EPOXYWORKS®

BUILDING, RESTORATION & REPAIR with EPOXY

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Historic Wooden Dories in the Grand Canyon

Cover story

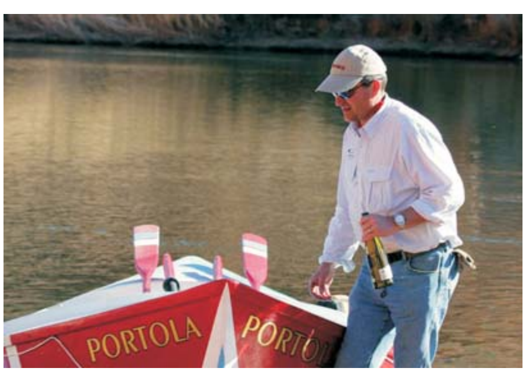
Author Greg Hatten battles white water on a trip through the Grand Canyon in his replica dory, *Portola*.

By Greg Hatten

On March 21, 2012, river runners from five Western states, Canada, Japan, and Chile launched five homemade boats, replicas of important historical designs, in an attempt to complete a 24-day self-guided traverse of the Colorado River through Grand Canyon. The replica boats represented a snapshot of river running in Grand Canyon during the 1950s and 1960s, just before Glen Canyon Dam took control of the Colorado River through Grand Canyon.

I built one of those boats: the 1962 *Portola*, originally built by Keith Steele for the Martin Litton/Brick Mortenson/PT Reilly trip of that same year. It was one of the last trips to experience the Colorado in its wild state before the Glen Canyon Dam was completed in 1963.

WEST SYSTEM and Six10 Epoxy Adhesive were used exclusively in *Portola's* construction.



After her christening, *Portola* would face some of the world's biggest white water on her maiden voyage.

My objective was to replicate *Portola* from the building material to the paint scheme to the oar length. Even though *Portola* vanished years ago in a fire, the *Susie Too* (with an identical hull) survived and is on display in the Grand Canyon National Park. With a line-drawing from the Susie Too and more than 50 pictures of the finished *Portola*, I went to work with over 8 months to complete the dory and launch it on the Colorado River.

Having built a McKenzie style drift boat a few years ago, I turned to my favorite techniques and brands for this historic project. Because the Colorado River puts an enormous amount of pressure and stress on every boat, high quality materials are essential. The only brand of epoxy I even considered using was WEST SYSTEM®, and Six10® Thickened Epoxy Adhesive worked extremely well.

Somehow, even with all that time, the deadline crept up on me. The paint (not the epoxy) was still drying as I pulled the boat out of my Oregon driveway and headed for the Colorado River. Trailering the boat over 1,200 miles across four states was made even longer knowing my "untested" *Portola* would have to withstand some of the biggest white water on the planet for almost 300 miles on her maiden voyage.

Suzie Too and Portola tied up at a quiet spot on the Colorado river.

Left—Hatten keeps his eyes open for the next rapids on a trip down the Colorado.

Right sequence—Maneuvering through a big rapids take lots of skill and a well-built boat.

Dave Mortenson photos

I held my breath as I backed it down the boat ramp at Lee's Ferry. It floated off the trailer and continued to float for the next 24 days. After a few "get-acquainted" close calls and a few riverside repairs, we worked well as a team. In 1964, they referred to these boats as "monsters" until they had them on the river and found out how responsive and nimble they were in big water. I continued to hold my breath, however, through Hance, Crystal, Bedrock, Lava, and many other rapids as waves of water covered me and *Portola* several times a day.

The *Portola* and a few other boats from this trip will be featured at the Port Townsend Wooden Boat Festival in September. More information about the journey of these five replica boats can be found on HistoricRiverBoatsAfloat.org. Check out the daily blog that we beamed up via satellite every day of the trip. ■

There are many spectacular views in the world that can only be accessed by boat.

Make Your Own Grapnel

By Capt. J.R. Watson

A grapnel or grappling hook is a device with curved tines or “flukes” attached to a rope used for retrieving overboard objects. For pleasure boaters, a grapnel should be small, lightweight and made of non-rusting materials. I think every cruising boat should have one. The only ones I could find were too large, or were a folding grapnel anchor, not a retrieving hook.

To get what I wanted I had to make my own. I settled on a treble configuration and chose galvanized steel.

Although plenty strong, this grapnel is intended for light service, up to about 40 lb, which is about as much as the average person can lift with a line anyway.

Grapnel specifications

Length	8½"
Overall diameter	6"
Weight	2 lb

Constructing a grapnel like mine calls for a few common, inexpensive components:

3–8" × ⅜" dia. galvanized spikes
1–8" × ¾" galvanized pipe
1–5⁄16" × 2" galvanized forged eyebolt

WEST SYSTEM® Epoxy (105 Resin and 206 Slow Hardener)
1–807 Syringe
Plumber’s putty

Tools required

Vice
Propane Torch
Channel locks
3" dia. × about 12" pipe
Plywood scrap
String

The plywood stand keeps the flukes aligned and holds the shank vertically so it can be filled with epoxy.

The finished grapnel

Step 1. Cut the pipe to 6¼" long removing any threads. This pipe is now your grapnel’s shank. File the ends flat and smooth.

Step 2. Cut the heads off the spikes to make the flukes. Place one spike in a vice, heat with a propane torch and bend to shape in steps using channel locks and a 3" pipe as a lever. They bend easily. When the fluke is at the desired shape, quench it in water to toughen the steel a little. Repeat until all three are completed. They should all be about the same shape.

Step 4. Using a ⅜" or ½" scrap of plywood, fashion three ⅜" wide slots cut as shown so the three flukes rest in the slots 120° apart in the end view. In a side view you want the curves of the flukes even, so the straight ends of the flukes stand vertical and level. This is the crown of your grapnel.

Step 5. Slide the shank over the three flukes until it stops where the bends begin. At the crown end of the grapnel, seal the shank’s end with plumber’s putty so the epoxy won’t run out of the end. Use a bit of string to suspend the eye bolt (with the nut on, just past the bolt’s end) from something in your shop and adjust until its shoulder is even with the shank’s cut end. Eyeball and adjust until you’re satisfied that it’s straight.

Step 6. Mix three pumps strokes of 105 Resin with three pump strokes of 206 Slow Hardener. This isn’t essential, but if you have 404 High Density filler on hand you can add a heaping tablespoon to the epoxy. Stir the epoxy mixture thoroughly. Pour into an 807 syringe and inject in the opening along side of the bolt. Reload the syringe and keep filling the shank until full. Allow to stand 15 minutes, then top it off. The surface tension of the epoxy will create a slight dome on the end, covering the cut end of the shank. Allow it to cure overnight.

Step 7. The next day, remove the plumber’s putty and scratch the cavity with an awl. Place the grapnel in your vice, crown up, and fill this cavity the same way you did in Step 6. It should only take a little epoxy.

You can paint the grapnel a bright color to help you see it better under water but I left mine galvanized. I tie the bitter end of a ¼" line about 50' long to a cleat, toss the grapnel in the direction of the overboard item, then drag it to me. (Never use a grapnel where there could be submerged cables or electric wire.) ■

Ted Moores is a renowned boatbuilder, author and teacher whose name is synonymous with stripper canoes. He and his partner Joan Barrett own Bear Mountain Boats in Peterborough, Ontario. This is the fourth in a series of articles by Ted Moores on lessons learned from 35 years of wood/epoxy boatbuilding and incorporated in the building of his 30' Electric Hybrid Launch *Sparks,* which was launched in June of 2010.

Note: The method described here is an advanced technique that has not been studied by Gougeon Brothers. While we have cautioned against the thinning of epoxy, Moores is an experienced professional and has produced exceptional results using this technique. For more information about thinning epoxy, visit www.westsystem.com/ss/thinning-west-system-epoxy.

Ted 's Cheap Tricks

LESSON 4

Sealing and Priming

By Ted Moores

The way a finish ages has everything to do with the way it is anchored to the wood. Sealers and primers are often taken for granted; we simply read the can and follow directions. There are so many reasons for using a sealer and many methods for applying them. Let's look at what we learned while sealing *Sparks*, the electric launch I built.

Getting *Sparks* ready for launching this spring, I thought about sealer and how our sins of omission had come back to bite us. When we built her, finishing the deck was one of the last things on the list. The deck is a veneer of ¼" cherry, basswood and white oak over ½" plywood that had been glassed both sides. My plan was to saturate the deck overlay with WEST SYSTEM® 105 Resin/207 Special Clear Hardener®, bury it under three full coats of this epoxy, then varnish. As can happen to good intentions, we were running out of time when the Windsor locks opened, so I took a calculated risk to save time. And it almost worked.

I had compromised, eliminating the three buildup coats of epoxy and relying on the epoxy saturation coats only to be a stable base on which to build the varnish. I'd thinned the first coat of epoxy with about 10% lacquer thinner and allowed it to soak in. About five hours later I spread on a second coat of unadulterated epoxy. At this point, the surface was very level with most of the grain filled.

Since the wide blade of the squeegee was controlling the thickness of the epoxy, a quick sand to cut the gloss was all that was needed to get it ready for varnish. Working on this smooth surface meant that building up the varnish went fast. There was little open grain to fill with varnish, so very little sanding was required to keep a high gloss, smooth surface building. If the three buildup coats of epoxy had been applied, it would have meant a bigger fairing and sanding job to fair the surface.

Sparks' **cherry, basswood and white oak deck after refinishing.**

The Mistake

This technique worked great on the cherry planks and basswood splines because the wood was porous enough to suck up a lot of that first coat of epoxy. The problem was with the white oak covering boards. I have never been a fan of oak, but it was traditional for covering boards on the steam launches in this area so I had to try it. What little epoxy there was over the wood bonded just fine, but the finish split along the grain in quite a number of places. My guess is that because the oak was so hard and open grained, it absorbed very little of the thinned epoxy. This allowed moisture to escape through the varnish and thin epoxy film, shrink the wood, split the finish and let the water in.

The Fix

The cracks were repaired before launching the second season but the splits opened up again before fall. I just couldn't see myself chasing cracks in the deck every year on a boat that was intended to require minimal maintenance. The only answer was to strip the varnish and epoxy, sand down to bare wood, go back to plan A (three coats of 105/207) and get it right.

The Interface

Sealer/primers are used for a number of reasons. They can make two finishes chemically compatible, or fill open grain so that the final finish builds faster, or add a pigment close to the final finish to get a jump on building the final color. The most important use is to get some penetration to create a mechanical bond inside the wood that the final finish can attach to.

Cheap Tricks

WEST SYSTEM 105/207 is ideal for saturating the wood fibers and filling the open grain thus creating a tenacious mechanical bond while leveling the surface. A varnish sealer out of the can will enhance the bond between varnish and wood, but epoxy, when used as a sealer, offers several advantages.

Saturating Epoxy Sealer

When epoxy is used as a saturating sealer it greatly increases the density of the surface. This is ideal for soft wood that will be getting some abuse. The greater density keeps the soft wood from caving in and cracking the finish.

Pre-finishing

One of my most useful cheap tricks is pre-finishing parts that will be both glued and varnished or painted. This saves a lot time and damage control while improving the final product. Using WEST SYSTEM Epoxy as the sealer means that the whole part can be saturated, yet the surfaces will be compatible with both epoxy and oil-based finishes. Working on individual pieces at the workbench, I can avoid applying and sanding in awkward corners. Hard-to-reach surfaces receive equal protection and finish. Sealing the end grain before assembly saves considerable time; you won't have to wait for the multiple per-coat applications to soak in before applying thickened epoxy.

Applying Sealer

Note: Most of these techniques are relevant for applying all types of sealer.

Preparing the surface for sealer is not just vanity. Carefully shaping and sanding a wood surface in preparation for finishing is about getting the best bond with the fewest number of steps. The bonus is that it will look good, age gracefully and simplify refinishing in the future.

Sanding

If it is not going to be seen, why sand? Any piece of wood that is ready to be finished will have been worked in some manner. It could have been run through a planer or plywood sanded at the factory where some of the wood fiber has been compressed into what appears to be a smooth, clean surface. When the sealer is applied, the bruised fiber swells up and stands on end. Sanding this tough, reinforced fuzz can be avoided by dampening the surface with water prior to sanding to bring up the fuzz. When dry, it will be easy to sand. For those who care how a certain surface will appear, dampening it offers a preview of the final finish, revealing any flaws to be taken care of instead of letting them turn up as a surprise at the end.

The underside of *Sparks*' cabin top is a basswood veneer applied in a traditional ceiling pattern. Working overhead is never pleasant so we finished it before installing. The basswood was very thirsty and absorbed enough to make a dense, stable base for varnish. A second coat was applied, rubbed in and wiped off to create a glossy surface. The scuffing pad was the ideal tool for this step as it fit into the cracks between the planks and worked the groove into a smooth, repeatable shape. Excess epoxy in the crack was picked up by the pad, preventing flooded joints.

Machine sanding

When we choose a type of sander for a particular job, we look for one that will best develop the shape we want. This means that to follow that shape it makes sense to use the same sander for all of the subsequent sanding steps. Changing sanders will mean removing more of the coating than necessary to fair the surface and cut all the gloss on the epoxy or finish coating.

Creating Durable Outside Corners

No finish is going to protect a sharp outside corner. The edge is often the most vulnerable area and gets dinged up first. The problem is that the brush applying the finish splits around the corner and deposits very little material. If by chance the finish does follow the corner, the surface tension of the finish will break along the sharp corner and pull the material back from the edge. Then when it comes time to sand between coats, the sandpaper wraps around the corner and takes off anything that might still be there. Fortunately there are a number of simple things we can do improve the odds of a durable edge.

Break the Edge

The least you can do is knock off the edge with a block plane and a few aggressive passes with 80-grit sandpaper. We keep a little router with a small round-over bit set up as a quick way of getting a soft corner that still looks crisp yet takes a uniform, durable finish.

Scuff the Edge

When sanding between coats of sealer or finish, avoid using sandpaper on the edges. The stiff paper will cut a line through the finish rather than cut the gloss evenly around the corner. What you want to use are scuff pads (see sidebar page 4).

Applying the finish

Apply the finish to the edge first using a diagonal stroke to completely coat the corner. It will run on either side of the corner but by coating the flat surfaces next, the runs are taken care of. By dealing with this hard-to-see and easy-to-miss edge first, we can coat it systematically to ensure complete coverage.

Applying a Penetrating Sealer

The purpose of a penetrating sealer is to saturate the wood fibers and occupy the air space around the fibers with the sealer. Thinned WEST SYSTEM Epoxy is ideal for accomplishing both objectives in one step. Thinning with about 10% lacquer thinner helps the epoxy to quickly saturate the wood fibers and create a wicking action that feeds the epoxy in and forces the air out. Bubbles are good to see because it means that the air is being displaced and the voids are being filled. It doesn't take long for the thinner to evaporate and the epoxy to gel; the timing is right for performing the void filling function.

Building up epoxy over a surface where the air is being displaced will make bubbles. The more material applied, the bigger the bubble. Breaking the bubbles messes up the surface that was trying to flow out smooth, especially if the epoxy has gelled enough to hold the wavy brush stroke shapes. But if bubbles are left to harden, sanding will leave pinholes or craters that are fussy and time consuming to fill. In other words, the surface may be inconsistent and many unpleasant steps away from a smooth and stable base on which to build the next coat.

By keeping the sealer below the surface, bubbles are not an issue as there is little semisolid material to become a bubble. Since epoxy cures by producing heat, air escaping during the curing process should be expected. Leaving the surface open will eliminate the bubble issue and leave a predictable surface that is ready for the next step. By making each step a preparation for the next, we don't have to wait for the epoxy to cure before moving on to the next step. The ideal time to apply the next coat is when the epoxy hits the 'green' or rubbery stage. There will be the least chance for surface contamination, and we'll get chemical bond between layers.

One-step Saturation

For the best result and the fewest number of steps, it is important to give the wood as much epoxy as it can absorb in the first application.

Liberally apply this thinned epoxy coat until the surface remains shiny. The shine indicates the wood has taken all it can drink and the epoxy is floating on the surface. If it looks dry, apply more epoxy.

Apply with a brush on small parts and complex shapes. On large surfaces, pour on and move about with a squeegee or roller. Don't worry about how it looks. Speed is important, and the surface will look good later when the excess epoxy and bubbles are removed. When the epoxy first begins to thicken, pack it in to remove the last of the air, level the surface and remove the excess epoxy while it is still liquid.

The laminated knees that support the deck on *Sparks* were sealed before installation. It would have been painful and hard to finish them in place. After dry fitting, the knees were dipped into thinned WEST SYSTEM 105 Resin/207 Special Clear Hardener and set to drain back into the paint tray. The excess was scraped off with a squeegee, rubbed in with a scuffing pad and wiped clean with a clean dry rag. The end grain was now sealed and ready for glue, and the surface was smooth and ready for the finish.

On large surfaces, use a spreader. Hold the spreader at a low angle to create downward pressure to pack the epoxy in and force the air out. Finish with a higher angle to scrape the surface clean and level. Try not to leave ridges, track marks or shiny areas. If the spreader is leaving tracks from nicks in the edge, reshape the edge with a sharp block plane.

Corners, Complex Shapes and Open Grain

When it comes to the cheapest and best Cheap Tricks, the tool with the most gold stars is the scuffing pad (see sidebar, page 7). It will grind up any raised grain, some of the surface wood and uncured epoxy to make a paste filler that will pack into the open grain. At the same time, it is picking up the excess epoxy and bubbles. A quick rub with a dry rag will leave a polished surface with nothing to sand later. Being flexible, the pad wraps around corners and follows complex shapes to treat all surfaces consistently. It blends shapes into a surface that is easy to follow with finer grades of scuffing pad as the finishing progresses. The magic of rubbing down each coat of finish on complex shapes and corners where components join is that at some point, the project stops being a bunch of assembled pieces and becomes one object.

Dry Fitting

When you have components made of several small or hard-to-finish pieces, it can be more efficient to dry fit a group of parts together, then take it apart and seal the pieces individually. When I build something, I find it hard to put all the pieces together then take them apart to prep it for the next step. I want to keep pieces coming together. I have to remember that when the pieces are individually prepared for finishing before installation, it's a big step forward with no pain from working in an awkward position or breathing dust while busting my knuckles.

When epoxying the parts together, clean up the excess glue before it cures so the component is ready for the next step. Pick up what you can with a putty knife, then wipe clean with a paper towel dampened with lacquer thinner. Along with saving time while avoiding sanding, joints that fit together clean are the mark of a professional. ■

A Sealing and Priming Essential Tool

Scuffing pads are like industrial grade pot scrubbers, available where auto body supplies are sold.

Maroon: Cuts similar to 120-grit sandpaper. Use for working in sealer where 120-grit scratches are appropriate. It is excellent with paint stripper. Use for final wet sanding/cleanup on complex shapes. Great for cutting epoxy gloss where the sander can't reach and working around corners. The pads will fit a 1/4 sheet palm sander for power scuffing large areas.

Gray: Cuts similar to 220-grit sandpaper. Use for working in sealer where a finer finish is important. It is also useful for scuffing corners between coats of varnish and paint.

White: Cuts similar to the backside of the sandpaper. It is useful as a carrier for applying wax or polishing metal with the appropriate compound.

Backpack Boat

By Paul Butler

This 23 lb, 5'-long boat can be backpacked, trailered or pulled over backcountry trails to access those deep holes in remote lakes where larger boats never go. Adjustable straps can be rigged to a daypack or packboard to comfortably carry the boat, or the dual skegs provide an axle location to mount wheels for pulling on rough trails or trailering behind a quad.

Seating is adjustable fore and aft atop the compartments or in a more stable relaxed position in a canoe chair placed on the bottom. The wide beamed boat will support an average size adult on flat water and can be paddled facing forward, or rowed facing aft with 3' oars. A double bladed kayak paddle also works well, or the smallest of trolling motors. The lightweight boat is an easy car-topper or can be hauled in the smallest of trucks.

Plywood and epoxy facilitates lightweight construction and compartmentalization, and no critical woodworking skills are required. The bottom is sheathed with glass and graphite and seams are covered with glass tape. The hull interior can be left open or the optional side compartments provide hull support, accessible dry storage and the safety factor of emergency flotation.

Only simple woodworking tools are required including jig saw, drill, block plane and a few clamps. Rectangular scrapers are used instead of sandpaper when finishing sealed surfaces. Aside from hardware attachments, no metal fastenings are required in the boat.

Building plans include 22 pages of photos, sketches, discussion of options, materials sources and step-by-step instructions, all written for amateur and first-time builders. Size can be increased a small amount by scaling up the patterns using graph paper. Plans are $42 from: butlerprojects.com, or from Butler Projects, PO Box 1917, Port Angeles, WA 98362. ■

Auto body repairs with WEST SYSTEM® Epoxy

By Tom Pawlak

Ten years ago the rear fender on my son John's 1991 Honda Accord was damaged just forward of the wheel. It had been repaired at a local body shop, but four months later the same fender was rusting. I took it back to the body shop. The manager apologized and agreed to redo the job, but said there wasn't much metal for his technicians to work with because the car had rusted significantly prior to the accident. He couldn't guarantee that it wouldn't rust again.

I asked him if he would consider painting both rear fenders in exchange for me rebuilding the problem fender, and he agreed. I planned to rebuild the fender myself with epoxy, and also rebuild the rusted fender on other side. I knew I'd be able to do a much better job with WEST SYSTEM Epoxy and fiberglass than with the polyester-based putties the auto body repair shop had used.

Prior to the repair when things were bad. Serious rusting is going on under the paint.

Note: These photos are from a more recent repair that used the same process.

A month later, I showed up at his shop with John's car. Both fenders had been rebuilt with fiberglass and epoxy, faired to the best of my ability and covered in a high-build epoxy primer. A few days later I was delighted to see the results. The paint shop manager must have been happy too because he asked if I was looking for work.

John drove his car for five years after the fenders were repaired, then sold it to a friend who drove it a couple more years. The fenders still looked great with no signs of rust working under the epoxy and fiberglass repair. This is significant because we apply lots of salt to our highways in Michigan during the winter months and that typically wreaks havoc on repaired metal auto body panels.

Here's how I went about this repair:

The fenders were still in good shape (aesthetically speaking-no pieces were missing, no major rust holes) allowing me to use them as male molds to make new, thin fiberglass/epoxy laminates to recreate the fender shape. These would later be glued to the metal after all the compromised steel that surrounded the wheel well was cut away.

To prep the mold, I applied duct tape around the perimeter of the wheel well, extending the tape beyond the inner edge of the fender (inside the wheel well) so epoxy and fiberglass would not get trapped behind it. I waxed the fenders with multiple coats of paste type mold release wax and applied a

Left—A quick, temporary application of body filler to shape the fender before molding a new part.

Right—Tape inside the wheel well extends the fender edges to allow for easier removal of the new fiberglass part.

Left—After three coats of Carnauba wax-based car polish were applied, a hair spray was applied in place of PVA as a backup mold release.

Right—A few layers of 105/206 plus 4oz fiberglass fabric were applied to recreate the fender's shape.

couple light coats of aerosol hair spray (water-based plastic) in place of PVA (polyvinyl alcohol). The hair spray and PVA are waterborne plastics that act as a backup mold release for the paste wax. Using these reduced the risk of sticking a fiberglass part on the fender mold.

After the hair spray dried, I applied three layers of 4 oz fiberglass cloth with WEST SYSTEM 105 Resin/205 Fast Hardener®. I chose this light buildup to recreate the shape and reduce overall thickness. This made fairing the fiberglass panel into the surrounding fender easier once it was glued in place. I allowed the part to cure overnight, then drilled a couple of small holes at either end of the panel to help position the part when it would be glued back into place. I worked wedges under the perimeter to pop the part free.

I repeated the process on the opposite side of the car. Here I had to temporarily fill a small rust hole with polyester body putty prior to waxing the fender and making an epoxy/fiberglass copy using the same process.

With the new fiberglass fender panels complete, I cut away all rusted and thin metal along the perimeter of the wheel wells and ground away the paint a couple inches back from the edges to prep for gluing on the new fiberglass molded replacements. I made the laminate light and thin so it would be easier to fair the 1" overlap into the surrounding fender. This also allowed me to reinforce it with more layers of fiberglass and epoxy applied from the back side of the fender after the molded part was glued in place. The extra fiberglass reinforcement tied the inner fender and outer fender together and created a very rigid repair.

I glued the new fiberglass parts to the steel with a mixture of 105 Resin/206 Slow Hardener thickened with 404 High-Density filler. If I were doing the work today, I would use

The body filler and corroded metal were cut away.

Areas that were difficult to sand properly were abraded by grit blasting with Black Beauty blasting slag. Epoxy was applied to freshly abraded steel to maximize adhesion.

Six10® Adhesive instead to make the job easier. During the gluing operation, I used spring clamps to hold the molded fiberglass part in place. The holes drilled previously at the front and back end of the panel made it easy to position on the fender during the gluing process. In addition, I applied a few strips of masking tape laid across the joint while dry fitting as witness marks that I could use to align to while assembling.

After the glue cured, I sanded the perimeter of the new section to break the corners and to sand the glue that squeezed out smooth and dull. The area was faired with epoxy fairing compound made with 105 Resin/205 Hardener thickened with 407 Low-Density filler to a mayonnaise consistency.

After abrading bonding areas of the fender and sanding the backside of the fiberglass part, the part was dry-fitted prior to gluing. The part had faded due to a month long exposure to sunlight between the time the part was molded and when it was finally fitted.

The new fiberglass part is glued in place with 105/206/404 High-Density filler. Spring clamps worked great for holding it in position during cure.

The following day the edges were sanded and the area was faired with 105/206/407 Low-Density filler.

I tied the fiberglass part to the inside fender by laminating strips of 15oz bi-axial fiberglass fabric and epoxy that extended from the back of the fiberglass fender lip to the inner fender, overlapping by about an inch. Tying the inner and outer fender this way made for a very strong and rigid new fender.

After the fairing had cured solid, I used heat lamps to warm the fender to 150°F for several hours to post cure the fiberglass. This step is important because the car would be painted dark brown. Dark colors get very warm in the sun and can cause fiberglass repairs to "print," meaning the weave of the fiberglass becomes visible. Heating the epoxy/fiberglass repair like this forces the fiberglass fabric pattern to print or telegraph to the surface a few thousandths of an inch. This fabric print was sanded away prior to applying an epoxy primer. Some people wait to post cure until after their high-build primer is applied.

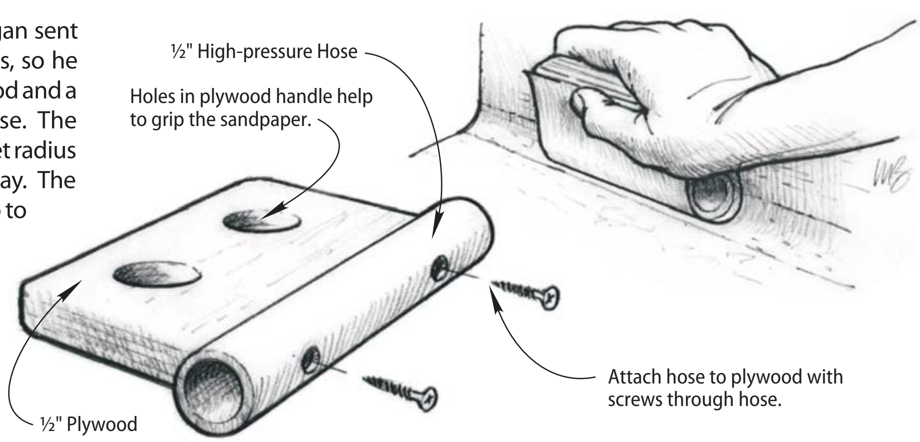
Another approach to preventing fabric print is to paint the epoxy repair with a dark primer then position the car in direct sunlight during warm weather for a few days. That way the print will occur and can be sanded out just prior to applying the final paint. Post curing assured John's car would look good for the long haul. Before taking the car to the body shop for painting, I liberally treated inside of the fender with auto panel rust inhibitor spray that was applied by gaining access through the trunk.

Unfortunately I was not good about taking pictures of John's car repair, but I did take picture three years ago of a similar repair done on a newer Honda. The sequence of photos used in this article are from that repair. Like before, I just made a light fiberglass part off of a quickly patched fender prior to cutting away all the bad metal. I repaired the damaged fender just enough with polyester putty so the shape would be close enough to mold a fiberglass part.

Regrettably, I never got a photo of the finished fender. I am confident that wherever the car is and regardless of the condition of the rest of it, the fender is holding up well. ■

Reader Tips A Fillet Sanding Block

Jim Cronan of St. Ignace, Michigan sent us this tip. Jim liked perfect fillets, so he made this tool made of ½" plywood and a length of ½" high-pressure hose. The hose radius is smaller than the fillet radius so the edges aren't sanded away. The holes in the plywood handle help to grasp the sand paper so it doesn't slide around. He said the sanding block's design permits him to use a lot of pressure to knock down imperfections in the fillets quickly.



Getting the Most Out of G/flex®

By Julie Van Mullekom

Are you the kind of person who just can't get enough of a good thing? Looking for a better way to squeeze out that last little bit of G/flex adhesive from your tube rather than resorting to pliers, a vise or maybe even Grandma's rolling pin? Maybe you'd like to get a fatter bead of adhesive or your tube is a bit clogged. Boy do we have the some easy and inexpensive tricks for you!

Issue 1:

"I love your G/flex adhesive! Do you have any nifty tips on getting the last little bit of adhesive out of the tube with ease?"

Useful and Inexpensive Trick:

Not long ago this very subject was the topic of discussion that came up between J.R. Watson and me. Squeezing in a bit of shopping on my lunch, it just so happened that I found myself face-to-face with a display of tooth paste squeezers. On my way back to work I felt as though I had just solved all the world's problems. Perfect! Or so I thought. Although the concept was good, the little tooth paste squeezer just didn't stand a chance next to the rigid metal G/flex tube. However, it did give the innovative J.R. Watson an idea. Using very little time and effort, we whipped up this very cool gadget making it a snap to squeeze out the last drop of adhesive.

Here's what you'll need:

½" diameter PVC pipe
1 PVC cap to fit the ½" pipe

Here's what you'll need to do:

You will obviously need to make two, one for the resin tube and one for the harder. But for simplicity's sake we'll just show one tube being created.

Cut the ½" diameter pipe to approximately 7" long. The additional length creates an easy to grip handle. So, for you extra-large handed men, petite handed women or vise/versa, cut to length accordingly.

Cut a 4" long slot through the center of the tube.

Insert the crimped end of the tube through both horizontal cuts.

For added 'G/flex' appeal add a PVC cap.

Take hold of the handle and you are now ready to roll.

Issue 2:

"I'd like a bit more of the adhesive to squeeze out of my G/flex tube, got any tips? By the way, your stuff ROCKS!"

Useful and Inexpensive Tip:

Simply poke the sharpened end of a pencil into the open tip, applying enough pressure to increase the diameter of the hole. It's cheap, easy and works like a charm. The amount of adhesive that comes out of the tube afterward can double in volume, depending on how far the pencil is inserted.

…and Mom said that cheap and easy was a bad thing! ■

Wayne Freiman of Yorba Linda, California, was repairing a 40 year-old Naples Sabot for his grandchildren, Madeline and Royce, when a man walking his dog asked if he wanted another. He now had a Sabot for each of his grandchildren. The production fiberglass hulls are gel coated on the outside and the seat, rudder, leeboard, boom, support for the mast and four corner gussets are hardwood. Freiman used 105/206 with 404 filler and 6oz fiberglass cloth to make repairs to both boats.

The challenge of working inside and outside the boats was made easer by using two engine stands and making them into a 'rotisserie.' "By turning the boat upside down I could epoxy the bottom (no new cloth) use a squeegee and allow it to drip off the edges. I could turn the boat right side up and turn the boat at an angle, if need be, to allow better access." Painting the boats (one purple and one orange) was also made easier by being able to turn them on the rotisserie. Both boats can be sailed or used as a rowboat. Freiman purchased a Harbor Freight trailer and made a small dolly that allows one boat to sit inside the other.

Readers' Projects

Steven Hirsh of The Wooden Boat House, De Leon Springs, Florida recently completed this new version of the super light kayak—14' long vacuum molded plywood, weighing in at 26 lb. It is made with WEST SYSTEM 105 Resin/207 Special Clear Hardener® throughout with six ounce glass inside and out, double layered on the bottom. Hirsh placed the veneers between the bottom two layers of glass to expose them on the inside of the cockpit. The combing is carbon fiber set in Six10® underneath and 207 on top, formed around a vinyl tube that was hot glued to the opening.

These photos are from Emmanuel Samaras, Gibson, British Columbia, Canada. "First and foremost thank you for your valued publication. I am retired pilot and pass my days sailing and in winter in my art studio where I use multiple materials and tools to accomplish my art/sculptured forms, among which are your epoxy products." His sculpture reflects human ingenuity in plastics and electronics as well as his aviation career. He is also experimenting with hull designs based on a reversal of the Bernoulli Principle.

Jack Sommerness built this stripper skiff name *Kemosabe*. The hull is cedar, transom is mahogany , gunwales and seats are mahogany and black walnut Sommerness is from Hutchinson, Minnesota.

Earl Rentmeester of Green Bay, Wisconsin recently launched a 50' cold molded sailboat built from scratch using West System Epoxy. He used 157 gallons of epoxy on this entire project, which took four years and ten months working full time to complete. *Driftwood* is a double headsail ketch with a pilothouse for inside and outside helms.

Building My First Skiff

By John Wojciechowski

When I told my brother that I was going to build a boat he asked me, “Why?” I didn’t discover the answer until after the project was completed.

I work in the Operations Department at Gougeon Brothers, Inc. and have been here 12 years making WEST SYSTEM® products: epoxy resin, hardeners, fillers, packaging fiberglass etc. But I’d really never used it on a big project. The company has always been involved in boats and boatbuilding, so I figured a boat project of my own would provide me with some ‘how to’ epoxy experience.

I could envision my two young daughters rowing a boat their dad built, but I had to convince my wife. I like to fish and so do my girls, so a good fishing skiff couldn’t hurt. “Think of all the fish fries,” I told my skeptical wife.

One aspect of my job is planning and keeping an eye on costs, skills I could use on this project. I’ll cover the project details that stood out for me, and provide both my estimated and actual work times for the various steps.

I selected a simple stitch and glue design by Glen-L Marine. I was told that full-size plans of a proven design would save time, money and frustration. As I proceeded, I realized just how true this was.

Starting out

I sketched out the layout of the components to be cut from my plywood panels. Then I began with the small parts: breast hook and transom knees.

Estimated time: 1 hour for each. Actual time: 2 hours each.

Panel preparation and coating

The plywood I bought was really good stuff, but printing, decals, scratches or simply wood grain patterns made one side more favorable than the other. I did the layout on the poor side.

To create mirror image surfaces I joined the sides, good side in, with double-sided carpet tape and a screw on each end to make their final shape identical. I also drilled the stitch holes at matching location to ensure craft symmetry. The last step for the bottom and side interior was marking guidelines for the fiberglass. I folded the 4" and 6" tape in half, then set my combination square to that dimension and struck a line that would aid nice straight application of the fiberglass tape.

After cutting out the pieces with saber saw and planing fair, I applied two coats of 105 Epoxy Resin®/207 Special Clear Hardener® and sanded with 80-grit paper (*Photo 1*). This made it much easier to complete the finishing assembly. I didn’t coat the outside hull sides and bottom as these remain easy to finish after assembly, and would require some shaping. I also coated interior components which hadn’t been coated before installation: seats, seat fronts. knees, breasthook, inwale and outwale. I rolled on the first coat with an 800 Roller Cover and allowed it to cure. I sanded that with 80-grit paper on a random orbital sander, then rolled and tipped the second coat. Once that cured, I again used the random orbital sander with 80-grit.

Estimated time: 5 hours. Actual time: 9 hours.

Gunwales

From rough-sawn Sitka Spruce planks I ripped my gunwales to size but made them 3' longer to utilize the cut-offs for other components later on. I rounded the bottom corner of the inner and outer gunwales. It was a lot easier done on a bench than it would have been after they were installed in the boat, because that corner would be up-side-down. Sanding produced two full buckets of sawdust.

Estimated time: 4 hours. Actual time: 3 hours. Ah, a victory!

Levels

Prior to stitching, I used double-sided carpet tape to adhere two small levels to the bottom panel, on centerline, at the bow and the stern. These would indicate any twist that needed to be addressed as the assembly proceeded.

Stitching and gluing.

This was probably my only deviation from the plans. Instead of copper wire, I used plastic tie wraps (*Photos 2-3*). They do require a larger diameter hole in the plywood, but they don't cut the plywood or fatigue the way copper does. Their adjustment is a ratchet arrangement, while copper wires require twisting with pliers (hence the fatiguing). The ratchets allow incremental and even tensioning to draw the panels into shape. The cost difference is a wash. Copper wires can usually be extracted, but when they break it's a problem. Both tie wraps and copper wire can be cut flush, but copper is harder to plane.

I installed the inner gunwales to help stiffen the shear and give it a nice smooth curve (*Photo 4*).

Estimated time: 3 hours. Actual time: 8 hours. (Two men working together 4 hours each—the side panels and bottom were awkward to handle alone.)

Filleting the interior chines

I made a mixture of 105 Resin/206 Slow Hardener® to give me more working time. With a faster epoxy in this application, the mass of the fillets can create an exothermic reaction, possibly resulting in air pockets in the fillets. I added 407 Low-Density filler and 410 Microlight® to the mix, blending them to a non-sag consistency. The resulting mixture was strong enough, sanded nicely, and closely matched the color of my Okume plywood. I mixed small batches (3 Mini Pump strokes of resin to 3 pump stokes of hardener) so I could take my time.

Despite ease of sanding, I was careful to sculpt neat, accurate fillets (*Photos 5-6*). Then I smoothly covered the tie wrap stitching. To apply this mixture, I made a wooden filleting tool the same radius as a 800 Roller Cover. When the epoxy cured, I could use 36-grit sandpaper over a roller cover to smooth it all out.

Estimated time: 4 hours. Actual time: 9 hours.

Glassing the interior chines

The most time-consuming step was cutting out all the glass tape. Plus, I made a mistake. I marked my cuts with felt tip pen. The ink bled up the tape and showed through when wetted with epoxy.

What worked well was to cut intersecting ends where three tows of fiberglass tape meet with rounded ends. This approach reduced the excessive aggregate build-up of tape layers. My plans called for one layer of 4"-wide and one of 6"-wide for all joints. Once all was cut, I used 105/207 to wet to those guidelines I'd made during the panel layout. Next, I placed the first layer of dry tape into the wet substrate (*Photo 7*). The dry tape absorbed the wet epoxy. Where it did not, I brushed a little more on. I then placed the second, 6"-wide layer over that while it was wet (*Photo 8*). I used a brush because the concave corner of the inner chine really doesn't allow good use of a spreader or squeegee.

The flat tape does not lay flat because of the boat's shape. The resulting wrinkles were removed by snipping a dart with scissors, then pressing down. What worked well was to cover these darts (about 3 per side, per edge) with a square of release fabric which was not removed until all had cured.

When the epoxy cured I could definitely feel the "steps" in the layers of fiberglass tape. Hand sanding with 80-grit and a sanding block eased these transitions so the blend was unnoticeable.

Estimate time: 5 hours. Actual time: 12 hours.

Putting release fabric on the whole chine fiberglass laminate would have saved a lot of time on sanding, but not all of it. Release fabric could be applied in overlapping sections, so no darts would be required. But release fabric is expensive, so I opted to use less of it. But as I was sanding, I thought about that a lot.

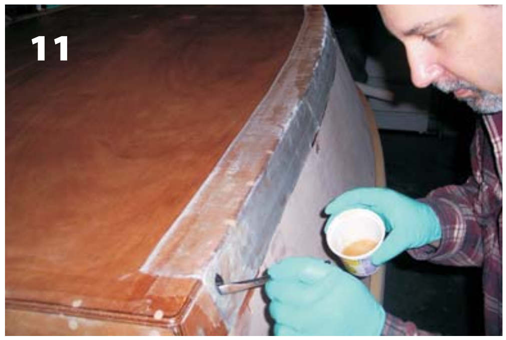
At this point the hull was flipped and the tie wraps cut flush with a sharp off-set chisel then counter sunk. The chine was rounded. I used a block to first create a flat at about 45°. Then I flattened the resulting two corners so the corner was faceted like a gem. Last, using a sanding block with 60-grit paper I rounded the corner.

Completing the bottom

I used a mixture of 105 Resin, 205 Fast Hardener® and 410 Microlight to fill the counter sinks where I'd removed the tie wraps and outside chines. After all was filled and cured, the Microlight filler made it easy to sand to my liking.

I used a square to transfer my guidelines for the 4" and 6" glass tape along the outside chines. I then applied a run of 742 12oz glass cloth along the entire bottom (much easier with two people). The exception was where the 4" and 6" tape lines would go to to prevent wear when pulling the skiff ashore.

The way to go was applying the glass cloth by rolling it up half way, coating the wood, then having two people unroll it over the wet out epoxy surface (*Photo 9*). We used an 808 Flexible Spreader to remove air bubbles (*Photo 10*). After the layer of fiberglass cloth was wet out I



moved onto wetting out the glass tape on the chine (*Photo 11*).

After sanding the chines and fixing minor flaws (*Photo 12*), it was time to coat the outer hull. I chose to use 105 Resin/207 Special Clear Hardener with West SYSTEMS* 503 Gray Pigment (*Photo 13*). I was told that this would really show any flaws I may had missed. Well it did, but the flaws weren't bad. I did have to do some minor adjustments. Finally, after it looked like I had it pretty close, it was time to sand again. This time I was able to use the random orbital sander on the majority of the bottom and sides. I hand sanded the hard-to-reach places.

Estimated time: 3 hours. Actual time: 5 hours.

Finishing

After the assembly I decided on a natural finish for the interior. I applied a coat of 105/207 to the entire interior. Once that cured, I sanded it with 100-grit and applied a coat of Z-Spar® Captain's Varnish (*Photo 14*). I had my girls select the pain color for the outer sides and bottom. They chose Largo Blue, with a little help from Dad because otherwise it would have been a multi-color paint job.

I applied two coats of Interlux® primer and sanded between each coat. I then applied two coats of Interlux paint using a Scotch Brite® pad between the first and second coat.

Estimated time: 3 hours. Actual time: 4 hours.

Now that my skiff is complete I realize how much time and money goes into building something that my daughters will be able to enjoy for many years to come. That is the answer to my brother's question, "Why?" The other reason was I had a chance to build this boat with a good friend who has been building boats for most of his life. You may know him as Captain J.R. Watson, retired Gougeon Technical Advisor. He offered to assist me on this little project and I figured that it was the perfect opportunity for me to gain some knowledge working with our products, along with some sailor language (I'm not talking dirty).

The project took me a little longer than expected (most of that extra time was spent sanding) and I went over my budget by a couple of hundred dollars (let's not let the wife know). All in all, I would say if you get the chance to build something with a friend, relative, or child, do it. I think the Gougeon Brothers were nearly as excited as I was when the boat was nearing completion and ready to go in the water.

As for the name, I combined my daughter's names, Hannah and Hailey, and christened her *Miss Han-Ley*. ■

Recycling & Disposing

By Glenn House

Over the course of the last couple years Gougeon Brothers Inc. has partnered with Waste Management Inc. to implement a comprehensive recycling program that has been both simple and effective. We are now recycling emptied plastic and metal containers, shrink wrap from bulk packaged items, dispensed adhesive cartridges, cardboard boxes, miscellaneous soft and rigid plastic items, office paper, magazines, etc.

Our customers may also recycle many of the containers and related packaging items associated with WEST SYSTEM® products, in accordance with federal and state regulations and local recycling guidelines.

There are container disposal regulations you need to follow which ensure the containers you are recycling are reasonably empty. This makes it less likely that chemical residue will enter the environment or otherwise cause harm to people. The guidelines are pretty straightforward and easy to follow. For business operators who are part of the regulated community, I have summarized a portion of a federal disposal guidelines here. Those of you who are do-it-yourselfers can also follow these guidelines or check with your local recycling authority or governing body for solid trash pickup to see if they have more specific instructions.

These guidelines apply to containers less than 110 gallons in size that held chemical products not defined as "acutely hazardous." This would include such WEST SYSTEM products as 105 Epoxy Resin®, Six10®, G/5®, G/flex®, fillers, etc.

The container is considered empty if:

A. All residue has been removed that can be removed using the practices commonly employed to remove materials from that type of container, e.g. pouring, draining, pumping, and aspirating, and

B. No more than one inch of residue remain on the bottom of the container or no more than three percent by weight of the total capacity of the container remains in the container.

If your container is larger than 110 gallons or held an acutely hazardous waste, then you may be required to take additional steps to ensure emptiness, such as repeat rinsing.

If you are operating a business and are unsure about the rules for container disposal, consult your state environmental authority. If you are a do-it-yourselfer or if you just want to know more about recycling and waste reduction consult your local waste recycling authority or a recycling company like Waste Management Inc. They can help determine what your recycling opportunities are and help you develop an effective recycling plan.

If you have any questions about our recycling program or if you need information about the types of materials our products, product containers or packaging is made of we invite you to call us.

Recycling sends less waste to landfills and can reduce the frequency and cost of your solid trash pickup. And if your recyclable volumes are large enough, you might find out that recycling is not only good for the planet, but also good for your pocketbook. ■

DETERMINING EPOXY'S Physical Properties

By Mike Barnard

In this article I'll describe our standards for testing epoxy and how we test epoxy to determine its handling characteristics and cured physical properties.

Testing Standards

These are the standards we follow no matter which epoxy we are characterizing.

Two-week room temperature cure

After proper metering and thorough mixing epoxy will continue to cure after it has solidified, until all amines have paired up. Over years of testing we have found that two weeks of curing at room temperature, which we define as 72°F (22°C), is a good indication of its full strength.

Neat epoxy

We perform our tests on neat epoxy mixtures. That is, nothing is added to the resin and hardener, because fibers or filler can affect many physical properties.

No post cure

Allowing the epoxy to cure at room temperature, then curing it further at an elevated temperature is called post curing. Doing this will improve physical properties in some cases. WEST SYSTEM® Epoxies reach full properties at room temperature, so it is not necessary to post cure for testing .

Only averages are reported

In order to generate the data we publish, we conduct the same test several times, generating average result numbers. We don't publish the highest values we achieve. We round our averages to the nearest unit, based on significant figures used.

ASTM standardized tests are followed

The American Society for Testing Materials was founded in 1898 and is now known as ASTM International. This non-profit organization is comprised of more than 30,000 members across 135 countries. Writing and updating over 12,000 test standards, they are recognized as one of the world's largest voluntary standards developing organizations. The scientific standards they write and maintain are for materials, products, systems and services. Not only do we adhere to ASTM standards, we have several employees who are members and help maintain and write ASTM standards.

Handling Characteristics

Mix Ratio

The mix ratio is crucial to a proper cure. Severely off-ratio epoxy may not cure at all. Unlike catalyzed resin systems, you cannot add more hardener to make epoxy cure faster. If too much or too little hardener is added, it is quite possible that the epoxy will not cure properly.

This process can be simplified by using our 300 Mini-Pump Set. These pumps are calibrated to dispense at the correct ratio of epoxy resin to harder at a rate of 1 pump resin to 1 pump hardener (even though the ratio of resin to hardener is still 3:1 or 5:1).

Mix Viscosity

In order to saturate fabric, the epoxy's viscosity should be low enough to flow through the layers of fabric. However, if the viscosity is too low the epoxy will not stay in the fabric. For most fabric weights, viscosity between 300 and 5,000 centipoise (Cps) saturates fabric without draining away.

Viscosity is a measure of how a fluid resists shear loads. It can also be defined as the internal forces that keep the fluid from flowing. The higher its viscosity the slower it will flow from one area to another. Water has a viscosity of about 1 Cps, ketchup has a viscosity of about 75,000 Cps and peanut butter has a viscosity of around 250,000 Cps. Almost all liquids will become less viscous (lower viscosity easier to flow) at higher temperatures. Epoxy is no exception.

The rotational viscometer spindle suspended in a jar of resin.

We use a rotational viscometer to measure viscosity. A spindle rotates in the epoxy to measure its resistance. A thicker fluid will give the spindle more resistance, indicating a higher viscosity.

Viscosity's effect on fabric wet-out holds true at the dinner table. Spilling a drink on your jeans means your leg gets wet almost instantly. But drop some peanut butter on your jeans and it may never reach your leg. This is due to the differences in viscosity.

Pot Life

Few things are more annoying than when your pot of epoxy cures sooner than it should.

We define pot life as the amount of time you have to work with 100 grams (3.8 ounces) of epoxy in a small container at room temperature (72°F). Timing begins when you start mixing and ends when the material gels. This relationship is dependent on hardener, temperature, volume of epoxy and size of container. To extend this time, mix smaller batches or after mixing, pour the epoxy into a larger container to dissipate generated heat.

Specific Gravity

This number helps determine your project's weight. Specific Gravity is the ratio of the density (mass divided by volume) divided by the density of water. We conduct these tests at room temperature so that the density of an object is comparable to the specific gravity.

Cured Physical Properties

Hardness

Hardness is a measure of how hard the surface of a substance is. The harder the surface of a coating is, the more abrasion resistant it is. We test for this with a durometer which accurately measures the hardness of the surface of cured epoxy. We use a Shore D test which specifies a range of hardnesses. Similar tests are conducted on metals where Rockwell or Brinell tests are used. In these tests, a metal point is forced into the material and a numerical reading is given which corresponds to the resistance at the point. Because hardness increases with degree of cure, the test is conducted after one day and 14 days of cure at room temperature. The results of a hardness test are important for comparative purposes or determining the degree of cure.

Compression Strength

Higher compression strength means that the epoxy will be able to support higher loads pushing on it. Compression strength is the load required to cause plastic deformation and is measured in pounds per square inch. Plastic deformation is the permanent change in shape or size of a solid body without fracture, resulting from sustained stress beyond the elastic limit. Similar to hardness, degree of cure is important. This test is also performed after one day and 14 days of cure at room temperature.

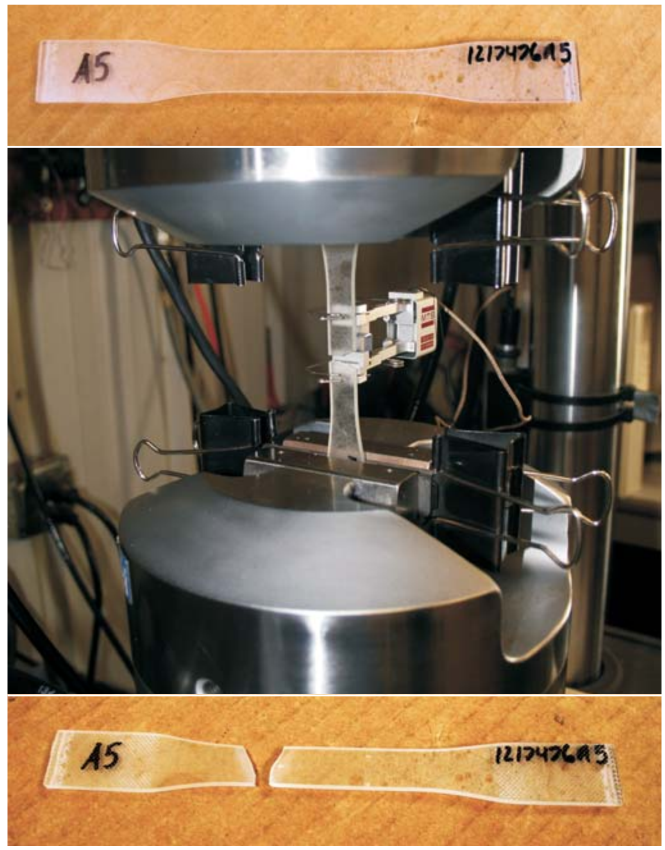
Compression test in progress.

A compression cylinder after testing.

Higher tensile strength means that the epoxy will be able to support higher loads pulling on it.

The tensile test specimen is made in the shape of a "dog bone" and fixed into clamps on a machine that will pull it apart from each end. This test continues until a fracture appears. The result of this test is recorded in PSI and is the value at which breakage occurs.

Tensile Elongation



Top—A tensile specimen before testing.
Center—A tensile test in progress.
Bottom—The same tensile specimen after testing

Higher tensile elongation means that the epoxy will be able to stretch more when being deformed. Higher elongation will often indicate toughness.

Tensile elongation is the change in length of a sample (strain) when loaded to failure. This value is measured at the breaking point, or when the sample has been stretched far enough to fail. For example, if a sample was 10" long and it stretched 1" at failure the elongation would be 10%, or .10.

Tensile Modulus

Higher tensile modulus means that the epoxy will have more stiffness.

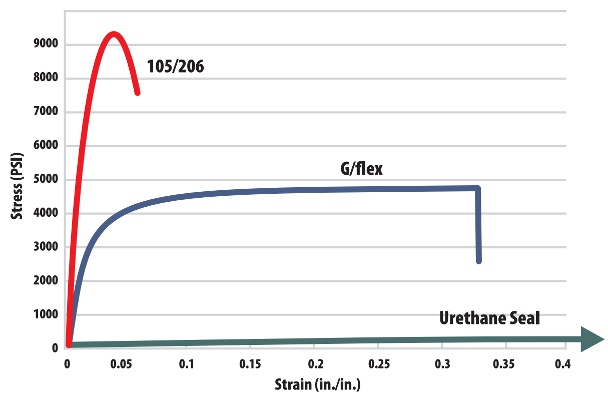
Tensile modulus describes the amount of stretch (strain) in relation to its ability to resist stress. When plotting stress vs. stain on a graph it is the slope of the line. A line that is closer to vertical indicates a stiffer substance. The

Stress is the amount of force on a sample divided by the cross sectional area and recorded in pounds per square inch (PSI).

Strain is the amount of stretch a material exhibits while a load is applied. This property is expressed as a percent of the original length.

Toughness is a relationship between modulus, stress, and strain that corresponds to the amount of energy a specimen can absorb prior to failure. A material can have very high strength and very little strain (105/206) a moderate amount of stress and strain (G/flex) or very low stress and very high strain (urethane sealant). The graph shows three stress-strain curves. The G/flex curve, which contains a mid-level of stress and mid-level of strain, has more area under it. This area corresponds to toughness and shows why G/flex is considered tougher than 105/206 and urethane sealant.

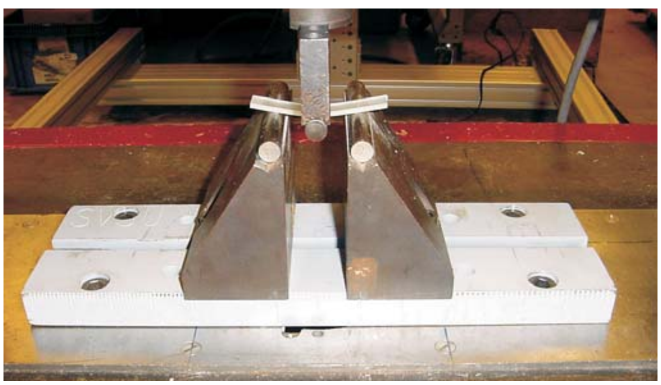
Stress vs. Strain Curve



plot in the Stress vs. Strain Curve above shows modulus as the initial vertical linear portion of the lines.

Flexural Strength

Higher flexural strength means that the epoxy will be able to support higher loads pushing on it while under flex. It is better able to resist fracture due to its ability to bend.



A flexure test in progress.

Flexure strength is similar to that of tensile strength but instead of pulling on the ends of a dog bone sample you are pushing down in the middle of a smaller, rectangular sample. The value of stress (in PSI) is recorded at the point in which the material breaks. This test determines max load when forces act perpendicular to the length of the sample.

Flexural Modulus

Higher flexural modulus means that the epoxy will be stiffer when higher loads push on it while under flex.

Flexure modulus is very similar to tensile modulus but the sample is tested in the same way as flexural strength. Instead of testing strength along the length of the sample it is testing the strength perpendicular to the length.

Heat Deflection Temperature

Heat deflection temperature (HDT) is the temperature at which the epoxy will deform under constant load.

The same type of bar and test that is used for the flexural strength and modulus tests is used to find the heat deflection temperature. This time the sample is submerged in oil at a carefully calibrated temperature and is pushed down with a 264 psi load in the center. The temperature of the oil is then gradually raised until the bar deflects .1" in the center. This temperature is considered to be the heat deflection temperature.

Onset of Tg

Onset of Tg, or glass transition, is the temperature at which the epoxy changes from a glassy (solid) state to a soft, rubbery state. It is the "softening point."

This is another way to measure at what temperature the unfilled epoxy will be affected. A differential scanning calorimetry (DSC) machine is used in this analysis. This test is conducted by placing a fully cured sample in the DSC machine and heating it to 200°C at a pre-defined rate. The heat flow into the sample is measured and compared to another sample of pure air. The "noise" is taken out by removing the results of the air (control) sample from the tested sample. On this heating cycle, there is a decrease in heat flow that indicates a loss of some properties at that temperature. We publish the Tg as the point where this decrease in heat flow begins

Ultimate Tg

Ultimate Tg is the highest temperature at which the epoxy will have some structural properties. In order to attain this temperature resistance in application we post cure the epoxy at a temperature equal to or greater than the ultimate Tg.

Ultimate Tg is basically tested the same as the onset of Tg, with a slight modification. Where onset of Tg is found on the first heat (first time the sample is heated to 200°C) ultimate Tg is found by heating the sample again up to 200°C. On this heat the onset is recorded. Because additional cure has occurred, this temperature will be higher than the onset of Tg. ■

Repairing *Jester* Who's laughing now?

By Greg Horvath as told to Bruce Niederer

The following photos detail some recent repairs made by the owner and crew of *Jester*, a 2005 C&C 99. *Jester* is well equipped and has been meticulously maintained by her skipper and only owner, Greg Horvath. *Jester* has only sailed in fresh water and is stored indoors during the winter. She is also the boat I've raced aboard here in Saginaw Bay as well as around the Great Lakes including the Port Huron to Mackinaw Race and the Ugotta Regatta in Harbor Springs.

The story of the repair process would not be complete without mentioning the outstanding customer service from the folks at C&C. Greg reports that from his first contact with a C&C rep throughout the entire repair process he was treated with respect and that he felt they were genuinely concerned about taking care of the problem. They provided, at no cost, enough parts and wood to complete three times the work *Jester* needed.

They also supplied the exact same finish coating for the floor that they use in the factory. Some manufacturers won't even tell you the color of the gelcoat they use but with C&C they were completely forthcoming with any information we needed. We appreciate good customer service here at GBI, so kudos to C&C!

As the saying goes, a picture is worth a thousand words—so let's get to it.

1. Moisture had wicked up through the cabin sole teak/holly plywood. When the floor was removed, moisture was suspended between the sole and cabin sole plate.

The cabin sole does not rest on typical floors, rather, it sits in a molded plate with drain holes that proved insufficient for complete draining into the bilge which caused the problem seen in this photo.

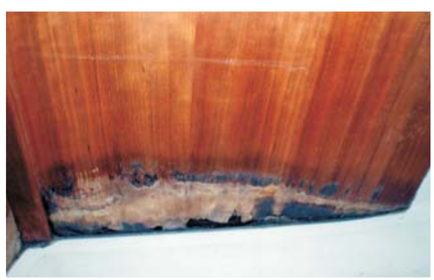
Additional drain holes were cut before installing the new sole.

2. This water damage is just forward of the mast. One doorway is to the head—the other is to the V-berth.

Water which likely came from the the anchor locker had wicked up through the sole to the bulkhead/sole gap.

3. Complete rot -though in the aft cabin. Water dripped through the closed hatch during rainstorms.

Note the halyards in the lower left corner. These can wick water down their length sometimes as well. The next photo describes the problem in more detail.



4. Complete rot-through in the aft cabin. All the wood below the dotted line was removed.

The cut was made with a saber saw set to create a shallow scarf angle. The actual cut was a straight line so the replacement piece could be easily cut to match.

Sections of water damaged bulkheads were removed and new bulkhead material, supplied by C&C, was scarfed in.

5. New cabin sole undersides were coated with three coats of WEST SYSTEM® 105/205 as a moisture barrier.

The end grain of new bulkheads was also coated. New material was stained with ML Campbell two-part stain used by C&C to match the original stain colors.

6. As you can see, the repairs were effective both structurally and cosmetically.

Jester is now ready to head to Port Huron and beyond for our annual July racing extravaganza-and we'll be doin' it in style. ■

Letters to the Editor~White Oak

By Bruce Niederer

We consider ourselves students as well as tech advisors and so are always open to learning something from others. Our readers are generally pretty savvy people, and when they take the time to write us a thoughtful letter, we feel compelled to share what we learn from them with the rest of our readers.

My article, White Oak Redux (*Epoxyworks 34*) generated two responses we wanted to share. The letters, along with my replies, follow.

Dear Editor,

Let me briefly comment on White Oak Redux in Epoxyworks 34.

The explanation given for the higher shear strength of the solid oak samples vs. the glued oak samples based on imagining longer shear lines in the solid wood does not hold up under critical scrutiny. One could imagine similar "long" shear lines in the glued samples.

A more plausible explanation: Think of a glued sample as a 3-ply block consisting of a thick ply of wood, then a thin, but finite ply of epoxy-infused wood, and another ply of thick wood. Plain wood and epoxy-infused wood obviously have different properties, in particular, they have different shear moduli. The magnitude of the two moduli are unimportant in themselves; what matters is that they are different. Since the three plies are exposed to the same load and they have equal shear areas, the shear stress in each is the same, but the shear strains are not on account of the different moduli. On the ply boundaries the shear strains will jump from one value to a different value, creating a high strain gradient at this point. High strain gradients are failure initiators. This predicts failure in the wood part of the glued sample in the area of high strain gradient at a smaller load compared to the failure load for the same wood in the absence of a high strain gradient. In short, plain wood is stronger.

Looking at the somewhat vague pictures of failed blocks in the article, it does appear the above hypothesis is confirmed. The failures occur in the wood on planes more or less parallel to and close to the glue surfaces, namely where the strain gradient is high.

Very truly,

Ralph Koebke
St. Augustine, Florida

Dear Mr. Koebke,

Thank you for taking the time to write your very insightful letter in response to my article White Oak Redux in *Epoxyworks 34*. Although you didn't mention your background or experience, we all surmised you must have some sort of engineering or science background. Many of our customers are very savvy builders with various levels of experience and training, but we don't often receive letters that reveal the level of understanding and sophistication we found in your comments.

We, of course, know that all things being equal, the solid wood will outperform a glued sample in shear. But in practice, all things aren't equal. Large parts of solid white oak can be very dimensionally unstable. It will change along its width and length plus it can twist with changes in moisture content. Coating the oak can help stabilize the moisture transmission and so too the dimensional instability, but we've known of many instances where the movement in the solid wood cracks the epoxy, which can allow moisture to intrude behind the coating. The resulting trapped moisture becomes a breeding ground for rot formation. For that reason, we promote using WEST SYSTEM® Epoxy to laminate thin strips of oak to build the necessary thickness for the part because it relieves much of the linear stresses found in solid wood parts. Alternating grain orientation in the laminate stack is a very effective way to accomplish building a stable oak part of nearly any size.

Failed control samples.

The ongoing controversy in the wooden boat building community is that there are a large number of "purists" who believe oak cannot be glued effectively with epoxy. The point of this follow-up article as well as the first article was to conclusively prove white oak can indeed be bonded using epoxy even and especially in highly loaded applications like stems, frames, and scarf joints. We felt that tensile adhesion did not tell a complete story and so we initiated the short block shear study and included the environmental cycling to torture the wood and glue lines to mimic a more realistic situation. Our goal was to do our best to dispel these deeply entrenched myths regarding epoxy adhesion to white oak.

I was looking at the differences in shear values between solid and glued shear samples from the solid block side because the failed samples were very interesting. In the aftermath of the test, the wood fibers that ran through the shear plane as described in the article were tenacious even after 6 weeks of cycling from saturated to dry. I had to force the two halves apart with a pry bar. I misspoke myself in the article by saying "As shown is this diagram, each solid oak sample has grain that passes through the straight line shear plane. This grain structure, not present in any of the glued samples, effectively increases the area of the shear plane which results in a higher value." Obviously, the shear plane is a set dimension regardless of grain orientation so the area doesn't change. What I should have said is "This grain structure, not present in any of the glued samples, effectively increases the relative strength of the block which results in a higher shear value."

That said, we believe your explanation is much more nuanced and provides a better and more technical explanation. You have provided our readership a more complete understanding of the science behind epoxy glued oak joints in this shear test and by extension, in boat building applications.

Thanks again for taking the time to write us.

Regards,

Bruce Niederer
Senior Tech Advisor/Chemist

Hi,

I have been a subscriber of your free Epoxyworks publication for many years and I still like it very much.

I used often WEST SYSTEM 105. In Epoxyworks 34, Spring 2012 I do not understand why they say in White Oak Redux just before the conclusion that "3M 5200 ...cannot be used below the water line." Here is the description from 3M: "3MTM Marine Adhesive/Sealant 5200 is a one-part polyurethane that chemically reacts with moisture to deliver strong, flexible bonds. It has excellent adhesion to wood, gelcoat and fiberglass. It forms a watertight, weather-resistant seal on joints and boat hardware, above and below the waterline. In addition, its flexibility allows for dissipation of stress caused by shock, vibration, swelling or shrinking."

We use it on many boats and everything seems to be fine between the hull and the keel. Am I wrong?

Claude,
Quebec, Canada

Dear Claude,

You are absolutely correct about the product description by 3M regarding 5200. I based my comment on the fact that I had a through-hull transducer that was mounted using 3M 5200 which began allowing water to seep through and find its way to the bilge. When I pulled the fitting to repair it, what I found was that the 5200 was basically disintegrating. I was able to push the transducer out by hand. To say the least, I was not favorably impressed.

Regardless, I know that many people routinely use 3M 5200 below the waterline in many applications, for instance, to restore classic Chris Crafts and Hacker Crafts. Don Dannenberg is an outspoken proponent for this technique. Some of the boats he's restored are kept at docks and not trailered, and we have not heard of any wholesale failure of the 5200 from these folks.

That said, I will retract my comments here and the online version will be edited such that the comment is removed. I should have kept my personal prejudices to myself.

I still won't use 5200 below the waterline on my boat, but I never argue with success. You should not let my comments give you cause for concern on any project you used the product for.

Please accept my apology and best regards,

Bruce Niederer
Senior Tech Advisor/Chemist

I'd like to thank both gentlemen for taking their valuable time to contact us, and for giving us permission to reprint their letters. Although I can't promise every letter to the Editor will get printed, I encourage all of our readers to contact us with questions or comments. We will always answer you, regardless of whether we publish your note in *Epoxyworks*. ■

A G/flex End Table

Rob Van Mullekom, Operations Supervisor here at Gougeon Brothers, built this oak end table with a ceramic tile inlaid top. The entire table was glued together with G/flex® 655 Adhesive—no mechanical fasteners. All joinery is edge glued using clamps and gravity. The table is finished with three coats of Minwax® semi gloss varnish.

The legs, frame and top were assembled with G/flex 655 only.

The assembled table awaiting tile dividers and varnish.

The finished table with three coats of varnish and the ceramic tile glued in place—with G/flex.

Stray Cat Strut

By Andy Davison

I have just about finished restoring a Gougeon Tornado. I've always had and loved catamarans, and this one had been sitting out in the sun at the Oklahoma City Boat Club for years. Bob, a fellow club member, offered some parts. His plans were to "chainsaw the hulls tomorrow" and put the pieces in the club Dumpster. That was the push I needed. In a moment of insanity, I told him there was no way I could let him do that.

I knew that boat needed some TLC, and I loved the idea of taking on the project—just not now. Would I ever find the time?

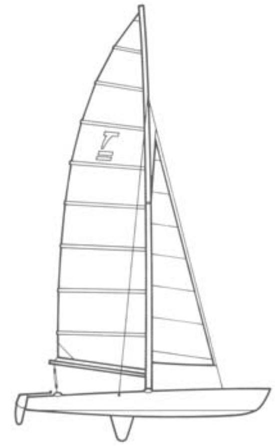
It turned out Bob was only looking for a trailer to haul his lawnmower. I probably saved him $1,000 in getting the custom tilt trailer converted. He took my check, went to Lowe's®, and was ready to go the same day. I promised my wife Julie I would finish the boat and then find a buyer who would appreciate it. We already had too many boats and didn't have a place to store it out of the sun.

I figured all I had to do was purchase sandpaper and some WEST SYSTEM® Epoxy, and in a few months I'd have her in the water. Well, as with most things in my life, I have a tendency to underestimate my time lines—at least according to my wife Julie. After a long conversation with the guys at WEST SYSTEM, it dawned on me that restoring a wooden boat is a little more involved than buffing out some oxidized gelcoat. It has been just about two years, but I am finally ready to take her out for a sail.

I had some incredible luck in finishing her. In Wichita, Kansas, there is a guy who used to manufacture Tornadoes back in the '70s and still has molds and various parts lying around. In his parts bin, he found a set of rudder castings that could be modified to fit the original wooden blades. He also had some great old stories of going to the race trials back in 1975 with a crew who fell in love with the eight Gougeon-built Tornado cats that were there. Six months later, he acquired one, which is very likely the boat I now have. Stu Bernd pitched in a couple of sets of sails lying around his place, and Jay and Pease Glaser were nice enough to send out some standing rigging.

The restored Tornado cat turned out so sweet that Julie is trying to convince me to keep it. Imagine that! I knew there was a reason I married her. Only once did she ask me, "How much more of that epoxy are you going to buy?"

Now I need to add on to the garage so I can fit the boat in it. Should have that done in about two weeks.



The sad shape of the Tornado's the hulls when they were rescued from the chainsaw.

The author and his restored Gougeon-built Tornado catamaran.

This article originally appeared on SailingAnarchy.com, December, 2010. Printed by permission. ■

For information about WEST SYSTEM® products or technical information for a building or repair project, Gougeon Brothers 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 Gougeon Brothers. They are also available free at www.westsystem.com.

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Visit www.westsystem.info to order online or call 866-937-8797 for the WEST SYSTEM free literature pack. It includes:

002-950 ***WEST SYSTEM User Manual & Product Guide***—The primary guide to safety, handling and the basic techniques of epoxy use. Includes a complete description of all WEST SYSTEM products.

000-425 ***Other Uses–Suggestions for Household Repair***—Repairs and restoration in an architectural environment. Many useful tips for solving problems around your house and shop with epoxy.

Also included are the current price list and stocking dealer directory.

How-to publications

For sale at WEST SYSTEM dealers, from the WEST SYSTEM Info Store at www.westsystem.info, or by calling our order department, 866-937-8797.

002 ***The Gougeon Brothers on Boat Construction***—A must for anyone building a wooden boat or working with wood and WEST SYSTEM Epoxy. Fully illustrated composite construction techniques, materials, lofting, safety and tools. 5th Edition, revised in 2005.*

002-970 ***Wooden Boat Restoration & Repair***—Illustrated guide to restore the structure, improve the appearance, reduce the maintenance and prolong the life of wooden boats with WEST SYSTEM Epoxy. Includes dry rot repair, structural framework repair, hull and deck planking repair, and hardware installation with epoxy.*

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002-898 ***WEST SYSTEM Epoxy How-To DVD***—Basic epoxy application techniques, fiberglass boat repair and gelcoat blister repair in one DVD.

*Available as a free downloadable PDF at www.westsystem.com/ss/use-guides.

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The Modern Bronze Age

By Kirk Williams

In 2010, I was given a commission to do a base relief sculpture for the Pioneer Care Center, a new retirement home in Fergus Falls, Minnesota. The sculpture, called "Creation of Life" was to be mounted on a wall about 14' off the floor. I knew I had to to make it strong and lightweight.

The method I used was to sculpt the design in oil based-clay on a large wooden easel. Then I covered the finished clay sculpture with several layers of clear silicone, occasionally adding cheesecloth for build up and strength. When the silicone was thick enough, I built a mold cradle, made of plaster and gauze reinforced with heavy metal wire over the silicone. When the mold cradle had dried, I removed it and the silicone mold and laid them flat.

I made a mixture of 105/205 epoxy and added bronze powder until it was the consistency of chocolate frosting. 105/205 gives me enough time to mix and spread it into the mold, but sets up within about an hour, making it possible to start another application. The epoxy/bronze mixture was buttered into the mold by using two fingers (gloved) to an eggshell thin layer, to avoid any possibility of air bubbles. When this cured I built up reinforcement layers using epoxy mixed with chopped fiberglass and Christmas tree flocking. For additional reinforcing I embedded heavy wire and small iron rods.

After the final epoxy application had cured, I attached the sculpture to a wooden frame with wires embedded in the back of the sculpture. With the frame standing vertically I gently pulled the silicone mold from the sculpture. I trimmed the rough edges with a Dremel® tool. Buffing the surface with steel wool brought out the metal, and gave me control over the amount of contrast. Olive oil rubbed over the surface gave the sculpture a smooth patina.

The 8' long sculpture weighs less than 150 lb and was lifted using a scissor lift and hung 14' above the floor level with ease. ■

1. Williams first sculpted the relief in clay on a wooden easel.

2. Epoxy/bronze mixture was buttered into the silicone/plaster mold.

3. The silicone mold was peeled from the sculpture.

4. Buffing with steel wool exposed the bronze powder.

5. The sculpture weighed only 150 lb and hangs 14' above the Care Center floor.