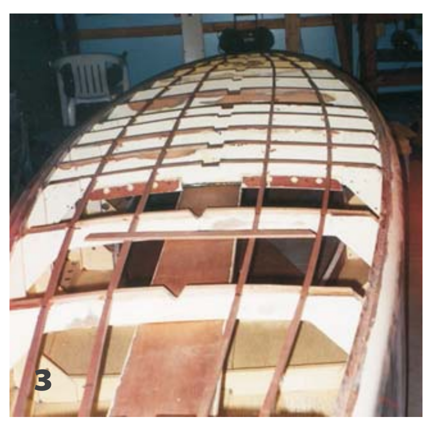
After replacing all of the bottom frames to give the boat the proper shape *(Photo 2)*, I added stringers fore and aft to give more structural stability between the frames *(Photo 3)* and to prevent the bottom from sagging between the frames, especially where the boat sits on the trailer. The frames and stringers were coated with clear epoxy and then sanded to allow for a mechanical bond. I used stainless screws to hold things in place until the epoxy hit its initial cure, and then I removed all of the screws.

I planked the bottom first and then repeated the process on the sides. Using marine grade ⅜" Douglas fir plywood, I used a special tool to cut a 7 to 1 scarf to join the plywood and make a continuous 24' piece. The plans call for a butt joint; however, with the bottom ply scarfed, the boat drains better. I used WEST SYSTEM 105 Resin with 206 Slow Hardener. I wet out the joint with straight resin/hardener, and then I mixed up a batch with 403 Microfibers for gap filling. I clamped the plywood together, and the resulting joint hardly shows and is stronger than the original wood.

Putting the bottom and sides on was a three-person job. I had two people mixing resin/hardener and adding 406 Colloidal Silica and 403 Microfibers. They would mix up

After replacing all of the bottom frames*(2)* to give the boat the proper shape, I added stringers fore and aft *(3)* to give more structural stability between the frames.





4—We scraped the excess epoxy off all of the surfaces on the inside where it had squeezed out and formed fillets with the excess epoxy.

5—I used epoxy/410 Microlight™ to fair the hull and extensively fair the keel to the correct shape.

about a 5-pump batch from the mini pumps and then add the fillers. The mix was then loaded into the handy reusable caulk gun tubes and applied to the frames and stringers.

Once the whole thing was glued and screwed, all three of us climbed in and scraped the excess epoxy off all of the surfaces where it had squeezed out. Using the stir sticks, we formed fillets with the excess epoxy *(Photo 4)*. This was quick and easy, and it made a much stronger joint.

To fair the hull, I used 410 Microlight™ and epoxy, thickened to a thick peanut butter consistency. I also used this mixture extensively to reshape the keel to the correct shape. Once the shape was achieved, I coated everything with several coats of the epoxy/barrier coat.

The keel is cast iron and very prone to rust weeping through. I wire wheeled the keel clean of rust and then wire brushed epoxy barrier coat onto the keel. I rolled the glue on and then wire brushed it into the pores of the cast. The next four coats were just rolled on one after another as soon as they were hard enough to take another coat *(Photo 5)*.

WEST SYSTEM epoxy worked equally well for finishing off the exterior of the hull. The interior got three coats of clear epoxy and then varnish. The exterior got seven coats of epoxy mixed with 422 Barrier Coat Additive *(Photo 6)*. This stuff worked great because it made sanding and seeing imperfections easier. It also made the surface much more impervious to water. The exterior is finished with Interlux™, Interthane Plus™ two-part polyester paint, applied with a roller and tipped out with a good brush.

International™ 110 Number 300 had a new lease on life *(Photo 7)*. This rebuild was done in 1994, and I haven't had to do any major touch ups to the boat. In 2003, after winning the National championships, I gave her a new coat of paint. I have since done several other 110 rebuilds and have learned a few tricks and tips to make the job easier. Planning sure beats sanding is probably the biggest lesson learned. I now use okume mahogany plywood instead of the Douglas fir. It is much more dimensionally stable. I also call the WEST SYSTEM Technical Services when I have a question instead of trying to figure it out on my own. The folks at WEST SYSTEM are very knowledgeable and always willing to help. ■

6—The exterior got seven coats of epoxy mixed with 422 Barrier Coat Additive.

7—In 2003, after winning the National championships, I gave her a new coat of paint.

Paul Butler offers plans for this 3' wide and just under 12' long duck boat. It can be built completely open or decked over with coamings for weather protection. It can be rowed, sculled, poled, paddled, or powered with a small electric motor. The boat weighs in at 50 lb and will hold 2 adults and gear in an open configuration and can be car-topped. This plywood stitch and glue project is easy to build and could make a good wood/epoxy starter project. Paul Butler, Box 1917, Port Angeles, WA 98362. Email: paul@butlerprojects.com.

This is a TALBOT LAGO T120 Baby Sport built in 1936 at Suresnes near Paris. In 1990, Claude Schmit,t a retired yacht broker from Cannes, France, found the remains of the car under the leaves in a forest and spent 4,500 hours over eight years to rebuild it. Very few parts were salvageable. The body had to be completely rebuilt. A frame of laminated ash replaced the original solid ash frame. Schmitt says, "This is a wooden car, maybe one of very few. The most important feature is that, after 22,000 miles and four years of rather heavy use for such an old car, sometimes rallying in very rough old roads, the entire body looks really great, as new. Absolutely not one defect can be detected. Thanks to the famous West System. Grateful appreciation for all the people involved in this technology. I greatly enjoyed the work and I fully enjoy the use of it."

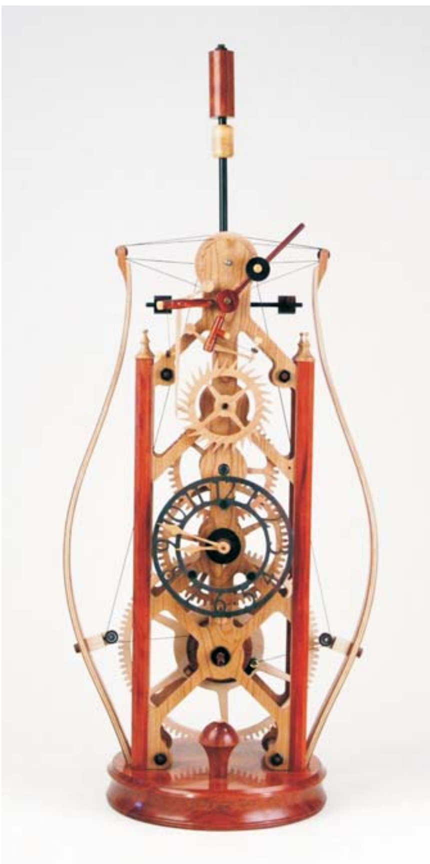
Readers' projects

Don Meyers of Cheboygan, Michigan, built this stripper bassinet for his first granddaughter. He used white cedar and West System 105/207.

J. M. Hyslop of Hopkins, Michigan built this 24' Karl Stanbaugh-designed sailboat. The *Emily P* is built of Douglas fir, marine fir ply and West System epoxy and draws less than 2' of water with the board up.

Cub Scout Pack #4120 from Sister Bay, Wisconsin, recently completed this 16' cedar strip canoe. Over 150 volunteer hours were logged by scouts, scout leaders, parents, and community volunteers. The canoe was donated to the scout's charter organization, the Sister Bay Lion's Club, in April, 2005. The project was overseen by craftsmen Bruce Yohe and Brian Buchholz.

It took Ed VanKirk, of Constantine, Michigan, 3 years and 10 gallons of West System epoxy to build this triple cockpit, 19' barrel-back runabout. The boat, launched in April 2005, was designed by Ken Hankinson. It is powered by a 5.7 liter Volvo Penta conversion (Chevy 350), which turns out approximately 280 horsepower.



Ray Lynch built this site trailer to be used on major renovation projects. Lynch first considered a standing seam roof, but chose the fiberglass/epoxy roof for its strength, weather resistance, lower cost, and lower wind resistance. He planned on adding a plywood/glass/epoxy holding tank for the sink and shower and a custom sink. Lynch lives in Odessa, Delaware.

These cedar-strip kayaks are based on "ancient skin boats of Cape Dorset, Baffin Island." They were built by Phil Pike of Greensboro Bend, Vermont, using West System 105/207 and 4 oz fiberglass cloth. Each boat took about 220 hours to complete, even though the boat on the right was assembled without using staples.

J. R. Beall built this clock to see if it was possible to run a clock with bow power. The bow clock is made of a variety of veneers bonded with West System epoxy and a small vacuum press. This plywood is great because the parts made from it are absolutely stable and allow for very fine tooth profile. The bows are laminated of ash, cherry and ebony. The escapement is called a Grasshopper and is ideal for wooden works because it is free from friction and will not wear the surfaces. The running time of the clock is extended through the use of cords to provide what amounts to a block and tackle arrangement to multiply the movement of the bows. The cord is wound on a spiral grooved windlass called a fusee, which compensates for varying tension. Beall says he has used West System epoxy for years, starting with a constant camber boat. He has started a forum for wood works clock builders, (www.bealltool.com/clockforum) which is open to all. Beall bides his time in Newark, Ohio.

Comparing cost and weight of flat panels

or

How to choose the best materials when building with flat panels

By Jeff Wright

We compared the cost and weight of four panel types:

- Epoxy coated XL Plywood Boat Panel
- Epoxy coated Okoume Marine Plywood
- Epoxy/fiberglass/balsa cored composite
- Epoxy/fiberglass/core cell foam composite

Many WEST SYSTEM® customers appreciate the benefits of cored composite construction. They understand that it creates a part that is lightweight, strong, and stiff. We often receive calls from these customers inquiring about using a composite panel when building or repairing something that would normally be made of plywood. Such projects may include a new center console for a fishing boat or the replacement of flying bridge side shields. Determining the best material requires consideration of many aspects of the project, but often comes down to cost versus weight.

Panel types

Plywood Panel construction requires that the panels be cut to fit and then sealed along all the end grain with epoxy. The panels need to be fastened in place with screws, wire ties, or nails. The panels are then bonded together by applying a fillet of thickened epoxy in the joint and possibly applying fiberglass tape.

Composite Panel construction requires the panels to be cut and assembled the same way but with the additional steps of laminating the panel. The lamination process requires a molding surface to be prepared with a mold release and the materials need to be cut to the required shape. The materials are wet out, possibly vacuum-bagged, and then allowed to cure. After the panel is cured, it is removed from the mold and sanded to remove any sharp edges. Any mold release is removed with the appropriate solvent, and the panel is sanded to ensure good paint adhesion. Finally the needed shape is cut from composite panel, just as it would be from the plywood panel.

A variation of composite construction, often referred to as a “one-off construction,” is to build the part using rigid sheets of foam or balsa core material, and then laminate reinforcing fabric to the shaped core. After the laminate has cured, the part will likely need to be faired, before it is sealed with epoxy and painted. The advantage is that one-off construction eliminates the need for a molding surface.

You can reduce the labor and time involved in using composite panels by purchasing prefabricated panels. Baltek Corporation, ATL Composites, and others offer fiberglass balsa-cored and fiberglass foam-cored panels that are available in various thicknesses with polyester or epoxy laminated skins. They can be machined with normal woodworking tools. These panels may cost more than laminating your own, but labor will be reduced.

Composite panels should have the edges treated in a manner similar to plywood. The foam or balsa core should be sealed to prevent moisture from entering. Low-density cores often require thickened epoxy to be applied to the exposed edges to protect them from damage and to provide a good surface for the final finish.

Cost

Before taking on any project, it is always a good idea to budget for the materials. Generally speaking, a composite panel will cost more than plywood. You will need to purchase the core material, reinforcing fiber (usually fiberglass), and epoxy. Some core materials, such as balsa, will absorb more resin than many of the foams, which will also affect the cost of the composite. A simple plywood panel only requires the wood and enough epoxy for three coats of moisture protection. If you use higher quality marine plywood and protect the plywood with fiberglass cloth, the cost difference is reduced. Laminating fiberglass will require more epoxy than simply coating the wood.

Weight

Weight reduction is the most common motivator for replacing plywood with a composite panel. The weight advantage of a cored panel over plywood increases as the panel gets thicker because the lightweight core material increases while the same amount of fiberglass and resin are maintained. When the thickness of plywood is doubled, the weight is doubled. However, if a ½" thick balsa core with 10 oz fiberglass on each side is increased to 1" thick balsa, the weight only increases 60%. On panels less than ⅜", a composite panel may not have a significant weight difference over plywood.

Material	Epoxy Coated Plywood Boat Panel	Cost	Epoxy Coated Okoume Plywood	Cost	Balsa Composite	Cost	SAN Closed Cell Foam Composite	Cost
Panel / Core	XL Plywood Boat Panel	$12	Okoume Marine Plywood	$21	Contourable Balsa	$27	Core Cell Foam	$38
Fiberglass*					2x745 (12 oz) Glass	$30	2x745 (12 oz) Glass	$30
Epoxy*	105 / 206	$9	105 / 206	$9	105 / 206	$11	105 / 205	$10
Total Cost		**$21**		**$30**		**$68**		**$78**

Figure 1—Cost comparison of ⅜" x 2' x 4' panels

Material	Epoxy Coated Plywood Boat Panel	Cost	Epoxy Coated Okoume Plywood	Cost	Balsa Composite	Cost	SAN Closed Cell Foam Composite	Cost
Panel / Core	XL Plywood Boat Panel	$18	Okoume Marine Plywood	$36	Contourable Balsa	$42	Core Cell Foam	$54
Fiberglass*					2x745 (12 oz) Glass	$30	2x745 (12 oz) Glass	$30
Epoxy*	105 / 206	$9	105 / 206	$9	105 / 206	$11	105 / 205	$10
Total cost		**$27**		**$45**		**$83**		**$94**

Figure 2—Cost comparison of ¾" x 2' x 4' panels

*prices based on proportion of 745-10 size of Glass Fabric and B Group of epoxy used to build a 2' x 4' panel.

A cored composite panel can often perform as well as plywood, even though it is significantly lighter. When the face of a panel is loaded with perpendicular force, the outermost surface of the panel experiences the greatest load. This principle is why a lightweight core with thin fiberglass faces can carry significantly more load than the core material alone. The combination of thin skins and lightweight core can result in a panel as stiff and strong as plywood but with a lower weight.

Stiffness

Increasing the thickness of a panel will increase the stiffness exponentially. You can see this with a yardstick. In the flat direction, it is very easy to flex; on edge, it is nearly impossible to bend by hand. Using a core material to increase the thickness will increase the stiffness very effectively.

The type of core material and the fabric used for the skins will also affect the overall stiffness. Using carbon fiber instead of fiberglass will increase stiffness when the core thickness cannot be increased. Different core materials also affect the stiffness. The density of a core material often indicates its stiffness. Foam cores with very low density are not as stiff as foam that is higher in density. The densities of foam can range from 2.5 lb/ft^3 to over 30 lb/ft^3, giving a wide range of properties. The high-density foams may make for a stiff panel, but the weight advantage over plywood is lost.

Remember that there is a difference between stiffness and strength. Stiffness is often used as the primary measurement when composites are designed for boats. When a panel is stiff enough for an application, in many cases it is strong enough and will have a long fatigue

Material	Epoxy Coated Boat Panel Plywood	Wt.	Epoxy Coated Okoume Plywood	Wt.	Balsa Composite	Wt.	SAN Closed Cell Foam Composite	Wt.
Panel / Core	XL Plywood Boat Panel	8.5 lb	Okoume Marine Plywood	7.5 lb	Contourable Balsa	2.4 lb	Core Cell Foam	1.25 lb
Fiberglass					2x745 (12 oz) Glass	1.3 lb	2x745 (12 oz) Glass	1.3 lb
Epoxy	105/206	1.0 lb	105/206	1.0 lb	105/206	2 lb	105/206	1.3 lb
Total Weight		**9.5 lb**		**8.5 lb**		**5.7 lb**		**3.85 lb**

Figure 3—Weight comparison of ⅜" x 2' x 4' panels

Material	Epoxy Coated Boat Panel Plywood	Wt.	Epoxy Coated Okoume Plywood	Wt.	Balsa Composite	Wt.	SAN Closed Cell Foam Composite	Wt.
Panel / Core	XL Plywood Boat Panel	16 lb	Okoume Marine Plywood	15 lb	Contourable Balsa	4.75 lb	Core Cell Foam	2.5 lb
Fiberglass					2x745 (12 oz) Glass	1.3 lb	2x745 (12 oz) Glass	1.3 lb
Epoxy	105/206	1.0 lb	105/206	1.0 lb	105/206	2 lb	105/206	1.3 lb
Total Weight		**17 lb**		**16 lb**		**8.05 lb**		**5.1 lb**

Figure 4—Weight comparison of ¾" x 2' x 4' panels

life. Swim platforms, decks, and hardtops are situations where a stiff panel is needed to resist flexing and eliminate the perception of being soft or spongy. In these cases, the panel is probably so stiff that the strength is higher than needed to avoid a failure.

When composites are used for critical or highly loaded areas, such as bulkheads, stringers, and hull bottoms, strength needs to be considered. Calculating the needed strength requires a good understanding of the loads applied and the mechanics of cored construction. Before using a composite panel, step back and analyze the situation. Then determine how the panel is loaded and what the consequences are of a failure. In many instances, the project is straightforward, but if there are any concerns, contact an engineer or designer.

The Details

Since weight reduction is the most common reason for using a cored composite panel, it deserves a little more attention. Spending some time to calculate the weight savings will help you determine if the results will be worth the time and money.

Earlier we looked at how to calculate the weight of the new panel and compare it to plywood. This may only be part of the overall weight of the entire structure. For example, if the component being built is a seat, then you need to consider the hardware, seat cushion, and insulation on the back to determine the percent weight reduction for the entire assembly. A 40% weight reduction in the panel may only be a 20% weight reduction of the entire assembly. Also be sure to consider any additional hardware backers that you may need since many light cores will not hold screws as well as plywood.

Plywood that is completely sealed in epoxy will last for many years and offers good balance between weight and strength. However, if weight reduction is a priority, cored composite panels may be the ideal material. Be sure to closely examine the time and money required and how much weight will be removed. With careful planning, you can use this method of construction successfully to help lighten the boat. ■

Plywood that is completely sealed in epoxy will last for many years and offers good balance between weight and strength.

However, if weight reduction is a priority, cored composite panels may be the ideal material.

Practical uses for razor blades

By Tom Pawlak

Necessity is the mother of invention, and razor blades are often called into service for a variety of tasks around the shop other than shaving. Here are a few.

Mini-spreader

Razor blades can be used in a pinch to apply caulks and thickened epoxies with great precision. They do a great job filling isolated pinholes and scratches, especially when the blade is laid at a low angle (nearly flat) when spreading the putty.

Mini-scraper

Sharp razor blades can be used as cabinet scrapers. Use with the blade on edge at 90° or so to the surface. Scrape off small imperfections like drips and dirt specks in cured/dried coatings before buffing or final sanding.

Dull razor blades also make useful tools

Everyone knows how handy sharp razor blades are for removing dried paint from windows. But single-edge razor blades can be modified for removing cured epoxy and dried paint drips on surfaces that are less scratch resistant, like gelcoat, Formica™, and other plastic laminates.

The trick is to dull the razor blade slightly with 600-grit sandpaper. Round the corners at each end of the blade at the same time. Then, try the blade on an inconspicuous spot to be sure it does not scratch the surface.

The edge of the blade acts as a very thin wedge. It works best if you start at the end of the drip that is thinnest. If you can get a peel started, you can usually get the drip off without damaging the gelcoat, Formica™, or well-dried painted surface. The razor blade will remove all but the most stubbornly adhered drips of hardened epoxy or dried paint.

When we were production building the Gougeon 32 sailboats, we found dulled razor blades remarkable for removing drips of cured epoxy from gelcoated surfaces. Even cured epoxy smudges often came off. Without this tool, we were forced to sand off the hardened drips and buff back the shine, which was time-consuming work.

A dulled razor blade also works great for removing old bathtub caulk on fiberglass tub and shower surrounds without damaging the gelcoated surfaces. Be sure to try the dulled blade on an inconspicuous spot to verify that is isn't scratching the surface. If the blade gets a little rough on the edge, run it over the 600-grit paper and smooth it out again. ■

Building a Guillemot kayak

By Jason Havel

I am a Captain in the Air Force and was stationed in Wichita, Kansas, in October2002 when I purchased Nick Shade's book, *How To Build A Strip Kayak*. After the first chapter, I was sold. I ordered the full-size plans for the Guillemot. While on vacation in Texas, I spent about $300 on the western red cedar, purpleheart, and yellow heart, then discovered I was to deploy to Saudi Arabia.

In the evenings prior to the deployment, I machined the cedar into ¼" strips and put the bead and cove on them using a router table. It was during the process of setting up my table saw that I realized how clear D-grade pine can be. I accidentally bought a few long boards of it to build an extra long, table saw fence for ripping the cedar. I was amazed how little grain was visible. That's where the idea of the lighter colored deck came from.

I got 6 or 8 strips on the mold before I left for my deployment. While I was gone, the confrontation with Iraq began. What was supposed to be 3 months turned into 5 months. The air-war ended and I came home and was informed I would be moving from Wichita, Kansas, to Altus AFB, Oklahoma. I knew it was only 300 miles, but I wasn't about to bring a couple hundred strips of cedar and an unfinished boat along for the trip. I spent every spare moment finishing the boat. I finished stripping in June, laid the fiberglass in July, and moved in August.

I used 6 oz cloth with 105 Resin/207 Hardener and was very impressed. Since July in Kansas is typically over 100°F, I was a little hesitant pouring epoxy. When I did all the epoxy work, it was 108° to 112°F. I could thoroughly mix the epoxy, lay it down, brush or squeegee it out, and make it look perfect. Ten minutes later, it started to harden. There were no issues with sheeting or running. In fact, I never saw any anime blush and had zero bubbles. Believe me, I looked for anime blush since every piece of literature mentions it. After an hour or two, I brushed on the next coat to fill the weave and add a nice smooth surface for the varnish. Since the epoxy wasn't fully cured, I got an excellent chemical bond.

I can't say enough about how great the 207 Hardener worked at over 100°F. I coated everything with epoxy, including the deck fittings, before I fastened them to the deck. I sanded the hull with 150-grit sandpaper on a random orbital sander and finished it off with five coats of Z-Spar™ Captains Varnish. Z-Spar also works great at 100+ degrees.

I'd do it again in an instant but next time it will be a canoe since my family will soon be a total of four plus our dog. Even though the kids will be small, it's tough to stuff them and my wife in a single place kayak and expect to get anywhere. ■

1—The stripping of the hull with western red cedar is completed.

2—The inside of the hull is glassed with 6 oz fiberglass cloth. Havel used 105/207 to wet out the cloth in temperatures over 100°F.

3 & 4—Purpleheart provides a nice contrast for the outline of the deck design and deck hardware.
Everything is coated with 105/207 and finished with 5 coats of Z-Spar Captains Varnish.

Giving *Bounty Hunter* a new skin

By Patrick Ropp

Five years ago, Captain Glenn James decided it was time to make improvements to his Coast Guard-inspected charter fishing boat operating out of Edgewater and Solomon's Island on the Chesapeake Bay. *Bounty Hunter* is a 65' cedar-strip planked hull, a one-off Davis™ hull built in 1967 at Harkers Island, North Carolina. The planks are fastened to frames on 16" centers with monel fasteners. The cedar strips are narrow, less than 2" wide, and are edge nailed with monel nails and edge glued.

The 65' strip-planked *Bounty Hunter* after sheathing with fiberglass and WEST SYSTEM epoxy. After 5 years, she still looks as good as she did then. In addition, her new skin quickly paid for itself though increased performance.

An experienced and successful night charterer, Captain James knew his wooden vessel well but found the upkeep and maintenance had increased over the years, taking more time away from fishing and family. He was ready to minimize the maintenance and hoped to increase performance at the same time. Having used WEST SYSTEM® epoxy for other jobs, he turned to the technical staff at Gougeon Brothers for advice and assistance. While Gougeon Brothers does not typically visit vessels, J.R. Watson was attending a surveyor conference in Annapolis and agreed to look at *Bounty Hunter.*

Any wooden boat repair has to be looked at holistically and take into account the owner's requirements and the vessel's construction, condition, and service. (See the WEST SYSTEM 002-970 *Wooden Boat Restoration & Repair Manual* for a fuller discussion of this and of techniques described in this article.) In this case, Coast Guard inspection requirements also had to be taken into consideration. Captain James and his son, Glenn, Jr., decided to restore *Bounty Hunter* by sheathing the hull with epoxy and fiberglass. They not only added many more years to *Bounty Hunter's* life, but the the dryer and lighter hull decreased her draft by 6", increased her top speed from 15 knots to 22 knots, increased fuel efficiency, and gave a smoother ride for paying passengers.

Coast Guard requirements

After the traditional carvel-planked wooden vessel, *El Toro II*, sank in the Chesapeake Bay in 1993, taking the lives of one crew member and two passengers, the Coast Guard developed new policy, the Navigation and Vessel Inspection Circular (NVIC) 7-95. This policy required owners of all Coast Guard-inspected wooden vessels, regardless of construction, to pull a sampling of planking fasteners at regular intervals during credit dry dock or when other indications provided the necessity to do so. An investigation found that degraded fasteners on the *El Toro II* caused a few planks to come loose and fail when she encountered heavy seas. Examination of other planks after the vessel was recovered showed that while many of the fasteners looked good on the surface, half of them throughout the vessel were wasted within the plank-to-frame joints to the point of providing no structural integrity.

Captain James wanted to explore avenues to minimize or eliminate the required pulling of fasteners, which in some instances could cause more damage than good, on *Bounty Hunter.* Unlike *El Toro II*, *Bounty Hunter* was originally glued and nailed together in a monocoque, cedar-strip construction, so the skin acts as one complete shell. Vessels constructed like this are ideal candidates for sheathing with fiberglass and epoxy because they require considerably less preparation. Once a vessel is sheathed, she will be considered a "composite" hull, one made of different materials, and consequently be subject to less stringent and invasive inspection standards than a traditional wooden vessel.

Captain James was required to seek Coast Guard permission prior to modifying the vessel. Here is the process that WEST SYSTEM recommended. The Coast Guard approved the plan and monitored each step carefully throughout the project. Sheathing *Bounty Hunter* proved to be an excellent decision, and the project was completed without reservation by any of the parties.

Hull preparation

Preparation is a common thread in any project. Sheathing a wooden hull with fiberglass is no different. Sheathing is only recommended for vessels that have planks that are edge glued together and are securely attached to the frames.The following steps were taken to ensure *Bounty Hunter* was structurally sound prior to sheathing.

All paint and loose material were removed from the exterior of hull.

The vessel was thoroughly inspected for damaged or deteriorated hull planks, seams, and fasteners. Any degraded items were removed and replaced in kind. Wood replacement adhered to applicable Coast Guard regulations and policies, such as NVIC 7-95. At least an 8:1 scarf is normally recommended for scarfing new planks into place, but longer scarfs are always a good option to maximize the bonded surface area. Any deteriorated seams were cleaned and old material removed. Mixed epoxy, thickened with 403 Microfibers to a peanut butter consistency, was forced into the seams to bond the planks back together as needed. Monel fasteners similar to the original ones were used to refasten planks.

High spots on the hull were taken down because the fairer the original hull is prior to sheathing, the easier the final hull will be to fair later.

The moisture content of the vessel was checked prior to sheathing to ensure that it was between 8%-12%. Remember to use a moisture meter recommended for the specific application (wood, fresh water service, salt water service, etc.); otherwise erroneous readings may be obtained.

Sheathing material

WEST SYSTEM 105 Resin was used with 206 Slow Hardener, combined at the proper mixing ratio, 5 parts 105 Resin to 1 part 206 Hardener by weight or volume. To make volumetric measuring easier, a cylindrical mixing pot with straight, vertical sides and a metering stick with pre-measured marks were used. Quality control was in keeping with WEST SYSTEM 000-742 *Quality Assurance Considerations*. Quality control dyes—yellow to the resin, blue to the hardener—were added at the factory. When a consistent green color was obtained, the two parts were properly mixed and ready to be applied.

The fiberglass cloth was two layers of 7.5 oz biaxial (+/- 45°) cloth stitched to .8 oz chopped strand mat. The orientation of the fiberglass (vertical or horizontal) was insignificant; in this case, it was applied vertically. Edges and seams were staggered at least 3" to gain full advantage of the fiberglass' strength.

Fiberglass application

Applying the cloth was tiring and required 3 "animals" with stamina and strength. The two layers were completely applied in just four days. Work was done for about two hours on one layer and, once this was tacky, a second layer was applied on the tacky first layer to promote a primary chemical bond between the two layers. Once applied, the cloth was worked hard to remove any entrapped air since air pockets in a laminate can reduce its strength dramatically. A resin-to-fiber ratio of 50:50 by weight produces optimum physical properties for a hand-laid laminate. However, a higher percentage of mixed resin is acceptable and not uncommon. A resin-starved laminate can weaken the structure.

The first layer was applied so that the resin-rich chopped strand mat was next to the prepped hull to improve adhesion. Even though the *Bounty Hunter* was painted white, the second layer was applied with the mat outside to help prevent print-through.

A layer of epoxy/407 Low-Density fairing compound was applied to the fiberglass surface and faired later. Up to a ¼" of fairing compound was applied to create fairness throughout the length of the 65' vessel. The fairing layer also helped to disguise print-through and minimize its effects.

Final fairing and finishing

Bounty Hunter was sanded to remove high areas and then faired. The fairing compound consisted of WEST SYSTEM 407 Low-Density Filler and the same 105/206 epoxy used in the laminate, mixed to peanut butter consistency (approximately 12 oz of filler to 1 qt of mixed epoxy).

Once the hull was sanded fair, two coats of Awlgrip™ High Build Primer were applied, followed by one coat of regular primer. *Bounty Hunter* was finished off with one coat of Awlgrip paint.

After 5 years of service, the hull is clean and shows no sign of degradation. It has held up to the extreme environment charter vessels face and has given Captain James a hull with minimal maintenance. Awlgrip and other two-part polyurethane finishes, although not inexpensive, are among the toughest on the market and have proven themselves in all types of adverse conditions.

Continued maintenance= long-term satisfaction

Continued maintenance ensures the longevity of a wooden boat restoration project. Deterioration in the final painting system needs to be addressed as soon as practical to limit exposure to ultraviolet rays of the sun. Dings and cracks to the hull also need to be quickly addressed to maintain the moisture barrier and protection that the new sheathing provides to the composite skin.

Ventilation also cannot be overemphasized. Captain James evaluated the ventilation in *Bounty Hunter* and determined that plenty of air was being changed throughout the vessel, including the bilges and other voids. Keeping the boat's interior as dry as possible is the best preventive maintenance for preserving the structure.

Time is the test

Bounty Hunter was sheathed 5 years ago and still looks as good as she did then. In addition, her performance characteristics increased, so the new skin paid for itself quickly. Because of success of *Bounty Hunter's* restoration, Glenn James, Jr. has taken on five similar projects since then.

The successful sheathing of *Bounty Hunter* with fiberglass and WEST SYSTEM epoxy gave Captain James and the Coast Guard confidence to turn a wooden boat into a lower maintenance composite hull. Now, with less time spent to maintain wooden boats, there's more time to enjoy the fishing. ■

Patrick Ropp was a Gougeon Brothers Technical Advisor until 2001 when he returned to active duty as Lieutenant Commander in the Coast Guard. He is also pursuing an engineering degree at Michigan State University.

Building a

Planter Box

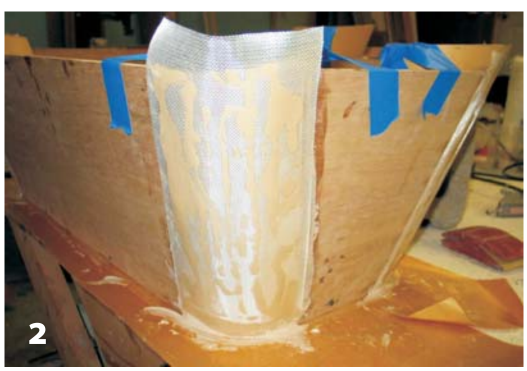
By Brian L. Knight

My wife gave me the basic guidelines for a planter box she wanted me to build. First, keep it cheap. Second, she wanted an "L" shape. Third, she provided some rough dimensions. The design was up to me. Logic seems to abandon me when I design something, and this project was no exception. A nice, straightforward box with square corners should have been the default. But after some doodling on paper, I decided to build a planter with flared sides and rounded corners.

First, the inexpensive part

I looked around my shop and found a scrap of ¾" treated plywood left over from another project. This made a good bottom for the planter. I found enough ¼" lauan plywood to make the sides, and I made the molds for the curved corners from an empty cardboard shipping tube. As for the design, I decided on a flare of 15° for the sides and a radius of 2⅝" (the radius of the shipping tube) for the corners.

1—The planter began as sheets of ¼" lauan plywood temporarily connected by sections of 5¼" diameter cardboard shipping tube at the corners. The shipping tube held the plywood sides in position while acting as a mold for laying up permanent fiberglass corners.



2—The ¼" gap at the edge of the plywood sides was filled with thickened epoxy. A layer of glass tape was laid over the corner and smoothed into the thickened epoxy. The glass was then wet out with epoxy and the edges were sanded smooth when cured.

The bottom

On the sheet of ¾" treated plywood, I drew the "L" shape, using the dimensions specified by my wife. For the round corners, I used the cardboard shipping tube to lay out the curve. The edges of the plywood base have a 15° bevel to provide the flare for the sides. I cut all the straight line sections on my table saw and sawed the round corners with a saber saw set at a 15° angle.

The sides

I ripped the ¼" lauan plywood into pieces about 15" wide (tall) to make the sides of the planter. Because the sides are leaning out 15°, the plywood sides are wider at the top and narrower at the bottom. I set the miter gauge on my saw to 75° to cut the ends of the lauan pieces. These pieces were glued to the 15° bevel previously cut on the bottom piece with a uniform gap left at the corners. The sides were also filleted to the bottom to provide additional surface area for the glue joint.

The corners

The gap at all the corners would be filled by laminated fiberglass; however, I needed a temporary mold to bridge the gap between the plywood sides and give the proper curved shape to the corners. I sawed sections of the shipping tube long enough to be used as male molds. I applied packaging tape to the cardboard for mold release, but cooking parchment paper or waxed paper would have worked just as well. I cut the bottom of the tubes to approximately 23°, so they rest on the bottom piece. Masking tape secured the sections of tubing at the top and one drywall screw in the bottom *(Photo 1)*.

I applied a thick mixture of WEST SYSTEM® epoxy/410 Microlight™ to the taped surface and applied 6" fiberglass tape to the wet mixture. I smoothed the fiberglass with my hands to distribute the epoxy/410 evenly below the cloth *(Photo 2)* and applied neat epoxy to finish wetting the cloth. After allowing the coated fiberglass to cure, I feathered the edges of the tape and applied one layer of 6 oz cloth to the entire outside of the planter, followed

3—After the mold/tubes were removed, a layer of 6 oz cloth was applied to the exterior. Holes were drilled in the bottom for drainage.

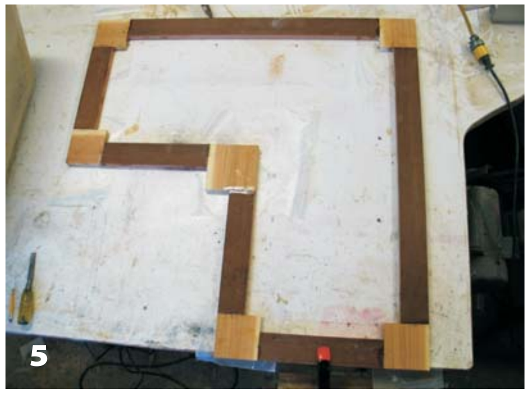
4—Excess glass was trimmed flush with the edge of the plywood, and the interior was given a couple of coats of epoxy.

by several coats of neat epoxy to fill the weave of the cloth. This layer of cloth ties the entire box together *(Photo 3)*. When the epoxy cured, I faired the outside of the planter with lots of sanding. I drilled several ¾" drain holes in the bottom (*Photo 3)* and later glued on wood pads so the planter would have a little air circulating under it *(Photo 6)*.

Finishing

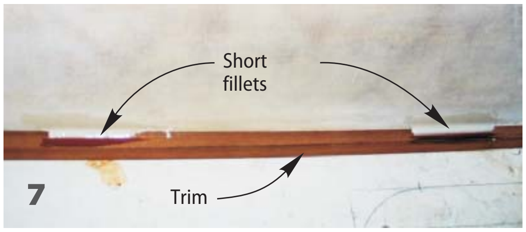
At the top edge of the planter, I trimmed the excess fiberglass and ground the corner pieces even with the plywood edge *(Photo 4)*. To prevent moisture from attacking the plywood, I coated the inside surfaces with a couple of coats of epoxy.

Next, I fabricated and installed the top trim that covered the raw edges of the plywood and fiberglass. It was made from redwood with cedar corners for contrast (this was the one area where I departed from my wife's original specification of "cheap"). To rough-out the trim ring, I cut square corner blocks and fastened them to the end of the redwood strips with biscuits *(Photo 5)*. The square blocks made installing the biscuits much easier than trying to work with rounded corners. The blocks were later rounded with a saber saw and the edges of the entire trim assembly were eased with a ¼" radius round-over bit. Epoxy fillets fastened this assembly to the planter sides *(Photo 7)*. I coated the top of the planter with WEST SYSTEM 105/207 and then varnished with 3 coats of Captain's™ 1015 Spar Varnish. The sides were painted with the house paint I use on the trim of my house *(Photo 8)*. ■



5—The top trim was made from redwood with cedar corners. The square cedar corner blocks were fastened to the end of the redwood strips with biscuits. The blocks were later trimmed to shape and the edges of the entire trim assembly were eased with a round-over bit.

6—Blocks were glued to the bottom for air circulation and the sides were glued to the trim.



7—When the planter was properly positioned, the sides were attached to the trim with short fillets.

8—The finished planter. The trim was coated with 105/207 epoxy and finished with spar varnish.

Improved mold strongbacks

By Tom Pawlak.

Back in the 1980s, Gougeon Brothers was one of the largest producers of wind turbine blades in the US. The blades were built of wood veneer and epoxy, and varied in length from 10' to 70'. They were built in halves and vacuum laminated in female molds built with WEST SYSTEM® Brand Epoxy. Tolerances were tight, and every aspect of the tooling was critical, from molding to assembly. If something wasn't right when the two halves were glued together, there wasn't much you could do to make it right later.

The most difficult tolerances to maintain were span-wise straightness and twist. Early strongbacks for molds and assembly jigs were made of wood and were built like tall and skinny "I" beams. Initially, everything worked well. But as the seasons changed and the wood picked up moisture, and the summer temperatures in the shop went up, we were pushing the limits of the tolerances. The engineers figured it was a combination of forces caused by wood's volumetric change, with changes in moisture content and difference in coefficient of thermal expansion between the wood strongback and epoxy/fiberglass molds. Our short-term fix was to cut the mold free from the strongback and isolate it with plywood supports (⅜" thick) that were installed perpendicular to the length and located every 16" to 24" apart. They ranged from 4" tall at the root end to 12" tall at the tip end of the mold. The differences in height were due to the fact that the molds were tapered to mimic the blade half-geometry (thick at the root end and tapered to thin at the tip). The plywood supports were attached to the top of the strongback and to the backside of the mold with thickened epoxy fillets. Separating the mold from the strongback with the thin plywood supports meant slight changes in length between the two did not cause a problem. This is because the supports easily deflected to allow relative movement but had almost no effect on span-wise straightness. Luckily the problem was caught early, but we decided we needed a better strongback design that would be more stable.

This box-beam strongback supports a female mold for a 70' Westinghouse wind turbine blade. (The plug that was used to build the mold is in the mold.)

The strongback is stiffened by ⅝" rebar glued into 1½"×1½" longitudinal stringers, one in each corner and one along the top and bottom surfaces.

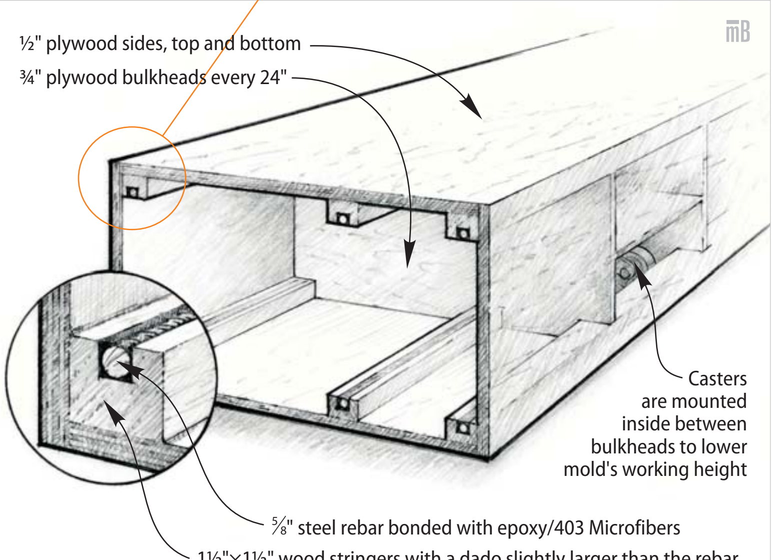


Figure 1

The solution was to make a box beam out of plywood and epoxy. This in itself provided significant improvement, but the engineers went one step further. They incorporated steel rebar originally designed for reinforcing concrete into the four corners of the box beam. The rebar, welded to full lengths, was glued into 2"×2" wood stringers that ran full length along the four corners of the box beam. To make room for the rebar, a slot was cut into the wood stringers that was wide enough and deep enough to accept the steel. Epoxy thickened slightly with 403 Microfibers was used to fill the gaps in the groove surrounding the rebar after it was in position *(Figure 1)*.

On molds up to 20' in length, we used ⅜" diameter rebar. On larger molds, we used ½" or ⅝" diameter. The 70' long mold strongbacks were reinforced with 6 stringers made of ⅝" diameter rebar, one in each of the four corners and an extra one in the middle between the corners of the top and bottom.

When the strongbacks were used for blade assembly jigs or for saw jigs, they were anchored to the floor to keep things stable. If the strongbacks were used to support molds, wheels were mounted inside the strongback (on the larger molds) to keep the center of gravity low and to keep the height of the mold reasonable. On smaller molds where the width of the strongback was too narrow for a caster to pivot inside the bow beam, the wheels were mounted on the outside of the structure.

Mounting wheels under molds with strongbacks can present some dilemmas. The wheels tend to get in the way of your feet. If you mount wheels under the mold strongback, you need to shorten the height of the strongback to make up for the wheel height. Otherwise, the mold gets too high for people to work on. Unfortunately, shortening the height makes the strongback less stiff, which can be a problem.

Mounting the wheels inside the strongback works best as long as you allow room for wheels to swivel without interference. Another option is triangular shaped strongbacks. We found this to be the best solution for 20' to 30' mold lengths. By positioning one of the three sides horizontally, wheels could be mounted under the mold on angled brackets *(Figure 2)*.

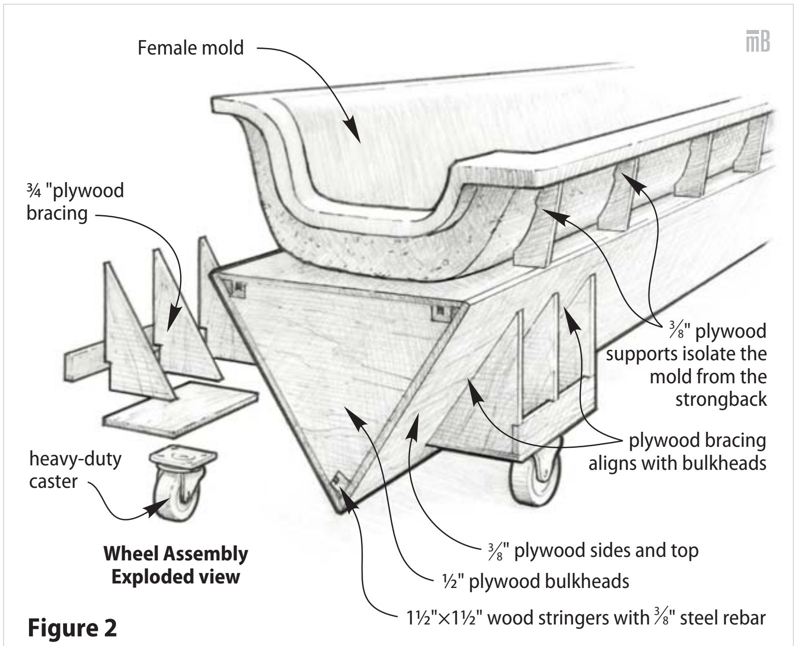


Figure 2

This allowed room for the wheels to pivot without getting in the way.

After the blade halves cured, they were pulled from the molds, positioned in saw jigs, and trimmed along the leading and trailing edges. From there, the blade halves were moved to glue jigs where a shear web was installed on the inside of the high-pressure side. Eventually, the two halves were glued together with thickened epoxy. ■

Staudacher strongbacks

By Brian L. Knight

Jon Staudacher, of Staudacher Hydroplanes and Aircraft, has been using a long, very flat, work table/strongback that is mounted on casters. The table was originally 32' long, but because of space considerations, Jon has since shortened it to 20' *(Photo 1)*. Four rubber casters support it, one at each corner *(Photo 2)*.

Jon uses this table as a surface to assemble airplane wings, so it cannot have twist or sag. Because of its stiffness, the table is not dependent on having an extremely level floor. When the table is moved to a different location, it is easy to shim it level. It is stiff enough that it does not sag, and if there is a little twist, it is easily shimmed out. Since the tabletop is the reference point for all objects being built, the table does not have to be perfectly level, but it must

1—This table is used to assemble airplane wings. It must not twist or sag. The table was originally 32' long, but has been shortened to 20'. Four rubber casters, one at each corner, support it. Built as a strongback, it spans 20' (previously 32') without sagging.

2— Four rubber casters, one at each corner, are mounted to brackets at the ends of the table to give it portability.

3—Access holes to storage spaces are centered between the top and bottom rails, and have oval ends.

4—The 1×4s that sandwich the top and bottom of the front and back panel are scarfed to improve straightness.

have no twists. If Jon expects to use weights for clamp pressure, as he often does when building the frames for wings, he temporarily shims the bottom rail of the table so it cannot sag under the weight. The table doubles as a strongback with grid lines drawn on the top for locating frames.

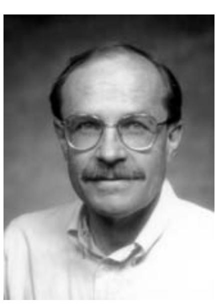
A table like this has to be built carefully, but the materials that go into the construction are very light and readily available. The table is a long box beam made with plywood, and all pieces are glued together to make the table very rigid. There are plywood bulkheads every 4' to keep the front and back of the table from buckling. In turn, the front and back of the table keep the top flat, without twist. The top is supported on 16" centers to prevent any drooping of the plywood top between bulkheads. In order not to waste space, storage is built into the front of the table. The access holes are centered between the top and bottom rails, and have oval ends. These are important dimensions. If the access holes were sawn too close to the bottom or top surface, the table would lose its rigidity. Because square corners can cause stress concentrations, the holes have rounded ends *(Photo 3)*.

Full or half sheets of plywood are used where ever possible. Construction starts by sandwiching the top and bottom of the front and back panel between two 1×4s *(Photo 4)*, which were scarfed together to improve straightness. A ¼" plywood bottom panel was glued to the bottom rails. Then ¼" plywood bulkheads and supports for the top were installed. The top was glued to the top of the side rails, bulkheads, and supports. Finally, brackets of scrap OSB were bolted to the ends of the table to support casters *(Photo 2)*. ■

Brian Knight steps down

Brian Knight, a WEST SYSTEM® Technical Advisor and contributing *Epoxyworks* editor since 1992, has retired. Despite the curmudgeon persona that no one bought for a minute, Brian's steadying influence and sage advice will be missed by customers and by those who worked with him. His technical knowledge reflects the depth of his experiences in research and product development and as a highly-skilled builder.

In previous lives, he was a teacher and a building contractor. He restored older houses, built new buildings, repaired wooden boats, built racing hydroplanes, and created a 40' composite sculpture.



He has been building a stitch and glue power boat for a number of years now. In his new life, we're certain he will have more than enough time to finish this project, entertain his grandkids, and improve his golf game. ■

Randy Zajac steps up

Randy Zajac spent a few summers here as an intern while attending Ferris State University. After graduating with a BS in Plastics Engineering, he is back as our newest WEST SYSTEM Technical Advisor.

He has lots of experience using epoxy for repairing composite body panels on his own snowmobiles, trucks, and jet skis. When he's not repairing his toys, Randy enjoys finding ways to make them go faster. He also races cross-country mountain bikes in the Michigan Mountain Bike Association Championship Point Series expert class. He hopes to win a race on a homemade advanced composite frame someday.

Randy is currently working in a group to build a 12' Shellback Dinghy and will be working on a vacuum infused kayak and a strip plank canoe on his own in the near future. ■

For information about WEST SYSTEM® products or technical information for a building or repair project, West System, Inc. offers a range of detailed publications that can help you get started. These publications are available at your local WEST SYSTEM dealer or by contacting West System, Inc.

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The Gougeon Brothers on Boat Construction — 5th Edition available

Our usual *Epoxyworks* schedule has been on hold for most of 2004 and 2005 while our editors and technical staff completed the 5th Edition of *The Gougeon Brothers On Boat Construction*.

This edition comprises a thorough review of best practices, 20% new and updated material, and a revised layout for easier navigation. Each chapter was reconsidered in terms of evolving technology, new techniques, and the successes and failures of over thirty-five years of experience. We believe that the updates and improvements will enhance the value of this reference text for amateur and experienced professional alike.

You will find detailed discussions of a wide variety of wood/epoxy boat building techniques, along with focused discussions on interior construction, application of fabrics and fiber reinforcements, and much more. We spent considerable time and attention on updating the chapters on hardware and fastener bonding, a hallmark of versatile, high-performance wood/epoxy construction. The simple proven techniques outlined in the book provide builders with a durable high-performance technology suitable for marine and non-marine applications alike.

We have been encouraged by the resurgence in amateur boatbuilding over the last ten years, especially in the area of paddle sports. Many people have cut their teeth on small craft and are feeling ready for a more challenging project. If you have built a kit kayak or stripper canoe and are planning that next boat project, this is the primary source on the techniques and materials needed to build any wood/epoxy composite boat, no matter how simple or complex.

As we have shared in these pages for over twenty-five years, epoxy composite technology is versatile, durable, and empowering. This book grounds you in the many techniques that allow you to build just about anything you can dream up. If your dog-eared, shop-worn copy of an earlier edition hasn't been returned by that friend who borrowed it, here is your chance to replace it with an up-to-date expanded copy.

The 5th Edition of *The Gougeon Brothers on Boat Construction* is available through WEST SYSTEM Dealers or contact West System Inc. at 866-937-8797 (toll free) or visit westsystem.com. Hardcover, 406 pages. Price: $36.40 US plus shipping.

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Epoxyworks online

If you are a new subscriber to *Epoxyworks* or haven't diligently saved every back issue in a three-ring binder, you can find issues going back to *Epoxyworks 14* (fall 1999) at www.epoxyworks.com. You can also click on the 'Epoxyworks Magazine' tab on the westsystem.com site. Browse back issues or find articles on specific topics by clicking on 'Articles by Subject'. Articles are arranged under Epoxy Techniques & Materials, Boat Repair & Restoration, Boat Construction, Epoxy's Non-Marine Uses, Readers' Project Gallery, and the Project Directory. We hope to add older issues over time, while continuing to add the current issue twice a year.

Sign maker Bill Boudreau of Maria, Quebec, uses WEST SYSTEM® epoxy to build conventional laminated cedar signs like these below. He also uses epoxy for projects that go beyond conventional sign making—like this 15½' guitar and an 8' tall tooth. The monster molar was built of wood, chicken wire, insulating foam, fiberglass, and epoxy. It's finished with polyurethane paint and has held up very well under conditions of extreme cold and a salty environment.

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